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Editor: *Systemist*
Professor Frank Stowell
University of Portsmouth
Portsmouth
Hampshire PO1 2EG
Tel: 02392 846021
Email: Frank.Stowell@port.ac.uk

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SYSTEMIST

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Preface

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Following the successful conference at the University of Portsmouth in 2018 the UK Systems Society International Conference returned to the Executive Business Centre, Bournemouth University, on Monday 24th June 2019. The theme of the Conference was *Systems Thinking and the Circular Economy*. It was well attended using systems ideas relating to understanding the circular economy. These ideas included ‘soft’ systems ideas as well as applications of ‘hard’ systems methods, including and ongoing applications of systems methodologies such as CVAM, SD, SSM and VSM.

The keynote speaker was Dr Marios Angelopoulos from the University of Bournemouth. In his paper he suggested that the circular economy is a paradigm for sustainable growth through various transitions, such as the redesign of societies, production and consumption of services and creation of a regenerative economic cycle. His approach to realising the multiple shifts was the paradigm *Smart Circular Economy* (i.e. data-driven) and the application of emerging technologies, e.g. 5G, blockchain, crowdsourced sensing, Internet of Things and Industry 4.0 systems. The keynote was undoubtedly thought-provoking and smartly set the scene for the Conference.

Claudius van Wyk, Kathryn Best and Mahoud Hassaan Al Hashash led the breakout sessions. Claudius presented a paper on *Adaptive Intelligence* and argued that it could be a catalyst for an evolutionary economic transformation. Kathryn and Mahoud how circularity and rising of the obelisks benefitted from a *Systems Thinking* approach that unearthed a long-forgotten ancient Egyptian invention. David Cole, Bruce McNaughton and Seymour Hersh and Michael Siebert followed. David et al. contested that the circular economy is only the beginning and proposed a *Living Systems* model and the use of technology for a more sustainable future. Michael argued for a *Systems Engineering* approach for the housing industry as an alternative to conventional methods, such as Off-Site Manufacturing, because of multiple housing industry complexities.

Edward Bentley, Paras Patel, David Powell, Laurie Rauch, Marianne Sice, Napat Saenthong, Petia Sice and Jethro Vernon presented the *Human Systems* papers. Napat Saenthong, Jethro Vernon, Marianne Sice and Edward Bentley proposed mirroring the heart by using self-organising maps to distinguish between stress and non-stress state heart rates. Laurie Rauch, Edward Bentley and Petia Sice argued to understand stress regulation and productivity in a circular economy we should examine stress as an autopoietic system. And David Powell contested how using *Systems Thinking* highlights how handicrafts such as railway modelling could help prevent dementia. Paralleling these were the *Systems* methodologies papers presented by Gary Evans, Akinola Kila, Karthik Suresh and Dennis Sherwood. Dennis Sherwood proposed how to save the planet using a systemic analysis approach by applying James Lovelock's Gaia Theory, and through understanding sustainability balances as a series of causal loop models. He summarised this as *geoengineering* and the fundamental solution to save the planet. Akinola Kila argued towards building an intelligent environment system based on the theories of cybernetics and the viable system model, and Karthik Suresh contested using Systems Thinking guided by SSM as an aid to project evaluation in the public, private and voluntary sectors. And Gary Evans use of the CVAM virtual paradigm methodology to conceptualise a physical activity, health and well-being hub of practice for those living with cancer in the south of England. All the papers stimulated much interest and debate that continued after the Conference.

Transition to a Smart Circular Economy

Dr Marios Angelopoulos
Principle Academic, Faculty of Science and Technology, Bournemouth University
mangelopoulos@bournemouth.ac.uk

Circular Economy is a paradigm for sustainable growth that envisions the transformation of how modern societies design, produce and consume goods and services towards a regenerative cycle. Future and emerging technologies, such as 5G, the blockchain, and crowdsourced sensing systems, along with innovative models and paradigms, such as the Internet of Things, Industry 4.0, and community networks, will play an essential role in the transition to Circular Economy by enabling and facilitating, among others, digitization (efficient asset management, open data, etc.) and collaboration (co-innovation, shared value creation, etc.). In this talk we will introduce the paradigm of Smart (i.e. data-driven) Circular Economy, we will review corresponding technological enablers and will present data-driven circular business models.

Keywords: business models, circular economy, emerging technologies, smart circular economy and sustainable growth.

Accessing Complex Adaptive Intelligence for a Circular Economy - a Meta-Perspective

Claudius van Wyk
The Evolutionary Transformations Group, 1 Broadsands road, Paignton TQ46JX.
Email: claudiusvanwyk@gmail.com **-** etgroupcom@gmail.com

Abstract:

This multidisciplinary meta-perspective offers complex adaptive intelligence (CAI) as a holistic approach capable of integrating epistemology and ontology with behavioural and evolutionary economics to assist the implementation of a circular economy. We propose (CAI) as an inherent capacity of all living systems at different levels of evolutionary development. By modelling the structures of subjective experience humankind can re-access this capacity to fast-track the epistemological shift required for transforming prevailing economics from extractive practices degrading our life-sustaining milieu, to sustainability.

The dichotomous tension between epistemology and ontology in economic theory is addressed from a phenomenological perspective. 'Experience' unifies subject and object and accesses CAI by enlisting the motivational role of emotions, as 'energy seeking purpose'.

The ontological view embraces evolutionary economic practice challenging prevailing assumptions embedded in economic epistemology. The incremental social and economic impact arising from those assumptions emphasises the need for a shift from a mechanistic and linear, to an organismic and non-linear viewpoint. Autopoiesis, as self-organisation, that characterises living systems, ultimately defines 'complex adaptive intelligence'. This insight will inform a new economic narrative supportive of sustainable approaches, such as the circular economy.

In accessing CAI, we differentiate 'complicated' from 'complex' situations and recognise our personal contribution to the problem-space. Thereby we enhance the capacity to 'map' multi-dimensional and complex dynamics.

Key words: complex adaptive intelligence (CAI), circular economy, economic epistemology, ontology, phenomenology, autopoiesis, self-organisation, coevolution.

Introduction

"The distinction of epistemology (what we can know) and ontology (what actually exists) becomes significant as we move higher up the Chain of Being"
E. F. Schumacher

The circular economy addresses economic challenge to human and planetary sustainability. The challenge is to introduce change on scale sufficient to impact the problem-space. We consider Schumacher's abovementioned challenge on epistemology (what we can know) and ontology (what has come into existence) as being relevant to economic theory. Beinhocker (2007) highlights flaws in conventional economic theory and draws insights from complexity theory especially focusing on economic non-linearity. This suggests that changing economic praxis will also demand a fundamental reformulation of underlying economic assumptions. The gap between designing economic models, and proactively changing the status quo presents an additional challenge. Gladwell (2005) shows how behavioural economics embraces the reality of the embeddedness of human habits in economic behaviour. 'Nudge theory' of Thaler et al (2008) endeavours to address economic habits by influencing collective human behaviour. Consequently we respond to Morin's (2008) challenge of *'developing an epistemology of complexity appropriate to the knowledge of human beings'* .

Schumacher's ontological challenge applies both in respect of economic momentum; the deep institutionalisation of its praxis, and economic evolution; its emergent nature. Whilst Thorsten Veblen (1898) originally introduced evolutionary economics, complexity thinkers like George Rzevski (2012) describe the emergent stages of economic evolution and their technological platforms from the industrial revolution to the digital knowledge economy. Currently economic theorists who strive to address the challenges of the so-called fourth 'artificial intelligence-driven' industrial revolution, might still be trapped in a materialistic perspective.

The successful implementation of the circular economy, aimed at rebuilding overall system health, could represent such a further economic evolution. We correlate 'health' to 'wellbeing, and link that in turn to the drive to coherence, as autopoiesis. The transition demands more than reducing the negative impacts of the extractive materialistic economy. It must promote a systemic shift embracing the contributory principle of interdependency to build long-term resilience, generate economic opportunity, whilst continuing to provide environmental and societal benefits.

Any fundamental transformation demands an accompanying epistemological shift to provide the broader enabling context. Amrine (1946), interviewing Einstein on his oft-quoted observation that *"...a new type of thinking is essential if mankind is to survive and move to higher levels"*, found the comment was directed at the use of nuclear energy. We contend that with the growing ecological threat presented by our economic activity, the cultivation of CAI would represent such a 'new type of thinking'. By assisting individuals and communities to greater awareness it could better inform 'safe-to-fail' experiment on the micro-scale with new economic practice.

Senge, commenting on Zohar and Marshall' (2004), identifies the challenge of perspective in any such systemic shift:

> *'...science today understands that living systems are very special systems with unique qualities that distinguish them from most non-living systems…the search for the qualities of full human intelligence must slip sideways into…the realms of complexity theory and the complex adaptive systems that it describes.'*

Systems thinking and the circular economy

The circular economy strives to reduce the environmental impact of conventional methods of production and consumption and drive greater resource productivity. Systems thinkers consider how the circular economy can address future resource security and scarcity issues. Fioramonti (2017) regards the circular economy concept as redefining growth to focus on positive society-wide benefits, decoupling economic activity from the consumption of finite resources. The burning question for systems thinking will be whether striving to design waste out of the system is to be addressed from a materialistic or organismic perspective. Jan Smuts in his 1931 Presidential Address to the British Association for the Advancement of Science, addressed the ontological question by predicting the impact of the new physics:

> *"Materialism has…gone by the board, and the unintelligible trinity…matter, life, mind…has been reinterpreted and transformed and put on the way to a new monism."*

With their systems view Capra and Luisi (2014), whilst contending that conventional economic theory has lagged behind praxis, refer to the current phenomenon of the '*dematerializing of our productive economies'*.

Cook (2004) promotes 'the natural step' approach to be an alternative 'sustainable' economic model informed by thinking based on systems theory and a scientific approach to complex issues. This demands a new whole-systems science. In the foreword to Cook's book, Robert identifies the epistemological problem. Contrasting the desire to *"...help decision-makers put sustainable development into action"* with the challenge of the *"...seduction of comforting and familiar habits"* he warns:

> *"Science…follows a similar reductionistic pattern and does not help us to see the wider picture or the wider consequences of our actions"*.

Cook proposes getting a better view of the whole system with improved knowledge of what is going on 'upstream' where the problem begins. He offers a science-based dialogue that addresses complex issues like the human generated system conditions that break the cycles of nature.

Whilst we recognise the value of systems thinking in striving to model all the relevant factors, we assert that dealing more effectively with the complexity of human generated system conditions requires accessing CAI to address human subjectivity. Beinhocker (2007) describes 'economy' as a complex adaptive system, as he puts it; '*a teeming evolutionary stew'.* The processes of economic evolution; differentiation, selection and amplification, are driven by the complexity of the biosphere which, in turn, drives the growing order and complexity of '*the econosphere'*. CAI also embraces this complex whole system perspective.

Spinosa et al (1997) refer to post-structuralism when identifying the underlying cultural dynamics and emphasise the growing importance of relativism versus formalism when considering institutions. Dewey and Piaget with their constructivist formulation lay the groundwork for a more focused inquiry into the cultural dynamics to be addressed in transforming economic systems. Post-structuralism claims that the ontological thesis, what appears to be 'natural', is an effect of social processes and practices; and that the epistemological thesis, knowledge of social phenomena, is itself socially produced. It asserts that with the methodological thesis the investigation of the social construction of reality needs to take priority over other methodical procedures. By exploring CAI, we will endeavour to address this requirement to assist a change in economic behaviour.
A glaring example of such an epistemological challenge is encapsulated in Margaret Thatcher's TINA acronym that *'there is no alternative'* to the market economy.

Spinosa et al (1997) by implication confront such a limiting view when they declare:

> *'Human beings are at their best not when they are engaged in abstract reflection, but when they are intensely involved in changing the taken-for-granted, every day practices in some domain of their culture…'*

By embracing subjective experience CAI strives to address the drivers of the problem-space of institutional, individual and collective economic behaviour. Ormerod (2012) considers this challenge through the lens of network theory. Network effects can now be more effectively employed to influence human behaviour. The 'nudge theory' of Thaler et al (2008) offers incentivization of 'good responses'. Ormerod adds a cautionary of our compelling human tendency to imitate each other. He considers bringing together these two factors of employing incentives and the tendency to imitate. (The Chinese 'social credit system' could represent a more recent application of 'nudge' theory.)

The role of human emotion

With behaviour being geared for adaptation, CAI accepts present behaviour as the best available choice, and emotion as the energy driving that behaviour. The application of CAI would thus refrain from blandly considering emotions, such as economic appetite and aversion, to be problematic. They are regarded as potential signals of a deeper need to engage in the on-going drive to coherence. Autopoiesis, as originally described by Maturana and Varela (1980), is the process of re-establishing coherence. We can therefore potentially calibrate our core value assumptions, the sets of criteria that inform our behaviour, with a state of coherence. Since this view can help enhance our dynamic engagement with the drivers of economic behaviour, emotion-driven values become an important functional agency to be mapped in complex systems.

When applying the CAI approach experience often reveal the identified problem-space as the ripple on the surface of deeper undercurrents. We discover that we ourselves are active contributors to our perceived challenges. In accepting the apprehended problem-space as surface evidence of potential deeper dynamics, we recognise the key contribution of our emotional state. Emotions are evidence of a disturbance of coherence and thereby signal the development of a problem-space. Whilst emotional attachments can aggravate a problem-space, rather than suppress them, they not only offer potential new awareness, but provide the energy to address it.

Problem-solving and the phenomenological stance

In the '*Process and Emergence Tool'*, (figure 1) van Wyk (2012), a change in the living context results in a previously 'unconsciously functional' response becoming 'unconsciously dysfunctional'. Since a typical response is to externalise the problem, circumstances might need to become sufficiently uncomfortable before we recognise our behaviour as being consciously dysfunctional. At this juncture we can introduce Borthoft's (2012) phenomenology perspective on the nature of first-person experience, and hermeneutics, on the process of interpretation. Contrary to the notion that all we can accurately map is the behaviour, emotional 'state' is the more effective indicator to apprehend and comprehend the tension between the dynamic context itself and our interpretation of it. A shift in perspective occurs when we willingly embrace emotional responses.

With CAI frustration, anxiety, deprivation, or aversion, as signals of disturbed coherence, can serve to prompt the response of re-evaluating and adapting behaviour. The conscious personal recognition when behaviour becomes dysfunctional enables a willingness to experiment with new responses. This accords with the contention of Spinosa et al (ibid) about *'history-making'* as '*…changing some everyday taken-for-granted activity'*.

In considering requirements to implement a circular economy, we can now recognise that whole sets of behaviours will of be challenged. As suggested new opportunity is unlocked with personal insight into the contribution of our economic behaviour to social and environmental degradation. Recognising the systemic and institutional challenges to be addressed, it requires a structural reorganisation in consciousness, individually and collectively. A collective sharing in both the 'pain' and 'responsibility' for the world invokes a personal 'evolutionary transformation'. The challenge is that unconscious responses, are deeply ingrained habits. This is the 'culture' as addressed in post-structuralism. A conscious response requires a shift from 'reactivity' to 'responsibility'.

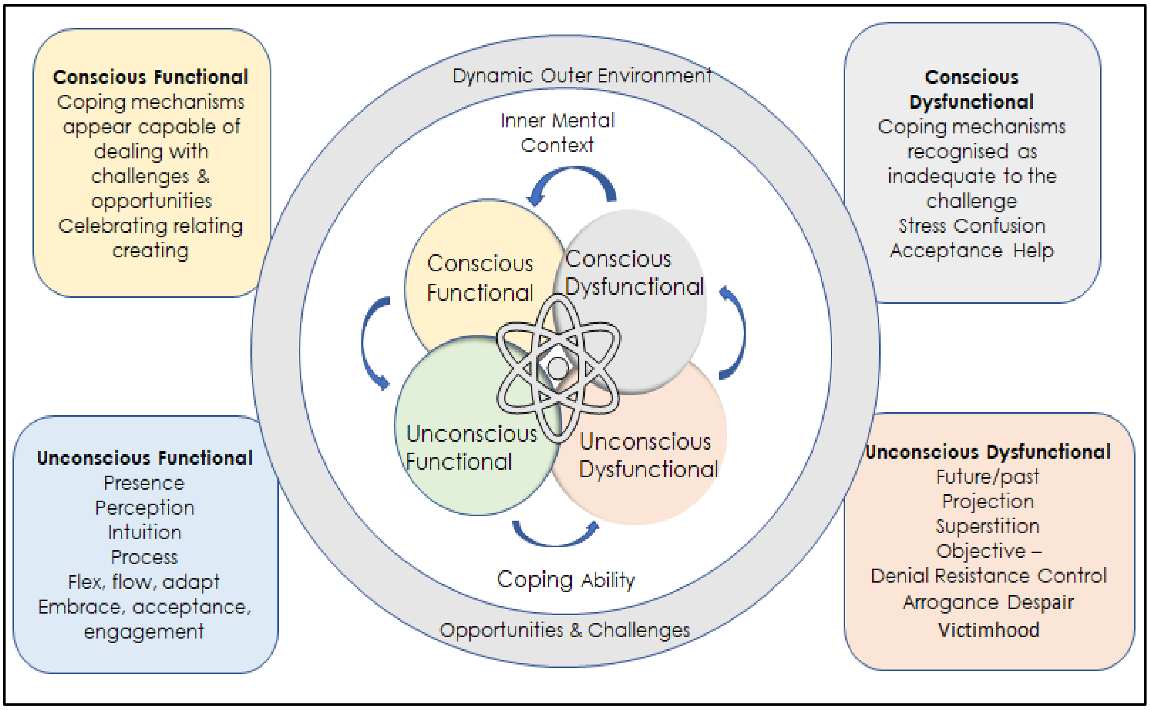

Figure 1. - The Process and Emergence Tool

Functionality versus dysfunctionality

In a 'slower' world accepted practice, including that considered 'evidence-based' with the accompanying logics, will continue to work well and represent conscious or unconscious functionality. We habituate response into unconscious functionality - 'good' individual or societal habit. In a 'fast-paced' world of change the once functional habit has a shorter life-span and easily slips into unconscious dysfunctionality - a 'bad' habit. By accessing CAI individuals and organisations become aware when responses become dysfunctional. More sensitive responses to subtle signals (both sensory and intuitive) helps indicate when commonly accepted praxis is dysfunctional. In a complexifying and interrelated world we, the problem-solvers, can no longer be positioned external to the problem-space. This perpetuates the subject/object dichotomy whilst we as 'observers' continue to address challenges with so-called tested and 'evidence-based' strategies *"…the seduction and comfort of familiar habits"* described above by Robert, in Cook (2004).

The subject/object dichotomy challenges practitioners of systems and complexity theory who might still operate from a materialistic perspective to learn not only model, but also to experience subjectivity. When employing CAI to address economic behaviour the 'experiencer' of the problem-space is thus positioned at its centre.

We have been guided by the contribution of two seminal thinkers who anticipated such a phenomenological approach. Smuts (1926) saw 'experience' in his holistic thesis as unifying subject and object, thereby bridging Descartes' matter/mind dichotomy. Einstein's 'relativity' demonstrated the real action of the universe not to be constituted by 'parts' but by the complex interactions of energetic entities. With this insight we recognise our actions are embedded in a greater field of wholeness, thereby having a direct bearing on economic behaviour. Zohar and Marshall's (2006) put it eloquently:

> *"Holism in science is a defining quality of both quantum and complex adaptive self-organising systems … the relationship of the different parts of the system help to define not just the system itself… but to give final form to the parts themselves…the emphasis is on 'stakeholder value', where stakeholders include the human race, present and future, and the planet itself".*

In applying CAI to a problem-space we focus on those core elements that can be positively influenced to redirect the involved agencies to the desired outcome. In a six-phase process we:

- identify the deeper undercurrents of the problem-space;
- differentiate between simple/ complicated, and complex/chaotic situations;
- focus on individual and collective contribution to 'map' the significant agencies;
- employ complex mapping to identify the interrelationships and influencers;
- identify ways to influence key actors and enablers;
- integrate the learnings.

Coupling a transformed epistemology to the change process

We have suggested 'autopoiesis' the principle of self-organisation, as a potential key to assist in introducing a transformed epistemology. The growing universal access to information and the rise of social media focusing on our human and technological ecological impact, might bring us closer to a collective shift in consciousness. New physics writers, Currivan (2017) and Davies (2019), emphasise that the shift must be from the materialistic and mechanistically linear, to a non-linear living systems and information-based viewpoint. For us the comprehension of autopoiesis, especially when experienced in oneself, can open the window to new perspective. As Smuts (1926) explains:

> *"…Self can only come to realisation…of itself, not alone and in individual isolation…but in society, among other selves with whom it interacts in social intercourse[1]… The function of the ideal of freedom is to secure the inward self-determination…[2]"*

The deeper implication for CAI practitioners will therefore be to willingly seek out and re-interrogate our own assumptions.

Adaptive qualities

Graves' study of emergent consciousness (in Cowen and Todorovic 2005) concluded that the next evolutionary transformation of consciousness might re-access previous intuitive human adaptive qualities. We consequently consider that as we co-evolve with the technological advances changing our economic, political, and social landscape, an enhanced intuitive capacity might become the pre-eminent factor in enabling and developing CAI. This becomes even more important with the rampant hi-tech exploration of biosynthesis and genetic manipulation driving the fourth industrial revolution. There is a danger of programmers inadvertently embedding outdated assumptions in the algorithms of artificial intelligence. This can be perpetuated in AI self-learning. Re-accessed human intuition might yet become the vital counter-measure.

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[1] Holism and Evolution p. 245
[2] Holism and Evolution p. 314

CAI in practice

The six-phase process described below, considered against the described context, elicits a deeper understanding of the human factors involved in the economic problem-space.

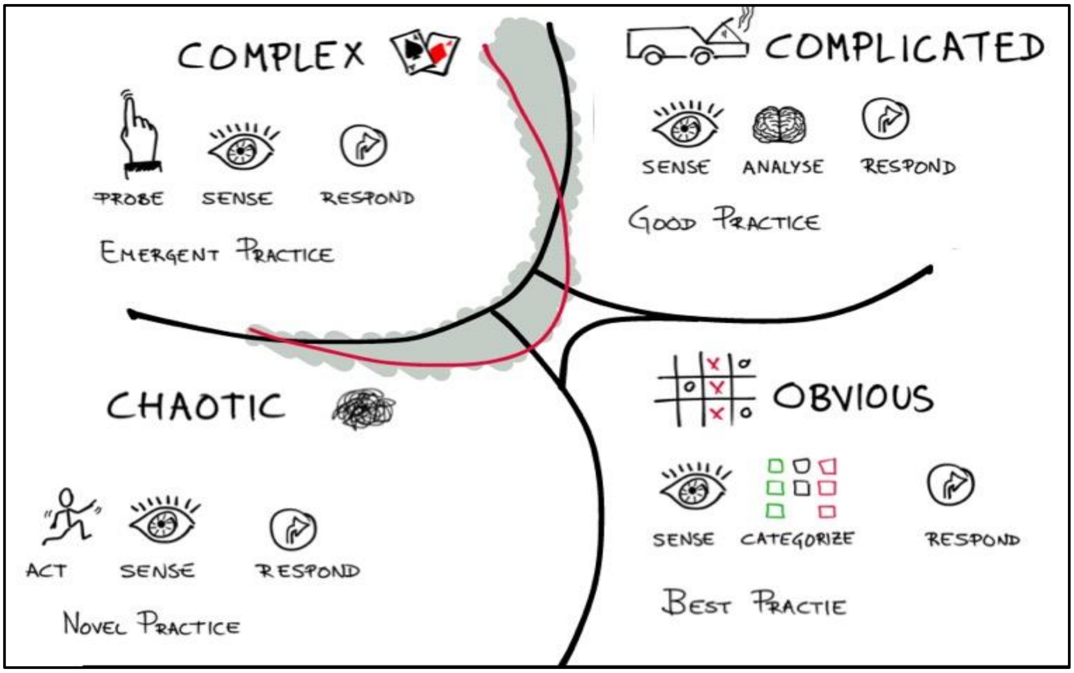
Phase one: Examining the nature of the economic problem with a specific focus on experience, we recognise the symptoms of our personal difficulties, and their further impact on the greater enabling milieu. We identify the personal and systemic drivers of economic behaviour. We investigate our involvement in the problem-space and why we consider it important to change it. We recognise the wider general impact and re-evaluate previous attempts at redress in order to harvest the learnings. With a better understanding of the deeper dynamics involved we see how simplistic attempts with piecemeal solutions exacerbate matters.

Phase two: We differentiate between simple/complicated and complex/chaotic situations. When applied to implementing the circular economy this offers the opportunity to learn how to discern the challenges that require appropriate 'best practice' applications, and those that demand a new approach. We find Snowden's (2007) 'Cynefin' approach useful in making this differentiation. 'Rational' approaches to problem-solving typically tend to employ statistics to identify the generalities of a situation and then apply evidence-based methodologies. In simple and complicated problem-spaces where all the relevant factors can be identified and linear causal relations tracked, these are helpful. In non-linear complex dynamical situations however, CAI will seek to track emergent patterns in a moving landscape and identify opportunities to influence the dynamics of the direction. The subjective nature of the experience of a problem-space must be included and adds a significant additional dimension to the consideration whether the problem-space is complicated or complex. Our subjective 'stance', the emotions we experience, affect how we cope with the problem-space. What is a straightforward issue for an expert, might turn out to be a complex situation for us.

CAI and leadership

Comparing Snowden's *'Cynefin'* model (figure 2) with the *'Process and Emergence Tool'* we can conclude that a degree of conscious dysfunctionality inevitably accompanies the act of addressing a complex problem-space. We have a typical and natural preference to reduce complex problems to simple, or at least complicated ones. This helps us feel more competent and in control. However, when we apply misdirected 'good-practice' solutions that fail, we might be inclined to fall into self-doubt, with the temptation to redirect blame externally. That is because the shift from unconscious dysfunctionality to conscious dysfunctionality typically generates a degree of discomfort. Developing tolerance both with ourselves and with others involved invites nurturing leadership. McKergow (2009) describes this as 'host leadership'. Shifting to the interface between conscious dysfunctionality and conscious functionality calls for courage with a willingness to experiment. Inspirational leadership is now required. Snowden's 'catalytic probe', is a subtle intervention to test responses and detect or intuit potential patterns. With approaches such as 'nudge effect' we can then experiment with amplifying the positive and dampening the negative tendencies.

> *"I look at the future from the standpoint of probabilities. It's like a branching stream…, and there are actions that we can take that affect those probabilities or that accelerate one thing or slow down another thing. I may*



> *introduce something new to the probability stream."* Elon Musk

Figure 2: Snowden's 'Cynefin model'

*Phase three:*_ With the complexity of the problem-space assessed we examine our individual and collective contribution, honestly assessing the role we as problem-solvers play in perpetuating the challenge. In this phase, when applied to implementing a circular economy, we would also focus on identifying the systemic and organisational contribution to the problem-space, and the accompanying constraints presented by that context. Our generalised perceptions, our unconscious assumptions, beliefs and values, could represent a significant factor in the perpetuation of a problem-space. Smuts, in his 1931 Presidential Address reminded us of this:

> *"Our world view is closely connected with our ultimate sense of values"*.

Tad James' representation of Grinder and Bandler's (1982) 'communication model' (figure 3) below illustrates the structures of subjective experience and perception, and the key role of values.

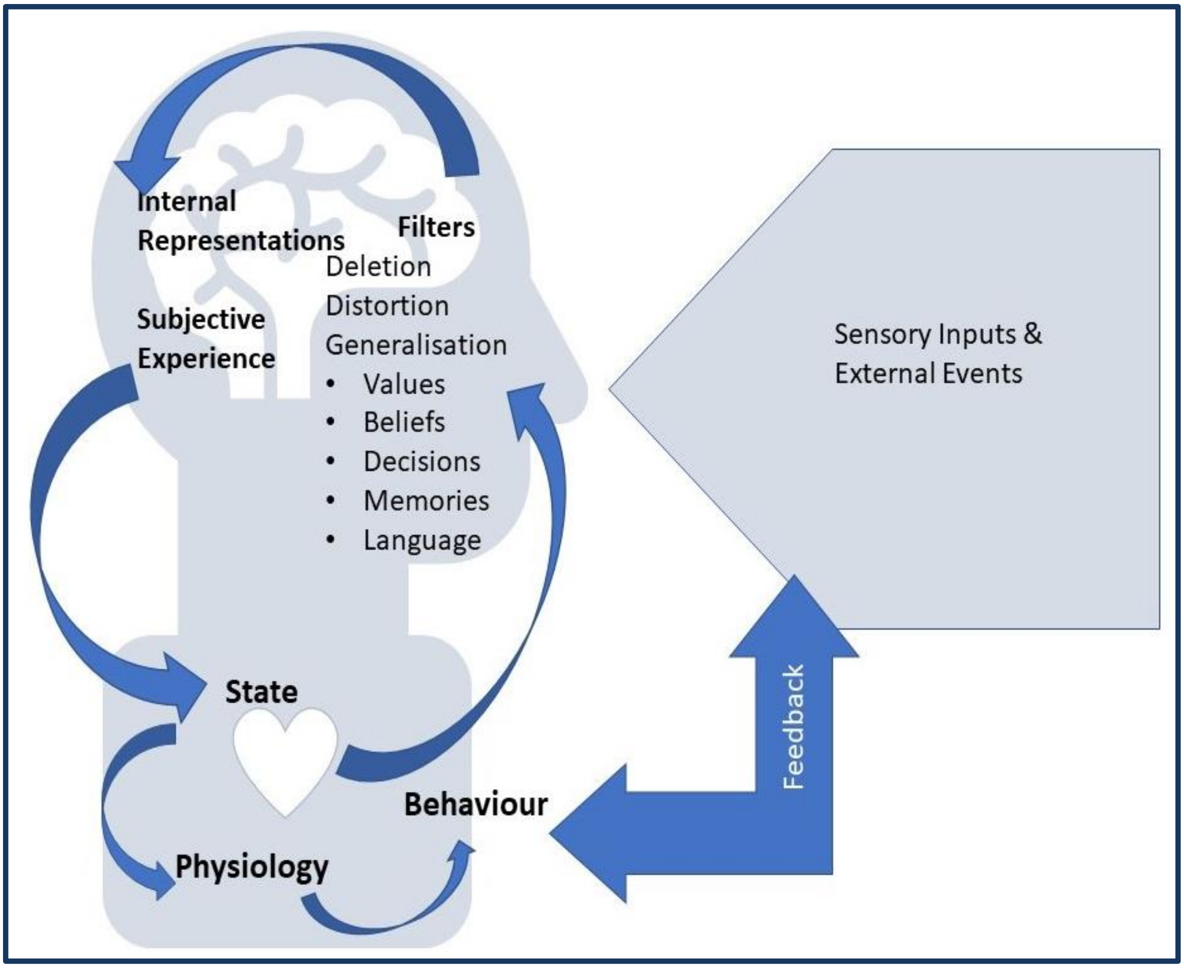


Figure 3: Bandler's 'communication model'

Korzybski's (1933) phrase *"The 'word' is not the 'event' it describes - the 'map' is not the 'territory'"* establishes that the way we experience and communicate about the world, as a function of our internal subjective representation, is not an accurate description. When we compare the 'map' concept with Bateson's reference to 'epistemology', and the 'territory' to his reference to 'ontology', it serves to further illuminate Borthoft's hermeneutic and phenomenological perspectives. The key issue is the modelling of the world and what is going on in it, and how that is converted into language and concepts. The question thus is how 'modelling' (epistemology) can better keep pace with rapidly changing conditions (ontology). Hermeneutics in turn; the way we interpret, informs phenomena; the way we experience. This serves to amplify Beinhocker's (2007) insights into the drivers of the growing order and complexity of '*the econosphere'*.

Key lessons can be highlighted relating to coherence. Antonovsky (1979) identified essential requirements for maintaining 'a sense of coherence' as 'comprehensibility', manageability, and 'meaningfulness'. Comprehensibility reduces the mass of potential stimuli to which we are increasingly exposed to useful information. We then project recurring patterns into future response to enable a degree of the 'manageability'. Neuroscience shows that our perceptual filters 'delete' the information we consider unnecessary or irrelevant. We 'distort' information to fit our pre-conceptions. We generalise information into assumptions and beliefs. These are then encapsulated in our language; how we 'label' events and entities in our structures of communication. Our subjective responses, the mental and emotional states, are thus not a direct response to the world itself, but to the way we have learned to interpret information. The activities that direct our behaviour follow from those mental and emotional responses.

Since conventional theory presupposes rationality in economic behaviour, the recognition of subjectivity becomes especially important when considering economics

Ormerod, Beinhocker, and others when pointing out the fallacy of the rational choice assumption, then also challenge the accompanying principle of linearity. This mitigates against fixed economic laws. More recent writers in physics go further and question the validity of the so-called objective scientific method, especially when related to living system responses.[3] As Smuts pointed out, the importance we attribute to information is a function of the way we apportion values; the sets of criteria informing our responses. They are a function of our life experience. It thus helpful in accessing CAI to understand how we individually delete, distort, and generalize information in interpreting the nature of our problem-space. The human and ecological challenges generated by our prevailing economic activities that the circular economy strives to address, are thus perpetuated either through our conscious wilfulness, or inadvertent complicity.

The economic praxis of neo-liberalism clearly fails to 'map' to critical system dynamics. This relates especially to the 'momentum', as a function of unconscious economic drivers, we identified earlier. At a deeper level, both ideologies remain

[3] It is significant to note that proponents of the new physics, such as Lazlo (2006), Davies (2017) and others, warn against the tendency to scientific abstraction. This 'subjectivity' extends they assert, to the so-called objective empirical method

rooted in mechanistic materialism. This observation applies equally to socialist economic approaches with the founding principle of dialectical materialism.

With a more informed understanding of our personal and shared values, we ought to be able to get to a better understanding of economic behaviour. This is about how we, in the business of exchanging goods and services, delete and generalize information, especially about the consequences. Such a further clarification of our economic values will also serve to address Antonovsky's requirement of 'meaningfulness' as we strive for a greater sense of coherence in bringing about economic change.

Engaging emotion in the exploration of the problem-space

Bateson (ibid) suggests that whilst we might believe we 'think our thoughts', our thoughts are 'thinking us'. Similarly, we conclude, our emotions drive our perception and behaviour. The emotional state affects the way we comprehend the problem-space, hence considering 'emotion' as 'energy-seeking-purpose'. Our challenge in accessing CAI is how to engage with the structures of emotion. Our research follows Eckman (2010) with six, and Plutchnik (2017) with eight basic emotions. We initially adopt those four basic emotions researched by Jack (2014). They are 'fulfilled' (glad), 'frustrated' (mad), 'deprived' (sad), and 'anxious' (scared). We added a fifth emotion, namely, 'averse' (loth) since it recognises the importance of the experience where our values are affronted.

Values as emergent structures of information processing

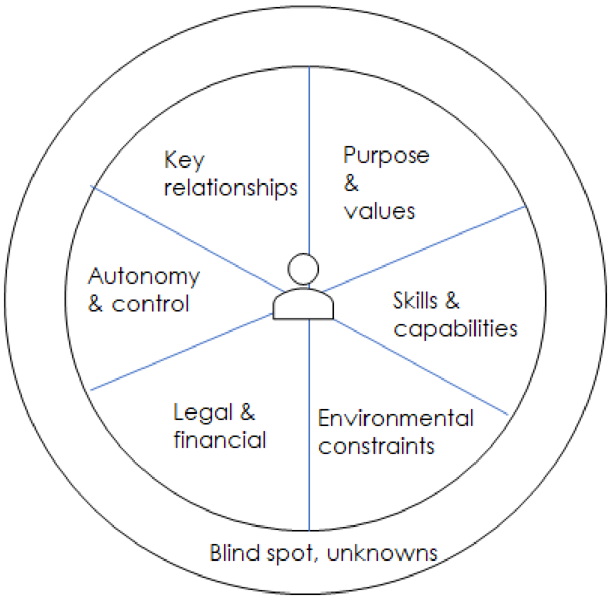
The 'communication model' illustrated the filtering function of values in our subjective experience. This is unpacked in Cowan and Todovoric's (2005) description of the bio-psychosocial model of adult values. Graves showed how we scan the environment to select information relevant to our physiological, psychological, and social needs. With emotional and psychological maturation, we will begin to embrace a broader spectrum of information in space and in time. An alternation between the 'expressive' focus on self and the 'sacrificial' focus on community drives our values evolution. It has bearing on economic behaviour.

We therefor offer Graves' values-based worldviews in nine archetypes to provide further insight into economic behaviour. It provides an understanding and empathy for the agents and organisations in the economic problem-space. By identifying agents' values stance, and with a fuller personal understanding of our own, we get a better insight into potential conflict areas and are more able to apply appropriate strategies.

> *The Caveman*: I scour the environment to find food and shelter in order to survive. I rely on instinct and am drawn to others like me. Core value: Survival. Economic behaviour: Scavenging - hunter gathering.
>
> *The Clansman:* We group together for safety and security and accept the authority of the bravest and strongest who protect us. Values: Loyalty - conformity - trust - sacrifice. Economic behaviour: Sharing - herding.
>
> *The Hero:* I want to be in control and enjoy the experience of power. I take authority since I am the bravest and strongest. Values: Courage - daring - authority – pleasure-seeking. Economic behaviour: Controlling - monopolising - self-enriching.
>
> *The Gatekeeper:* We establish rules and procedures so that all can behave in a disciplined way. We find virtue in respecting the rules. Values: Order - obedience - trustworthiness - honesty - integrity - consistency. Economic behaviour: Ordering and rationing,
>
> *The Achiever-strategist:* I want to be seen as being successful in life and enjoy the fruits of success. I enjoy working creatively to develop new opportunities. Values: Energy - commitment - entrepreneurship - risk evaluation - innovation - achievement. Economic behaviour: Multiplying - innovating - growing - beneficiating.
>
> *The Eco-humanist:* We believe that all should have equal opportunity and be treated with dignity, and nature respected. We find value and fulfilment in consensus, levelling the playing field, especially for the disadvantaged. Values: Consensus - equality - dignity - compassion - love. Economic behaviour: Equalising - distributing.

> *The Systems-synthesizer:* I use systemic thinking to deal more effectively with daily challenges and opportunities in the complex and dynamic world. I adapt my behaviour to enable on-going human advancement. Values: Flexibility - principled pragmatism - information networking - adaptive intelligence. Economic behaviour: Value-chain networking.
>
> *The Universalist:* We transcend self-interest in order to embrace the requirements of dynamic wholeness as an emergent property of sustainable coherent diversity. Values: Coherence - self-organisation - coevolution - planetary views and integrative complex whole-system responses. Economic behaviour: Harmonising with natural cycles.
>
> *The Shaman:* I resonate with integrative structures and self-similar fields responding to signals of synchronicity representing the deep information of cosmic intelligence. Values: Wholeness - unity. Economic behaviour: Life-enriching exchange of energies.

Phase four: This 'maps' the relevant dynamics, identifying the complex agencies - the actors and factors involved who might enable or disenable solution-finding. With their rich interactions individual issues cannot be addressed in isolation.



Six categories are provisionally offered to help newcomers to employing methodologies of complex mapping begin to group the enabling or dis-enabling 'agencies. They are:

1. *Purpose and value* - this category helps locate factors of motivational importance. *What are the reasons for wanting a successful outcome?*

2. *Environmental constraints* - this category helps establish geographic /technological considerations. *What are the various factors that might stand in your way?*

3. *Key relationships* - this category helps identify important collaborators/ partnerships /interested parties. *Who are the people or institutions than can enable or dis-enable your project?*

4. *Autonomy/control* - this category helps establish the degree of self-control versus authority. *Whose permission/agreement must you get in order to progress?*

5. *Skills and capacities* - this category helps evaluate requisite competence/ experience/knowledge. *How able are you to do what is necessary - what skills do you need - or what help/expertise do you need to acquire?*

6. *Legal and financial* - this category helps identify issues related to money/contract/ law. *What are the legal constraints, existing financial commitments, laws, etc.?*

7. *Additional* - in mapping the problem-space there could of course be many more segments on the chart. We emphasise exploring further potential categories relevant to our unique problem-space.

Agents that are tightly linked are positioned closer to the centre. We link enablers that are interdependent or co-dependent and map the flows of engagement. Finally, we identify the values-archetypes of the key enablers on the map.

Phase five: This access greater creativity, identifying new innovative approaches, especially to influence enabling agents in the economic problem-space. CAI promotes a collaborative and generative co-coaching methodology to enhance creative thinking.

Phase six: This *integrate* the learnings of every endeavour, whether successful or not. It guides the harvesting and systemic internalization of the learnings. It incentivises the learnings for transformed future responses. With his 'antifragile' notion, Taleb (2012) shows how the ability of robust living entities and systems to bounce-back in the face of stress can be further transformed into becoming stronger and even more resilient. That is the CAI intention of learning.

Discussion

With the focus on individual subjectivity we have also emphasised that any attempt at implementing a new system, such as the circular economy model, will encounter a typical push-back from any meta-system. This is the tendency of vested interest to perpetuate the institution itself. Perpetuation becomes the overriding concern. As Shirky (2010) puts it: *"Institutions will try to preserve the problem to which they are the solution."*

This rigid and mechanistic institutional paradigm is also contrasted with the principle of self-organisation. This we have identified as the central idea of a transformed paradigm functioning as the distinguishing feature of any vital living system. Materialism limits autopoiesis in lower forms of sentient expression to adaptation to changes in the environmental in accordance with principles of natural selection. Holistic science however detects purpose in existence, even at basic levels. For Smuts the drive to wholeness through self-organisation was not just about survival, it was an evolutionary process of universal self-realisation. From the materialistic viewpoint teleology is restricted to the study of objects with a view to their aims or intentions. There is no purpose in the developmental process of the entity. Only the observer imbues objects with purpose. From the holistic viewpoint purpose is a universal phenomenon functioning throughout all the subtle processes of self-organisation. Smuts put it this way in his 1931 address:

> *"Life is not an entity…it is a specific principle of central or self-organisation."*

For Aristotle '*entelecheia'* described the organising function of purpose embedded in living organisms. In a broader sense this is *'…the set of circumstance in which a potentiality can become an actuality'.* Systems thinking and complexity theory define the actualisation of potentials as emergence - it is an 'emergent property'. Those invisible processes that facilitate dynamic wholeness, as systemic coherence, can now be re-evaluated as an underlying subtle factor that includes us humans. Smuts named that tendency 'holism' and Bohm (1980) referred to some underlying *'implicate order'*. This holistic view might thus become both the 'imminent telos' and eminent emergent property of a circular economy. That in turn will represent autopoiesis in economic evolution. As such the implementation of the circular economy will be supportive of the requisite paradigm shift.

Conclusion

Our prevailing economic paradigm largely functions in a neo-Darwinian perspective where emergence is considered a random phenomenon and self-organisation is a stimulus/response survival mechanism. The holistic perspective holds a deeper creative function to be at work. At more advanced levels of conscious expression, self-organisation includes conscious design. In this Anthropocene era we humans have become nature's instrument of evolution. With 'complex adaptive intelligence' we will be able to co-evolve with the technological advance affecting economic, political, and social structures. It will hopefully resonate better with ecological principles. This will help to transcend Schumacher's ontological and epistemological dichotomy. As 'reality' informs 'knowledge', so too 'knowledge' transforms 'reality' in the continuous co-evolutionary unfolding of our existence. That specifically includes our economic mode of existence. 'Complex adaptive intelligence' will enable us to restore the relationship between human culture and nature to an autopoietic dance that recognises our embeddedness in nature and its embodiment in us. The implementation of a circular economy would be an eloquent expression.

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Circularity and the Raising of Obelisks: How a Systems Thinking Approach Unearthed a Long Forgotten Ancient Egyptian Invention

Kathryn Best
Associate Professor, College of Architecture, Art and Design, American University of Sharjah, United Arab Emirates
kbest@aus.ed

Mahmoud Hassaan Al Hashash
Independent Scholar, Luxor, Egypt.

"Beauty is Nature in perfection; circularity is its chief attribute" O. Henry

A circular economy is an economic system aimed at minimising waste and making the most of resources. According to the Ellen McArthur Foundation, the notion of circularity has deep historical and philosophical origins. The idea of cycles in real-world systems is ancient, and civilisations that held a mindset of *circularity* were able to see waste as a valuable resource (there is no waste) and engage reason in a non-linear and cyclical way (there is no beginning or ending). In ancient Egypt, a circular mindset, a desire for *ma'at* or balance in life and an ability to align with the laws of nature are evident in their belief systems, agricultural seasons, structures of governance, monuments and engineering and their multi-dimensional understanding of duality, the human and the divine. Living with systemic and interrelated awareness of how culture and technology, experimentation and development, part and whole, came together was key to the success and longevity of ancient Egypt and the greatness of their monumental achievements therein.

In this paper, the authors take a systems-thinking approach to investigate an archaeological puzzle that has fascinated academics and amateurs for centuries – how the ancient Egyptians achieved the exceedingly difficult task of raising a monolithic obelisk. We describe the significance of obelisks and outline previous obelisk-raising attempts before proposing our hypothesis – that the evidence of obelisks existing in pairs, with few exceptions, was critical in ancient Egypt both *mechanically* and *symbolically*. By testing our hypothesis in three scaled-down experiments, we demonstrate that the proposed method works and speculate that a

full-size model would also succeed. No records survive which explain the methods by which obelisks were erected, and the search for the answer has lured the attention of the adventurous and the inquisitive for over a century. Our research results may necessitate a review of the relationship between the *mechanical* and *symbolic significance* of the pairing of obelisks, as well as our current underestimation of the *systemic* and *circular* mindset of the ancient Egyptians.

Keywords: antient Egypt, circular economy, inventions, modelling obelisks and systems thinking

Towards Sustainability - The Circular Economy, Industry 4.0 and the Global, Research, Innovation and Discovery Centre (GRID)

Dr David Cole[1] Dip SysPrac (Open), Bruce McNaughton, Seymour Hersh MA
[1]Edinburgh Business School, Heriot-Watt University.
Email David.Cole@hw.ac.uk, bruce.mcnaughton@change-aide.com, seymour@dynamic-dialogues.ca

Abstract

There are currently underway two areas of radical change, unprecedented in human history. One is a human created, rapidly worsening systemic, ecological and social crisis. The other is a rapidly evolving, deeply systemic, human created digital technology revolution.

The root cause of the ecological crisis is largely a crisis of perception. We are clinging to an outmoded world view - the Newtonian world machine, instead of more biomimetic and systemic worldview based on a new conception of life.

Technologies are increasingly being used to augment human cognition, the digital is merging with the physical, and is ever more encroaching into the processes of life. We need a moral compass.

As an antidote to the machine metaphor we present a model of a city as a living complex adaptive system, using a moral compass for goal seeking and with several aspects of its non-linear flows of matter, energy and information (its 'metabolism' and its cognition) being augmented with digital technology.

Keywords: biomimetic and systemic worldview, complex adaptive systems, ecological and social crisis, digital technology, machine metaphor, Newtonian world machine.

Introduction

Today as a result of the Industrial Revolution arguably one half of humanity is better off than their ancestors, 40% are marginally better off. One billion people are worse off. The seven richest people in the world's combined wealth equals the accumulated wealth of one half the human beings on earth – about three and a half billion people. The global economic system is dysfunctional and broken.

In order to explore how emerging industry 4.0 technologies can either help with sustainability (or accelerate climate change), we propose a model of the processes of energy, material and information flows which ensures that the activities of the city minimise the negative impact on the planets ability to support life.

We have seen that a linear mechanistic approach to the economy when applied to global consumerism, focusing on GDP only has caused many very serious social and ecological problems.

There are now alternative economic models emerging, which are largely biomimetic; they are based on the intelligence, adaptability and sustainability of natural living systems rather than machines. These include the circular economy[2], the doughnut economy[3] and the token economy[4].

In order to explore how Industry 4.0 technology can relate systemically to these economic systems, we will take a biomimetic view, rather than a mechanistic view, of a city as an example (although this could be extended from the levels of households up to a nation state)

Firstly, we invoke a vision of the world to predict the scenario we will face with a "business as usual" attitude and a vision of the world that invokes a sense of sustainability, health and safety. (see envisioning part two)

Envisioning part one - the future vision for NO-CHANGE Business largely as usual

GDP continues to slow all over the world, the cost of fossil fuel extraction is continuing to increase. Nuclear fuel remains too expensive. **T**he global energy system continues to depend on fossil fuels. Real time climate change is now the norm. The target change from the Paris accord in global temperature has been exceeded and continues to rise. Not just CO_2, but Nitrous Oxide and Methane are still being pumped in large quantities into the atmosphere. For every 1^{o}C rise in temperature the atmosphere is sucking up 7% more water from the surface.

The water cycles are changing unpredictably giving rise to wild, extreme, uncontrollable weather events; increasing extreme snow, flooding, droughts, wildfires and deadly heat waves. Category 3, 4 and 5 hurricanes are increasingly occurring with some areas seeing wildfires lasting for five months of the year with accompanying loss of life. Ecosystems are not adapting to this rapid change and many have collapsed resulting in mass extinctions. The claim of the Anthropocene bringing the 6th extinction event of the planet is recognised. Unlike the mass extinction events of geological history, the current extinction challenge is one for which a single species - ours - appears to be almost wholly responsible.

There are rapidly growing problems with food security, pollution is out of control and the seas continue to die, wiping out fish stocks and contributing to food scarcity. We are seeing rapidly increasing problems of soil erosion, aquafer depletion, collapsing fisheries, deforestation and grass land deterioration. Unchecked population growth, and 3 billion people trying to rise-up the food chain to consume more eggs and meat, has put insurmountable pressure on the food system. Grain is still being diverted to making biofuels to counter the energy crisis worsening food security. Water for food processing uses 2000 litres a day further depleting aquafers and water tables have irreversibly plummeted in countries that contain half the world's population including the big three grain producers; China, India and the US.

The melting of sea ice in the arctic continues exponentially, causing sea level rises and increasing climate change even further. Low lying islands and coastal area are being submerged causing migration. Glaciers in the mountains of Asia are melting rapidly and irreversibly. These glaciers feed the big rivers of Asia; the Indus, the

Yangtze the Yellow and the Ganges, and depletion increasingly threatens food security in Asia. The poorest nations on earth are collapsing and the number of failed states, with the state unable to feed and provide security and basic services, is increasing rapidly.

The number of migrants and refugees is rising alarmingly. Out of desperation terrorism, war and violence is endemic. In developed countries, out of fear and confusion, extreme right wing, populist and totalitarian politics is on the rise, decreasing the aid given to failing states and paradoxically exacerbating the problems.

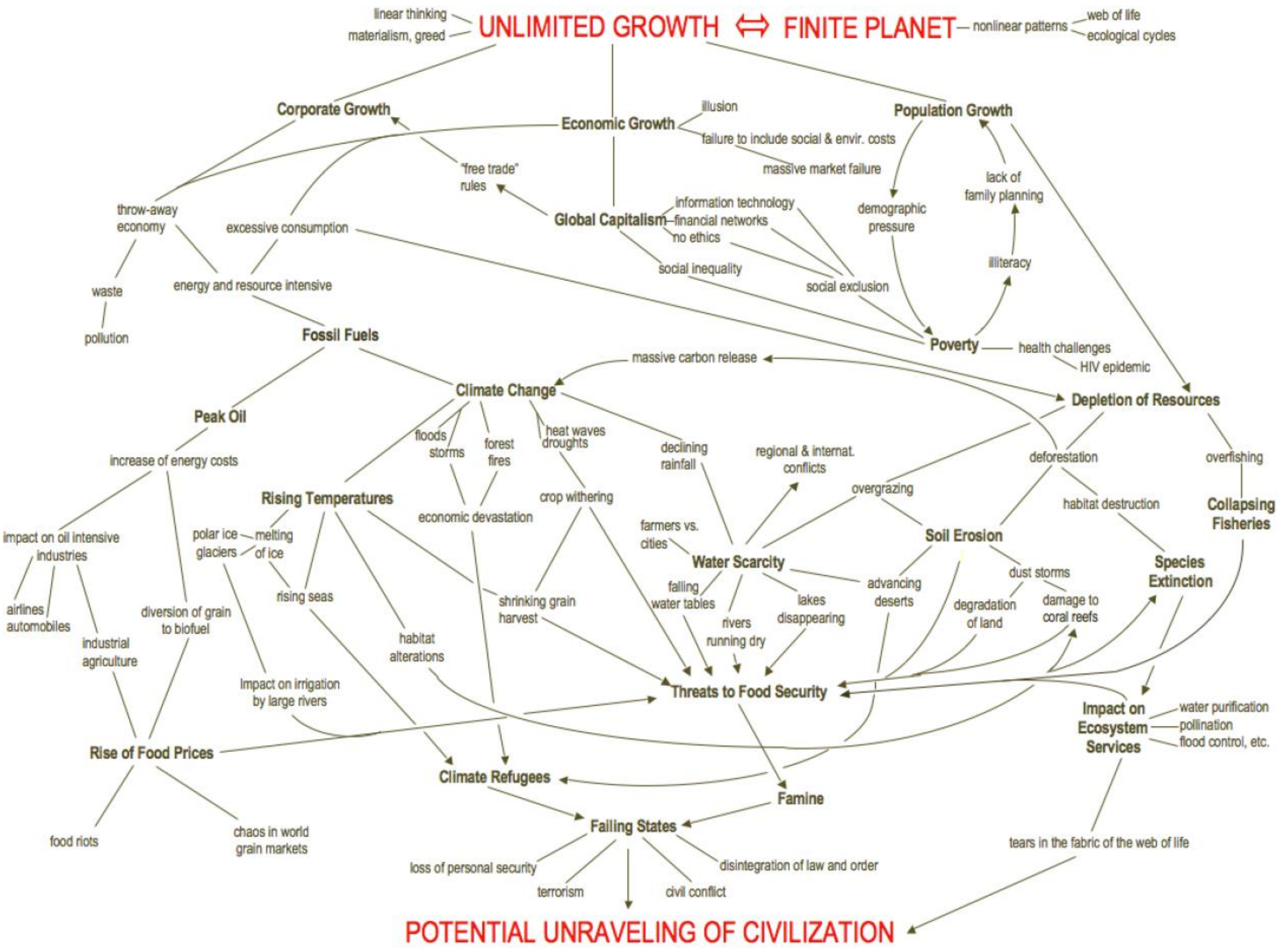

Fig 1. Capra[1] (2014)

Industry 4.0 and 21st Century Economic ***Emerging Industry 4.0 technology***

A list (not exhaustive) of Industry 4.0 technology and trends is shown below: These technologies are emerging systemically. Changes and development of one effecting others creating applications and effects that are sometimes difficult to predict. As a result, adopting an ecological and social framework is both as important as it is urgent.

Autonomous Vehicles	**Blockchain**	**Biotechnology**
3D Printing	**Big Data**	**Waste management**
Robotics	**FinTech**	**Artificial Intelligence**
New Materials	**EdTech**	**Smart Cities**
Shared/Token Economies	**E-Commerce**	**Virtual and Augmented Reality**
Internet of Things	**Cloud Computing**	**Nanotechnology**
Hydrogen storage cells	**Solar cells**	**Wind and wave turbines**
Game Based Learning		

The Global Research, Innovation and Discovery Centre at Heriot-Watt University

GRID is Located at the heart of Heriot-Watt Universities Edinburgh Campus; GRID is designed to excite tomorrow's thinkers and challengers. It's a globally networked space where students can learn, tackle and immerse their curiosity and intellectual passions. Create and experiment with ideas that could design solutions to real-world challenges. Featuring the very latest in technological innovation, including Augmented Reality, Virtual Reality and Gaming studios it will have the capability to connect with global industry partners and our other university campuses around the world.

Students will have the opportunity to work on real-world problems, working across disciplines to deliver practical solutions with global impact.

This paper argues for a framework for identifying and prioritising GRID technology projects with urgent social and ecological benefits.

A City as a Complex Adaptive System

A city is undoubtedly a complex system, in which the interaction of agents (people in the cities social systems, organisms on a cities ecological communities, and increasingly “smart” technology in a cities socio technological systems) interact in a non-linear fashion creating a network of connections in which agents are acting and reacting to each other’s behaviour. Through adaptation agents have the capacity to synchronise their states or activities with other agents at the local level. The system can then self-organise with the emergence of global patterns of organisation. The technological interactions, increasingly using Artificial Intelligence and “Big Data”, can be seen to be creating smart control and monitoring feedback loops, aiding relevant feedback increasing the system’s ability to adapt.

Metabolism and Life

What features and processes of city might qualify it to be considered as living? To quite Paul Ormerod and Eric Beinhocker[5] “The economy is a complex adaptive system – much more metabolism than a machine. It is also a story about the possibilities of abundance, of meeting people’s needs by designing out waste and recreating the kind of elegant abundance so evident in living systems. That is economic growth, but not as we define it today. It has much more in it about a quality of life than mere throughput: it’s the connections, the relationships not the stuff that is in focus.”

Extending this to the flows of matter, energy and information through a city we may view the city as if it has a metabolism, aided by the flows of, and controls therein, of information through advanced digital technology. And according to the biologist Lynne Margulis[6] metabolism is the key feature of living systems.

Looking from this viewpoint we can see that the pattern of organisation for metabolism is that of a non-linear network (non-linear networks is a pattern in nature found everywhere), exhibiting non-linear dynamics – that is dynamics governed by positive and negative feedback loops.

Technology supported non-linear networks of metabolism and regulation

It is interesting then to explore how digital technology may interact and influence with these "city metabolic" networks in systemic way. We have identified 6 network systems, to explore how technology currently interacts and may interact differently if designed with new goal seeking. These networks are not actually separate but mutually interdependent.
They are:

1. **Distributed networks of finance and values**
2. **Smart distributed networks of energy and transport**
3. **Monitored and nurtured urban ecosystems**
4. **Networks of collaborative and community based social systems**
5. **Networks of industries built upon circular economic principles**
6. **Educational networks that teach Ecoliteracy and Systems Science**
7. **The "dark web"**

For each network we explore a vision of what is currently emerging as a result of using technology from the mechanistic point of view and a proposed vision of what might manifest differently if technology is designed from a living systems perspective.

Goal Seeking, Values and Morals

A complex adaptive system is goal seeking, if the goal is largely economic as GDP, and societal benefits will "trickle down" then the system will not be making use, more widely, of information about its stability, ecological and social health and will therefore not be adapting to changes in these vital systemic properties. But what goals should the system be seeking? What values should it embody?

Since sustainability is our greatest challenge goal seeking must focus on this systemically. Capra's[1] working definition of sustainability is "to design a human community in such a way that its activities do not interfere with the process of life[1]

Morals and ethics present a large area of study and views, but fortunately the United Nations have devised the UN sustainability Goals and the Global Civic Society has thought deeply about the question of ethics and extensively through collaboration and has devised the magnificent Earth Charter.

The UN Sustainability Goals

The Sustainable Goals are a UN Initiative. The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations General Assembly in 2015 for the year 2030. The SDGs are part of Resolution 70/1 of the United Nations General Assembly, the 2030 Agenda.

The goals are broad based and interdependent. The 17 Sustainable Development Goal's each have a list of targets that are measured with indicators.

Fig 3 The UN sustainability Goals

The Earth Charter

Created by a global consultation process, and endorsed by organizations representing millions of people, the Charter "seeks to inspire in all peoples a sense of global interdependence and shared responsibility for the well-being of the human family, the greater community of life, and future generations. "It calls upon humanity to help create a global partnership at a critical juncture in history.

The Principles are:

- Respect and care for the community of life
- Ecological Integrity
- Social and Economic Justice
- Democracy, Nonviolence and Peace

The "Doughnut" Economy as Moral and Ecological Compass.

The doughnut economy is a very visual economic model that has been devised by Kate Raworth[3] and envisions a world "in which every person can lead their life with dignity, opportunity and community – and where we can all do so within the means of our life-giving planet."

It introduces further qualitative measures to measuring the performance of an economy in addition to GDP. The centre hole of the model depicts the proportion of people that lack access to life's essentials (healthcare, education, equity, etc.), while the crust represents the ecological ceilings (planetary boundaries) that life depends on and must not be overshot. Consequently, an economy is considered prosperous when all twelve social foundations are met without overshooting any of the nine ecological ceilings. This situation is represented by the area between the two rings: 'the safe and just space for humanity'. *Raworth*[3]

Fig. 5 shows the desired economic pattern for a sustainable and healthy future, while fig 6 shows the current state, which has both serious overshoots in areas of planetary health and serious shortfalls in social foundations, which are systemically linked to overshooting the ecological ceiling.

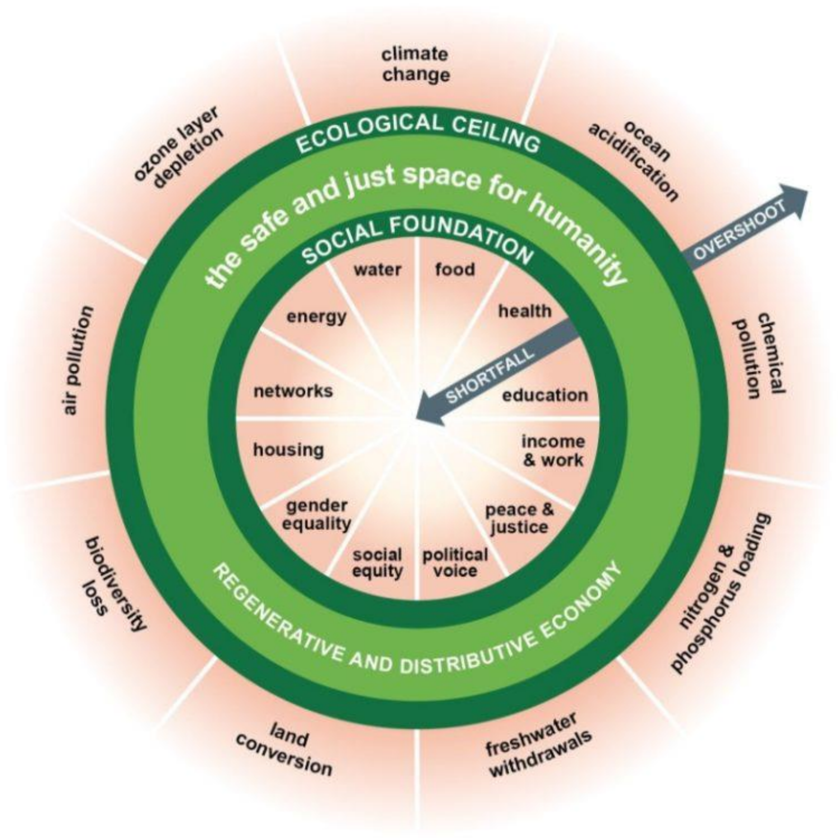

Fig. 5 the Aspirational Pattern

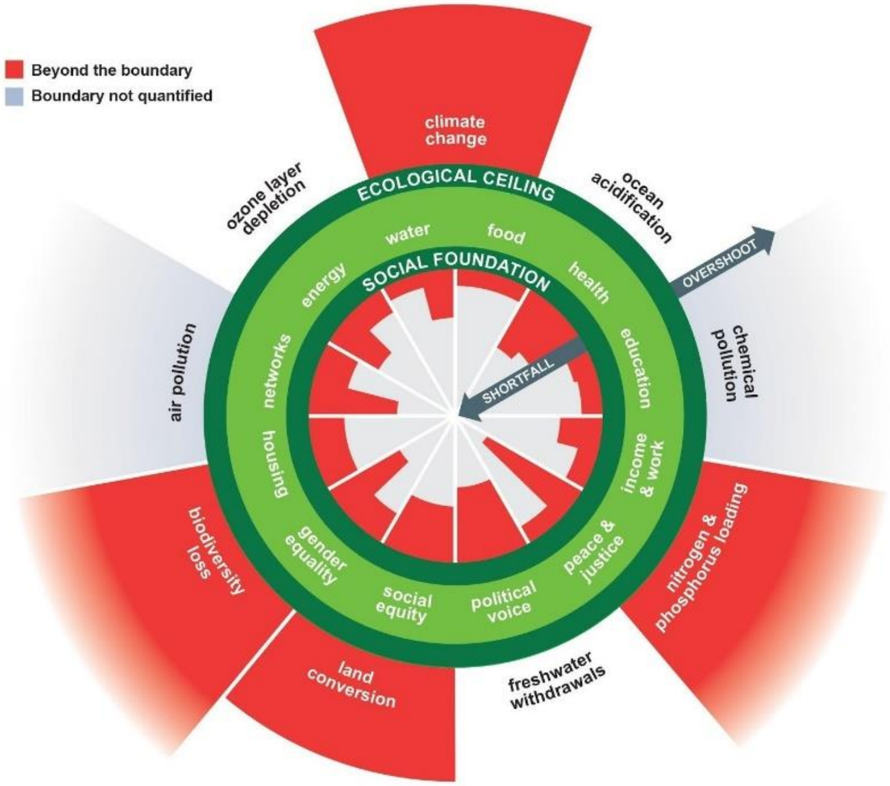

Fig. 6 the Current State

The Crisis of Perception

Classical economics has been deeply shaped by the Newtonian machine metaphor. Being conditioned by that metaphor, human economic activity has largely ignored ecological and social costs, or it has minimised them as "externalities". Having removed life conceptually, we are now in real danger of removing life literally as we may be entering the 6th extinction event of the planet shaped by economic activity[6].

If the crisis of perception is the root cause of the ecological crises, it is of interest to ask if technology can assist a correction of perception. Capra[1] states that in order to shift the world view to a more ecological one, we need to teach Ecoliteracy. He states that "we should be eco-literate and should act accordingly". "Acting accordingly" suggests something of a transformative nature, since we can intellectually understand systems science and Ecoliteracy and use its insights for our own short-term self-interest.

We think there are transformative aspects of the paradigm change which may be supported by the most radical aspect of the Systems View of Life and that is the "Santiago Theory of Cognition" (Maturana[7], Verela[7]).

In order to explain this briefly, we can consider the mind and the brain. Mind is seen as a cognitive process and the brain as the structure supporting the cognitive process. The process is autopoietic (self-making), the structure both supports the process and is continually regenerated by the process.

In each act of perception an organism "structurally couples" with the environment, the organism undergoes a structural change in response (for example a re-configuring of neural paths in a nervous system). The next time the organism interacts with the same stimuli it may behave in a different way. This is the basis for learning. It is important to note that an organism has a large degree of autonomy. It both chooses what to notice and directs its own structural change; the system specifies the extent of its cognitive domain. The environment may "disturb" an organism but cannot cause an organism to change. Verela[7] and Maturana[7] describe this as "bringing forth a world" in the act of perception. This is not a snapshot of reality but an ongoing process of engagement with reality itself.

In this sense cognition can be seen to be the process of life itself and elegantly heals the Cartesian mind-matter split giving the insight that as human beings we are both determined (by structural changes) and free (by autonomy)[1]. "Cognition is the activity involved in the process of self-generation and self-perpetuation of an organism. Cognition is the "very process of life"[1]. The process of life is a cognitive process at all levels of life. Mental activity is embedded in life. Consciousness emerges from cognitive activities at a certain level of complexity (i.e. a brain and nervous system)

We are seeing changes of how we make sense of the world by valuing epistemic knowledge over objective knowledge and approximate knowledge over Cartesian certainty. So the assumption made is that consciousness and cognition is at the root of the social systems we create and we will build them based on what we choose to value. What we value and choose to focus on has a central role in what we create.

The proposed model is a lens based on emergence theory, but to be clear it is in harmony with the idea of an embedded economy as shown in fig 7

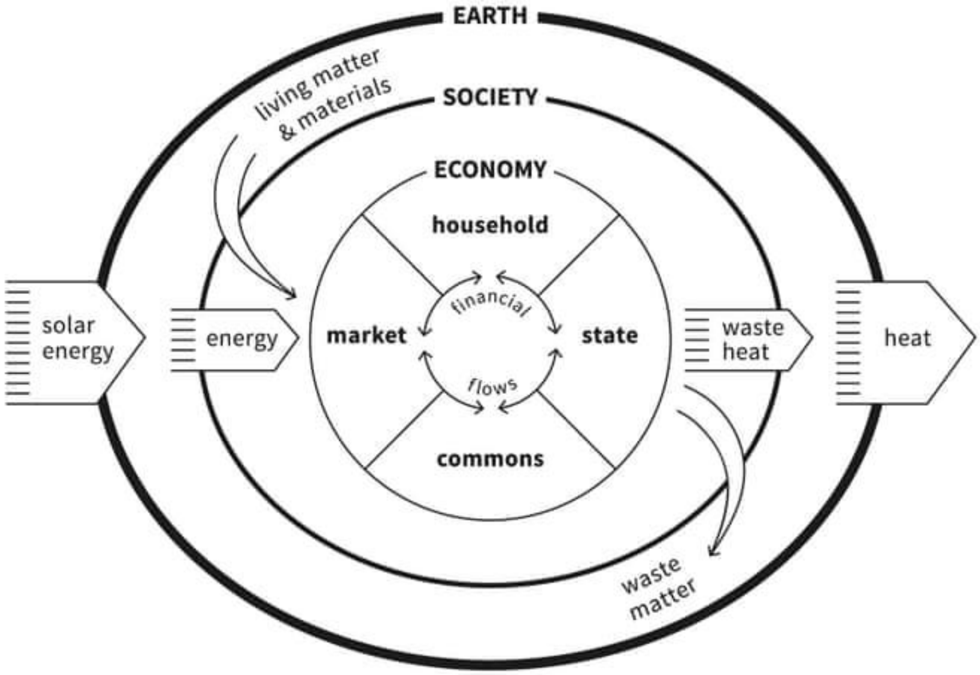

Fig7 the embedded economy - Kate Rawarth[3]

The "Living City" Emergent Levels and "Metabolic" Networks

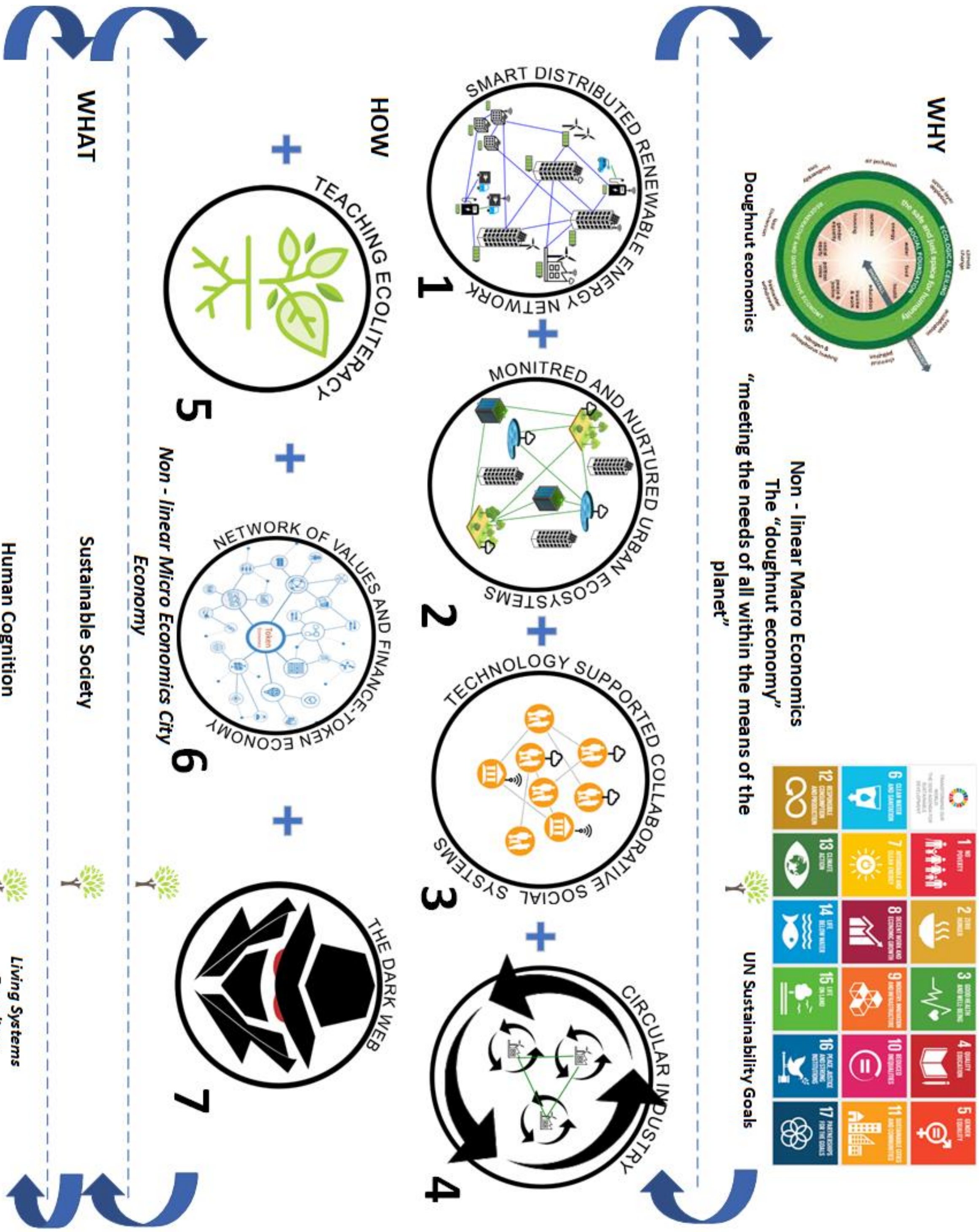
WHY
Doughnut economics
Non - linear Macro Economics
The "doughnut economy"
"meeting the needs of all within the means of the planet"
UN Sustainability Goals
HOW
SMART DISTRIBUTED RENEWABLE ENERGY NETWORK
1
MONITRED AND NURTURED URBAN ECOSYSTEMS
2
TECHNOLOGY SUPPORTED COLLABORATIVE SOCIAL SYSTEMS
3
CIRCULAR INDUSTRY
4
TEACHING ECOLITERACY
5
Non - linear Micro Economics City Economy
NETWORK OF VALUES AND FINANCE-TOKEN ECONOMY
6
THE DARK WEB
7
WHAT
Sustainable Society
Human Cognition
Living Systems Paradigm

Fig 8 the resulting framework for aligning Industry 4.0 technology with sustainability

Network 1: Smart Distributed Networks of Energy and Transport

Industry 4.0 Technologies of Interest

Autonomous Vehicles	✓	Blockchain	✓	Biotechnology	
3D Printing		Big Data		Waste management	
Robotics	✓	FinTech		Artificial Intelligence	
New Materials		EdTech		Smart Cities	✓
Shared/Token Economies	✓	E-Commerce		Virtual and Augmented Reality	
Internet of Things	✓	Cloud Computing	✓	Nanotechnology	
Hydrogen storage cells	✓	Solar cells		Wind and wave turbines	✓
Game Based Learning					

***From Business as Usual*: Centralised fossil fuel-based energy and transport**

Systemic Lenses:

POWER	Centralised. Power resides in large corporations that can achieve vertical economies of scale and petrochemical companies.

***Towards sustainability*: Distributed renewable energy and transport**

Jeremy Rifkin[8] describes a non-linear network of distributed renewable energy where every building becomes a solar / geothermal / wind mini power hub producing energy for its own needs and distributing (selling) any surplus to the smart distributed energy grid. When the wind doesn't blow and the sun is not shining, surplus energy is stored in hydrogen energy storage systems. Automated electric transport systems, drawing on energy from this renewable grid improve air quality.

Scaling up this distributed internet of energy requires modern technology. We need a technology platform to manage the logistics of the transport system, to manage the flow of electricity about the energy network and to manage the distributed financial transactions based on distributed purchase and selling of energy.

"Five pillars of the third industrial revolution", according to Rifkin, are as follows

1. Shift to Renewable Energy
2. Transform Buildings into Micro-Power Plants
3. Develop Hydrogen Fuel Cells
4. Create a Smart Grid using the Internet
5. Transition Cars to Electric and Fuel Cell Power

Systemic Lenses:

<table>
<tr>
<td>MEANING</td>
<td>Rifkin insightfully describes the change in human consciousness that occurs whenever there is a revolution in energy, transport and communication technologies
1^{st} Industrial revolution

revolution in energy – steam power
revolution in transport – steam locomotives
revolution in communication – newspapers from steam powered printing press

These changes expanded human consciousness enabling organisations to do more complex tasks, create more skilled workforces.
2^{nd} Industrial revolution

revolution in energy – electric power from cheap fossil fuels
revolution in transport – internal combustion energy
revolution in communication – telephone, cable, telegram

The 3^{rd} industrial revolution (the current revolution under way)

revolution in energy – distributed decentralised renewable energy
revolution in transport – distributed automated fleet of electric vehicles using renewable energy
revolution in communication – internet technologies

When we combine this 3^{rd} industrial revolution networks of energy, transport and communications with the network of material flows of the circular economy we start to shift consciousness in a profound way.</td>
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	There is a shift in consciousness (through the mechanism of downward causation) that starts to appreciate the interconnectivity of life beyond traditional geopolitical boundaries, since energy can potentially flow across continents. Power relationships are changed, big fossil fuel power companies do not hold all the power. Through the internet there is shift in consciousness to sharing and collaboration becoming “prosumers”. There may also be a shift in consciousness (which we are already witnessing) to realise how we all share, and participate in, the planets biosphere - both with our fellow humans but also with the myriad (but rapidly declining) species of our fellow creatures. Rifkin calls this Biosphere consciousness. Hopefully positive feedback loops in the dynamics at different levels will accelerate this change in consciousness as we need to race towards sustainability.
POWER	Energy becomes decentralised. Energy companies no longer sell power but have shifted business models to selling infrastructure, energy efficiency and smart grid software management platforms. Empowers the sharing society and the commons. Democratises energy and consequently allows local small-scale manufacturing to compete with large corporations. Fig 7 shows the essential split of power for an embedded economy. One quarter market, one quarter household, one quarter state one quarter commons. This is a departure from the current economic wisdom that the state should not interfere. Rifkin states that the state always played a major role in facilitating economic revolution transitions. Commons and the sharing society also now play a pivotal role.

GRID Projects and Heriot-Watt university synergies to close the gap

- ReFlex Energy system of the future.

  OIC, Aquatera, Solo Energy, Community Energy Scotland, Heriot-Watt University, Doosan Babcock

- Centre for Sustainable Road Freight

  Heriot-Watt University

Network 2: Monitored and Nurtured Urban Ecosystems

General Discussion

The benefits of engagement in civic ecology practices and stewardship of urban green space are increasingly recognized in supporting human health and well-being, providing ecosystem services in urban environments and enabling learning and interaction with local ecosystems.

Industry 4.0 Technologies of Interest

Autonomous Vehicles		Blockchain		Biotechnology	
3D Printing		Big Data	✓	Waste management	
Robotics		FinTech		Artificial Intelligence	
New Materials		EdTech		Smart Cities	
Shared/Token Economies	✓	E-Commerce		Virtual and Augmented Reality	
Internet of Things	✓	Cloud Computing	✓	Nanotechnology	
Hydrogen storage cells		Solar cells		Wind and wave turbines	
Game Based Learning	✓				

Network 3.Collaborative Social Systems

General Discussion

This category includes technology platforms that encourage and support the formation of sustainable communities. The global civil society has been empowered by the use of communication systems and platforms. Also virtual reality has been clinically found to help positive responses to psychological problems such as agoraphobia and social anxiety

Industry 4.0 Technologies of Interest

Autonomous Vehicles		Blockchain		Biotechnology	
3D Printing		Big Data	✓	Waste management	
Robotics		FinTech		Artificial Intelligence	
New Materials		EdTech	✓	Smart Cities	✓
Shared/Token Economies	✓	E-Commerce		Virtual and Augmented Reality	✓
Internet of Things		Cloud Computing	✓	Nanotechnology	
Hydrogen storage cells		Solar cells		Wind and wave turbines	
Game Based Learning	✓				

GRID Projects and Heriot-Watt university synergies to close the gap

- Virtual reality for therapy

Dr Mel Mckendric - Assistant Professor in Psychology, Heriot-Watt University.

Amelia Morgan – Chief Executive, the Venture Trust

Network 4. Circular Industries

General Discussion

To realise the circular economy at scale, technology has an essential role to play

Industry 4.0 Technologies of Interest

Autonomous Vehicles		Blockchain	✓	Biotechnology	
3D Printing	✓	Big Data	✓	Waste management	✓
Robotics	✓	FinTech	✓	Artificial Intelligence	✓
New Materials		EdTech		Smart Cities	✓
Shared/Token Economies		E-Commerce		Virtual and Augmented Reality	
Internet of Things	✓	Cloud Computing	✓	Nanotechnology	
Hydrogen storage cells		Solar cells		Wind and wave turbines	

Game Based Learning	✓				

***From Business as Usual*: The Linear Economy**

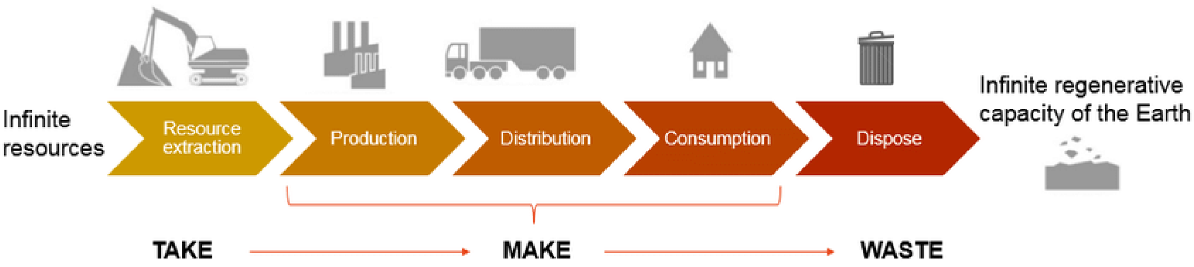

Fig 9 The linear economy

Systemic Lenses:

PROCESS	Linear vertically oriented value chains
MEANING	The assumption is cheap and abundant fossil fuel energy and that externalities are unimportant. Economic laws are still thought to be in-line with Newtonian physics instead of much more applicable thermodynamics, self-organisation and cyclical nature of ecosystems
POWER	Power is maintained by large corporations that seek to maximise GDP on behalf of their shareholders – indeed they are legally bound to.

***Towards sustainability*: The Circular Economy**

A circular economy (often referred to simply as "circularity") is an economic system aimed at minimising waste and making the most of resources. In a circular system resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops; this can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. This regenerative approach contrasts with the traditional linear economy, which has a 'take, make, dispose' model of production.

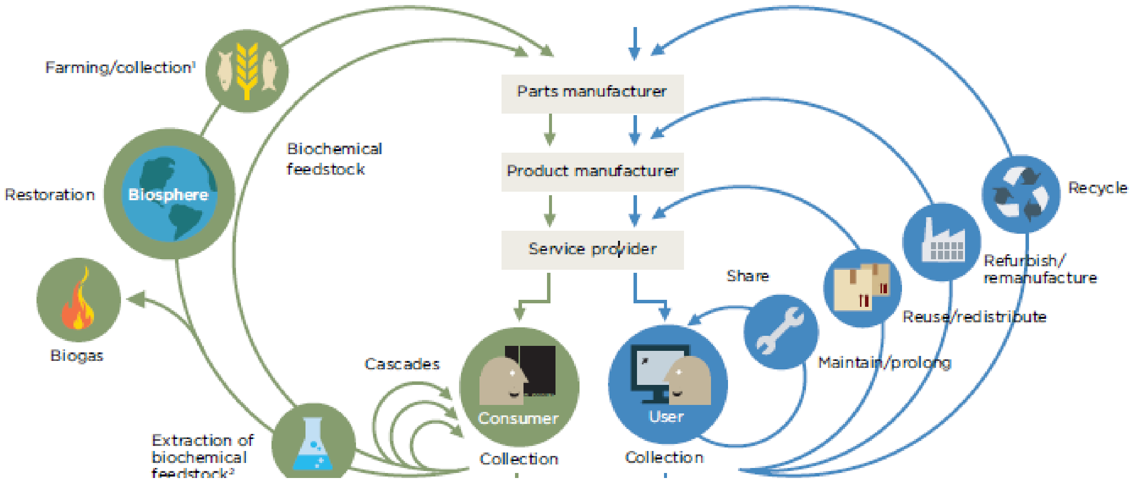

Fig 10 the Circular Economy

The Circular Economy and Intelligent assets

Connected devices in the Internet of Things (IoT) optimises the monitoring and control of location, condition and availability within a circular economy. The value overlap of IoT and the circular economy are shown below.

	INTELLIGENT ASSET (IoT) VALUE DRIVERS		
CIRCULAR ECONOMY VALUE DRIVERS	Knowledge of the **location** of the asset	Knowledge of the **condition** of the asset	Knowledge of the **availability** of the asset
Extending **the use cycle of an asset**	Guided replacement service of broken component to extend asset use cycle Optimised route planning to avoid vehicle wear	Predictive maintenance and replacement of failing components prior to asset failure Changed use patterns to minimise wear	Improved product design from granular usage information Optimised sizing, supply, and maintenance in energy systems from detailed use patterns

Increasing utilisation **of an asset or resource**	Route planning to reduce driving time and improve utilisation rate Swift localisation of shared assets	Minimised downtime through to predictive maintenance Precise use of input factors (e.g. fertiliser & pesticide) in agriculture	Automated connection of available, shared asset with next user Transparency of available space (e.g. parking) to reduce waste (e.g. congestion)
Looping/cascading **an asset through additional use cycles**	Enhanced reverse logistics planning Automated localisation of durable goods and materials on secondary markets	Predictive and effective remanufacturing Accurate asset valuation by comparison with other assets Accurate decision making for future loops (e.g. remain vs. recycle)	Improved recovery and reuse / repurposing of assets that are no longer in use Digital marketplace for locally supplied secondary materials
Regeneration of natural capital	Automated distribution system of biological nutrients Automated location tracking of natural capital, such as fish stocks or endangered animals	Immediate identification of signs of land degradation Automated condition assessment, such as fish shoal size, forest productivity, or coral reef health	

Systemic Lenses:

PROCESS	With the circular economy and the advent of 3D Printing, smaller companies or even individuals can create products with close to zero marginal cost. Cloud platforms enable small start-ups to have sophisticated technology available that can scale up

	or down quickly with no hardware costs and with no maintenance costs. Ideas can be tried and dropped or scaled depending on the success of the venture with very little cost. So many more innovations are possible and natural selection will depend which ones succeed, but not at very high cost to those that fail.
STRUCTURE	
MEANING	It has become clear that a network of intelligent assets bring more value when business and industries collaborate, as it is the relationships between assets and the context that provide value. The circular economy encourages the idea of a sharing society. Being biomimetic its adoption and understanding by society encourages understanding of cycles and non-linear processes in nature.
POWER	Power is again decentralising. Small scale local businesses can provide products and service at low cost to the local community that values them and can compete with global corporations. The sharing economy is becoming more evident. The four equal power splits of State, Market, Commons, Household is emerging.

Regeneration

For good or bad it is becoming clear that global economics is becoming the major factor in planetary regulation. We need to monitor and understand the state of the world urgently in order to adapt and allow regeneration.

GRID Projects and Heriot-Watt university synergies to close the gap

- Fisheye: an image data capture system for sustainable fisheries

  Michal J. Kaiser – Lyell Centre, Heriot-Watt University

- Cbed: Citizen-science to map the diversity of life on the seabed around Orkney

  Michel J. Kaiser, Jo Porter, Kate Johnson, Mike Bell & Sandy Kerr – Lyell Centre, Heriot-Watt University

- Iwokrama's invisible river carbon: bringing rainforest science into our daily lives using the digital revolution.

Ryan Pereira the Lyell Centre – Heriot-Watt University
Dr David Cole – Edinburgh Business School

- Sustainable shellfish production in Scotland
  Dr Dimitris Christopoulos, Dr Helen Cross Edinburgh Business School centre for networks

- Smart Manufacturing
  Professor Theo Lim: Engineering and Physical Sciences Heriot-Watt University

Network 5. Educational networks: Ecoliteracy and Systems Science Literacy

General Discussion

We have seen that the primary cause of our current ecological crisis is that of a crisis of perception. The single most powerful point of systemic intervention is to teach ecoliteracy.

Industry 4.0 Technologies of Interest

Autonomous Vehicles		Blockchain		Biotechnology	
3D Printing		Big Data	✓	Waste management	
Robotics		FinTech		Artificial Intelligence	
New Materials		EdTech	✓	Smart Cities	
Shared/Token Economies		E-Commerce		Virtual and Augmented Reality	
Internet of Things		Cloud Computing		Nanotechnology	
Hydrogen storage cells		Solar cells		Wind and wave turbines	
Game Based Learning	✓				

Towards Sustainability

Education and higher education can embrace interdisciplinary learning, with options both to specialise and to generalise, recognising the value of Systems

Science as a framework for understanding the complexity of the 21st century world. Generalised degrees should include Systems Science with modules such as Systems Biology, Systems Ecology, Cognitive Science and Holistic Science. All specialised sciences should also include a required Systems Science module. Ecoliteracy is taught at all levels at school and higher education and especially to entrepreneurs, leaders and politicians

GRID Projects and Heriot-Watt university synergies to close the gap

- Teaching business management to refugees
  Professor Heather McGregor Executive Dean, Edinburgh Business School

- The EBS game enabled Distance Learning Platform and The virtual classroom
  Mark Fowler, Dr David Cole Edinburgh Business School

- Cyber-physical systems for safe teaching health and safety
  Samuel Harper & Professor Theo Lim School of Engineering and Physical Sciences Heriot Watt University

- Supermarkets and Plastics - Gaming Innovation for Education, Change (or Climate) and Society (GIECS)
  Dr David Cole Edinburgh Business School, Agnessa Shpakova Edinburgh Business School

Network 6. Distributed Networks of finance values & trust

General Discussion

Industry 4.0 Technologies of Interest

Autonomous Vehicles		Blockchain	✓	Biotechnology	
3D Printing		Big Data		Waste management	
Robotics		FinTech	✓	Artificial Intelligence	
New Materials		EdTech		Smart Cities	
Shared/Token Economies	✓	E-Commerce		Virtual and Augmented Reality	
Internet of Things		Cloud Computing	✓	Nanotechnology	

Hydrogen storage cells		Solar cells		Wind and wave turbines	
Game Based Learning					

From Business as Usual

The current dominant economic view is that of global capitalism. According to Capra[1] "The new capitalism, which emerged from the information technology revolution during the past three decades, is characterised by three fundamental features. Its core economic activities are global; the main sources of productivity and competitiveness are knowledge generation and information processing; and it's structured largely around networks of informational and financial flows that form its very core."[1]

Manuel Castells[9] explains: "Capital is shuttled back and forth between economies in a matter of hours, minutes, and sometimes seconds. Favoured by deregulation … and the opening of domestic financial markets, powerful computer programs and skilful financial analysts/computer wizards sitting at the global nodes of a selective telecommunications network play games, literally, with billions of dollars … These global gamblers are not obscure speculators, but major investment banks, pension funds, multinational corporations … and mutual funds organised precisely for the sake of financial manipulations."9

This powerful network of machines is programmed and utilised for a single purpose – to make money. It is a global casino completely divorced from ecological reality and to other values important for human and planetary life and health.

Systemic Lenses:

PROCESS	"Capital works in real time, moving rapidly through global financial networks, from these networks it is invested in all kinds of economic activity, and most of what is extracted as profit is channelled back into the meta-network of financial flows. Sophisticated information and communication technologies enable financial capital to move rapidly from one option to another in a relentless search for investment opportunities. Profit margins are generally much higher in the financial markets than in most direct investments; hence all

	flow of money ultimately converge in the global financial networks in search of higher gains
STRUCTURE	World Trade Organisation rules And others see OU stuff
MEANING	Materialism, greed is good, simple linear cause and effect
POWER	Centralised. Power resides in banks and organisations like the WTO. Large Corporations hold disproportionate power over smaller localised businesses

Towards Sustainability

Capitalism (at least for now) and technology of financial flows do not need to be abandoned. However, the financial system needs radical redesign. It needs to include ecological costs and additional important Human values.

Blockchain and Token economies

Blockchain technology could have a profound impact on how our economies run, and this emergent area of study has been called Token Economics or Crypto Economics. Traditionally, how we organise people, resources and technology which are channelled and structured around a set of centralised and bureaucratic institutions, based around the nation state and the enterprise.

This model is facing disruption from the network society which is enabling encrypted transactions to be securely and transparently recorded in distributed ledgers using Blockchain technology. Ledgers in effect store the records of transactions of some value. We have seen that society is moving out of an industrial economy into a new model of services and information economy, and this technology could be a platform that may empower actors hitherto disempowered and small local businesses to compete with large corporations.

Systemic Lenses:

MEANING	Actors can see that they can contribute. Actors feel empowered that the things they value matter in an economy
POWER	Power is radically distributed away from large corporations and may allow the inclusion of local actors and the inclusion of ecological and social values.

Network 7. The Dark Web

General Discussion

With the greater adaptability that is achieved by integrating technology into non-linear networks results in vulnerability to tampering, attacks and disinformation. Cyber criminals, State interferences, fake news and disinformation become big issues for technology supported systems.

This will need comprehensive systemic understanding with emerging security solutions. These systems can become so powerful that a moral compass as described in this book should always inform design and development

Industry 4.0 Technologies of Interest

Autonomous Vehicles	⚠	**Blockchain**	⚠	**Biotechnology**	⚠
3D Printing	⚠	**Big Data**	⚠	**Waste management**	⚠
Robotics	⚠	**FinTech**	⚠	**Artificial Intelligence**	⚠
New Materials	⚠	**EdTech**	⚠	**Smart Cities**	⚠
Shared/Token Economies	⚠	**E-Commerce**	⚠	**Virtual and Augmented Reality**	⚠
Internet of Things	⚠	**Cloud Computing**	⚠	**Nanotechnology**	⚠
Hydrogen storage cells	⚠	**Solar cells**	⚠	**Wind and wave turbines**	⚠
Game Based Learning	⚠				

Envisioning Part Two

An Alternative Sustainable Future Vision

Poverty is closer to eradication, as population growth comes under control, as the result of education and investment in communities in poorer nations.

World governments have realised that global capitalist consumerist economics is dysfunctional. It is now clear that, the almost magical thinking; that things will just get better when economic growth, based on GDP, improves is seen as a fallacy.
Biomimetic economic models are now widely adopted, the circular economy is implemented in industry ecosystems, and genuine progress is being made towards the UN Sustainability Goals and the Earth Charter. The "doughnut" economic model has been adopted as a moral compass, data is increasingly captured across the planet (systemically to include human, ecological, industrial, financial, values and resources) and using "big data" and Machine Learning it is clearer how economic activities are affecting "The safe and just space for humanity" possibly in near real time, allowing informed assessment and adjustment. It is likely that by this time economic activity, for good or bad, will be the major regulator of the planet. Therefore, paying attention to global patterns emerging from economic activity is essential.

World governments in developed and undeveloped countries alike recognise that large investment for a wholesale move to renewable energy is essential.
Although large centralised energy systems (in Algeria and other North African countries export energy by huge solar farms in the desert) most energy is self-produced for local use where every building and facility is its own micro power plant using solar, wind and geothermal capture. Increasingly efficient hydrogen energy storage cells are used locally to store energy when the sun isn't shining, and the wind isn't blowing. Surplus of energy can be fed back and sold into the grid where energy is a source of revenue for the business or house holder.

Education and higher education have embraced interdisciplinary learning with options both to specialise and generalise. The value of Systems Science, as a framework for understanding the complexity of the 21st century world, is recognised. Generalised degrees include Systems Science with modules such as Systems Biology, Systems Ecology, Cognitive Science and holistic science. All specialised sciences also include a required systems science module. Ecoliteracy is taught at all levels at school and higher education and especially to entrepreneurs, leaders and politicians.

This is, however, not a utopia and the human condition will still be the human condition. With the increasing complexity of using machine learning and big data to help monitor and control aspects of cities and biosphere requires a response to cyber criminals, cyber warfare, terrorism, fake news and social manipulations. This, however, also offers tremendous economic opportunities in the cyber security industry.

One hopes that the effects and necessity of all these transformations continues to expand “Biosphere Consciousness” and a sense of stewardship of the planet for human beings and our fellow creatures.

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The need for a Systems Thinking approach in the Housing Industry

Mike Siebert
Department of Built Environment & Architecture, University of Nottingham, University Park, Nottingham, NG7 2RD
Email: Michael.siebert@nottingham.ac.uK

Abstract

The UK housing industry is currently in a crisis that neither government nor the industry itself seem capable of resolving. This is not for a lack of proposals stating what needs to be done (Farmer, 2016), but more for a lack of consensus over what the root causes are that are to blame for this predicament. The government accuses the industry of complacency whilst the industry accuses the government of inconsistency, the net result being a stalemate that only strengthens an increasingly dysfunctional status quo.

This paper stems from recent research by the author into the barriers to innovation in volume housebuilding where the emphasis was put on the reasons why innovative solutions have failed to take hold rather than the many well-rehearsed reasons why they should be adopted. The concern that emerges is that there is a basic lack of process for dealing with these complex problems and for delivering the consensus position that needs to be reached.

Keywords: housing, innovation, barriers, complex problems, systems thinking, off-site manufacturing, decision making process

Introduction

The purpose of this paper is to investigate the potential for a Systems Thinking approach in helping to resolve the issues within the housing industry that have thwarted innovators and so many government led initiatives promoting that innovation over the past decades. With successive governments calling for the housing industry to behave more like manufacturing and boost its productivity levels to a similar degree, it is suggested here that the promotion of the methodology central to that success story should at least be well received.

The approach taken has been to first explain the predicament that the UK housing industry finds itself in, starting with an historical perspective. The purpose of this is to show where the similarities and the differences lie between the two industries, manufacturing and construction, before then looking at how a Systems Thinking approach to housing might be beneficial in this instance. The initial proposal for a systems approach is one that emerged from the research carried out by the author, which is then discussed in the context of Systems Thinking and its many incarnations over the decades of its own evolution. The culmination of this is effectively a proposal put to the Systems Thinking community to collaborate in finding the most appropriate way forwards that would benefit both the housing industry and the advancement of Systems Thinking into this new field of development.

The state of the UK Housing Industry

For now, at least, innovation in the housing industry is closely linked to sustainability, as this is by far the main driver for innovative new products and processes being developed. But to assume that sustainability will become embedded within the lexicon of design parameters forever more is not a given. It is well known that the term sustainability has been used broadly and loosely for many decades and means different things to different people, with other terms – whole life costing, the circular economy, resilience – orbiting around it with equal abandonment. It is also well known that the proponents of all architectural movements, in their moment, assume that they have defined the pinnacle of architectural design for evermore. There are indeed already signs of sustainable development, under the banner of 'eco architecture' slipping into the realms of just another fad alongside post-modernism, deconstructivism, and so on and so on. Ensuring that sustainable development and the objectives of a circular economy are seen as a permanent realignment of the fundamentals of design is therefore the driver behind this discussion.

To say the UK housing industry has lost its way would be to suggest that it was ever guided by any universally held objective, but what can be said with some certainty is that the current push towards alternative methods of construction is lacking in cohesion. This state of affairs, which has led to a recent government white paper suggesting that the industry is in a ‘near existential crisis’ and to liken it to a dying patient (Farmer, 2016), comes from a combination of inaction on behalf of the majority stakeholders - the volume house builders - and undirected action coming from the remaining, well-intentioned but often under-informed SMEs, councils and housing associations.

None of this is encouraging when there are so many critical issues to be dealt with that all require oversight, consensus and collaboration. These statements are not unique to the housing industry, with similar scenarios existing elsewhere, which has led to answers being sought elsewhere too. The government has for some time now, and with increasing exasperation, suggested that the housing industry should ‘behave’ more like the manufacturing industry (Construction Leadership Council, 2018), their hope being that it could emulate the increase in productivity seen in this sector over the same period that the construction industry has been flatlining. This plea, however, has been widely interpreted in too literal a fashion, with a drive towards off-site manufacturing and the development of volumetric housing solutions as the next panacea to our housing crisis.

As a country, we’ve been here before on more than one occasion, and the off-site manufacturing solution has never managed to live up to its expectations (Adam et al., 2016) - but this is not to say it’s a wrong solution. In fact the reason for pursuing this as an area requiring further research is due to the potential that off-site manufacturing has to drive our housing industry forwards and deliver housing far closer to the circular economy ideal (Miles and Whitehouse, 2013). The manufacturing and housing industries are in reality very different processes, but Off-Site Manufacturing (OSM), and in particular full factory built volumetric housing, does offer up a middle ground where the similarities are greatest, and for this reason, provides a useful vehicle for comparing the approaches used within the two industries for dealing with similarly complex issues that in housing are creating barriers to innovation.

The suggestion being made here is that the cyclical failure of OSM within the housing industry is symptomatic of the industry’s broader inability to understand

and deal with the complex and inter-related problems that define it. It is for this reason that the industry is in part paralysed within a dysfunctional status quo and in part chaotic in its scattergun approach to innovation that is failing to define a clear path ahead for others to follow. By highlighting the decisions that are being made through the housing industry's very linear and insular processes – alongside the factors that are being overlooked through this approach, the intention is to show how necessary it is for a more holistic methodology to be introduced in order to resolve these issues more productively.

The history of Off-Site Manufacturing

OSM in its first incarnation after the Second World War was known as Pre-Fabricated Housing. It is because of the connotations associated with this term that the name OSM was introduced, but at the time, prefab housing was seen as a successful and a necessary intervention (Grindrod 2011, p.21). It provided modern, affordable housing at a time when there was a desperate need, a shortage of labour and high debt levels. In that respect, our situation today could be said to be comparable. There were also differences however. The facilities used to build these houses were often the existing and no longer required armaments factories, and in some cases the labour force consisted of ex-prisoners of war yet to be repatriated. There was an explosion of 'systems', numbering over 200 at one point, before being reduced down to a far smaller number that went on to be commercially successful (Ross, 2002a). But in time this approach to housebuilding was replaced by conventional methods, as has been the case with every subsequent resurgence of OSM. The pattern follows the boom and bust cycles of the national economy, with interest in OSM peaking with the 'green shoots of recovery', when there is a high demand, but a shortage of both materials and skilled labour. As the economy and supply chains begin to normalise themselves again, and labour becomes more plentiful, as first happened in the 1950s, the reversion to less expensive, more flexible traditional methods begins. OSM, requiring as it does a steady flow of orders to maintain its profitability, quickly collapses as the costs of servicing its considerable assets begin to accumulate.

Whilst no two cycles are identical, and there are always new factors to consider, this is nevertheless the underlying pattern that is in danger of repeating itself. Without a process in place to interrogate the factors that feed into this narrative, it is difficult to rule out the possibility of a repeat performance, or more importantly, to know what decisions would need to be taken beforehand to guarantee a different outcome. This is what a more holistic decision making process would help to resolve, as illustrated here (figure 1) using Causal Loop and Stock and Flow concepts to show the reinforcing nature of this dysfunctional chain of events and what balancing interventions might be capable of changing future outcomes.

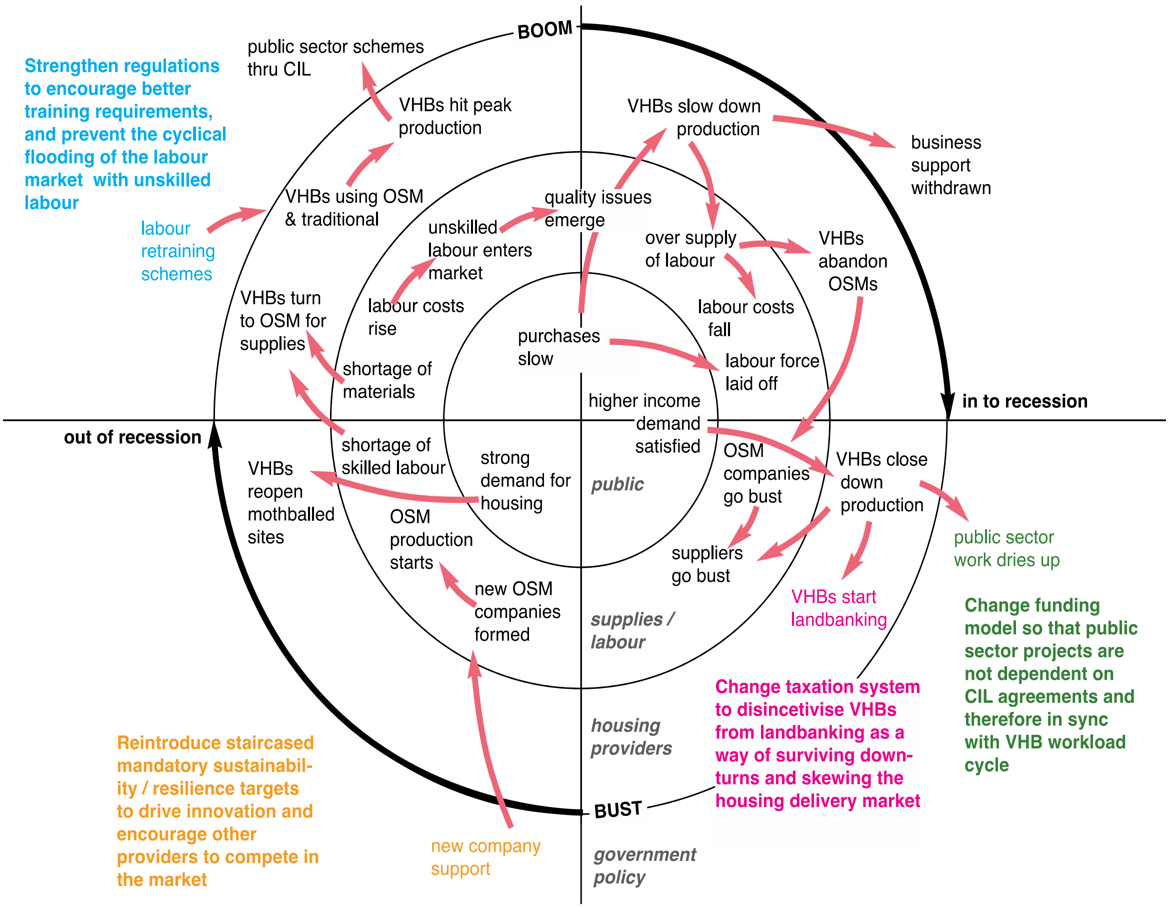

Figure 1: The boom and bust cycle of Off-Site Manufacturing

Approaching Systems Thinking through the lens of the Housing Industry

The following five questions and the information they lead to, define the interrogative process that it is proposed needs to be introduced, looking first at the benefits to be gained from adopting OSM, then the barriers to be overcome and lastly how that can be achieved by recognising the inter-relationships between those barriers and the need to confront them collectively, not in isolation.

What are the benefits of OSM from the perspectives of all the sectors involved?
The government is currently very keen to promote the concept of OSM as the solution to our housing crisis (London Assembly Planning Committee, 2017). To fully understand the thinking behind that position however, would require inside knowledge that is very difficult to obtain. The public facing message is one of encouragement - for the housing industry to innovate, diversify and thereby reduce costs, increase productivity and build more housing and to a higher environmental standard. These are all genuine advantages that OSM could deliver, but signs of genuine governmental support for the fledgling industry where it is most needed are harder to come by. The known break point, where demand falters towards the end of a boom period, is where government could maintain demand levels by gearing up its social housing programme. Why it is that this has not been addressed strays into the realms of internal policy making that is less open to the public, but will be returned to later as a clearer picture emerges.

What are the barriers to adoption from the perspectives of all the sectors involved?
None of the other sectors that make up our housing delivery system (figure 2) are fully in support of OSM.

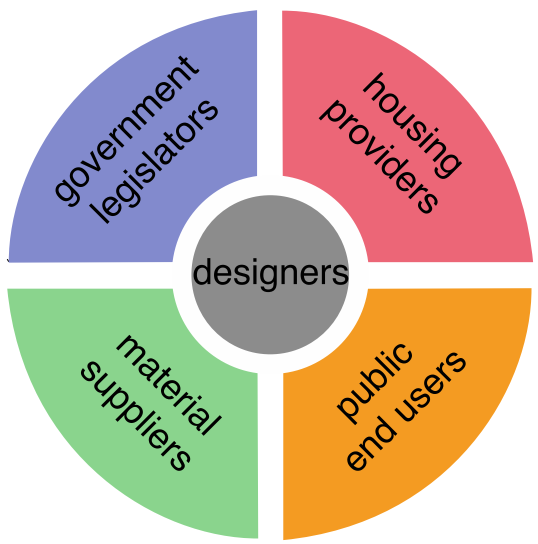

Figure 2: Sectors defining the housing delivery system

Some housing providers are willing to consider it as an option due to these potential benefits, but they are still only potential, and for them, the path ahead is littered with barriers to adoption that are not being fully addressed by government policies. One example of this would be the improvements in carbon emissions that can be achieved through a more controlled building environment, but without government driving the sustainability agenda (Hawkes et al., 2016), this is no longer the catalyst for change that it once was. Neither are the buying public convinced of its benefits, their wariness being in part due to the warranty industry's reluctance to certify any method of construction that has not been in existence for at least 60 years (Ross, 2002b). Perversely, part of the Warranty Industry's concern, beyond that of constructional risk is the lack of enthusiasm shown by the public and the potential drop in value any turn away from OSM housing in the future might have on their books. Ultimately, for the housing industry, it is a question of individual risk versus a possible collective gain, which is not incentive enough to drive the changes in behaviour needed to consolidate OSM as a mainstream solution.

Which sector dictates the decision-making process?

As important as the different motivational drivers exhibited by different sectors, is the hierarchy of decision making that exists between those sectors. Invariably only one sector has ultimate control over the decisions being made, and this varies, primarily on the type of housing being delivered. In the affordable housing market, due to the control government has over the funding mechanisms, it is government policy that ultimately dictates the decisions taken, whereas in the speculative housing market, it is the small number of major volume house builders who control not only their sector, but to a large extent government policy across the whole industry. The public, whilst housing remains an undersupplied commodity, have little or no voice regarding what is built, to what standard or for what price.

Where do these barriers sit within a hierarchy of causes and consequences?

Once the barriers to adoption have all been defined and prioritised in terms of how influential they or their proponents are to the decision-making process, the inter-relationships between them need to be considered. None of these issues exist in isolation, and it is these often-obscure links between seemingly incomparable and often contradictory factors that make these such complex problems to resolve: The true benefits of OSM can only be realised if and when OSM becomes a mainstream solution that can offer the mass customisation that housing requires. To date that has failed to materialise leaving OSM as a more expensive option that is only appropriate in a small percentage of cases, where the site conditions, location and property type coincide with the product being offered and the stage in the economic cycle reached at that time. Without consistent and targeted intervention from government or elsewhere to help manage the industry through these early stages of its growth curve, it seems unlikely that the industry can ever reach its mature form. A fundamental question that arises from this approach is that as one of the industry's strongest supporters, why is it that the government have failed to provide this support? This takes us back into the realms of policy making that are less open to public scrutiny. What is known is that no government can be seen to be providing unequal support for any one sector of an industry before being forced to compensate the other, especially, as is the case here, if the aggrieved party, the speculative house builders, can claim to be providing a more financially viable solution in the first place.

Also from this approach come possible answers to these questions that so often go unasked: One way in which government could avoid such a conflict of interests would be to ensure that the new supported provider is not in direct competition with the existing mainstream market provider, which in this case would require the fledgling OSM industry to focus on a less contested sector – for example affordable rented accommodation, possibly at higher densities and on inner city sites. On this occasion, this represents a clear fit between need and appropriate use for what the OSM market is best placed to provide, but increasing the percentage of rented accommodation in the UK is not a politically acceptable path for a government whose policies are predicated on home ownership to pursue. Causes and consequences.

How can these barriers be dealt with? – remove, avoid, accept.

What we are left with is therefore a scenario where the barriers to progress for OSM are laid out in their entirety with their inter-relationships and their relative influence on the decision-making process made clear, and the hierarchy of causes and consequences that dictate where the root causes lie now visible. An informed decision can now be taken regarding which is the most appropriate route forwards, remembering that not just some, but all barriers must be dealt with before any progress can be made. Dealing with a barrier does not necessarily require its removal however. Some barriers are best avoided by taking an alternative route, and on other occasions they just have to be accepted as being beyond one's ability to deal with and the decision taken to work within the constraints of their existence – which is very different to denying their existence (figure 3).

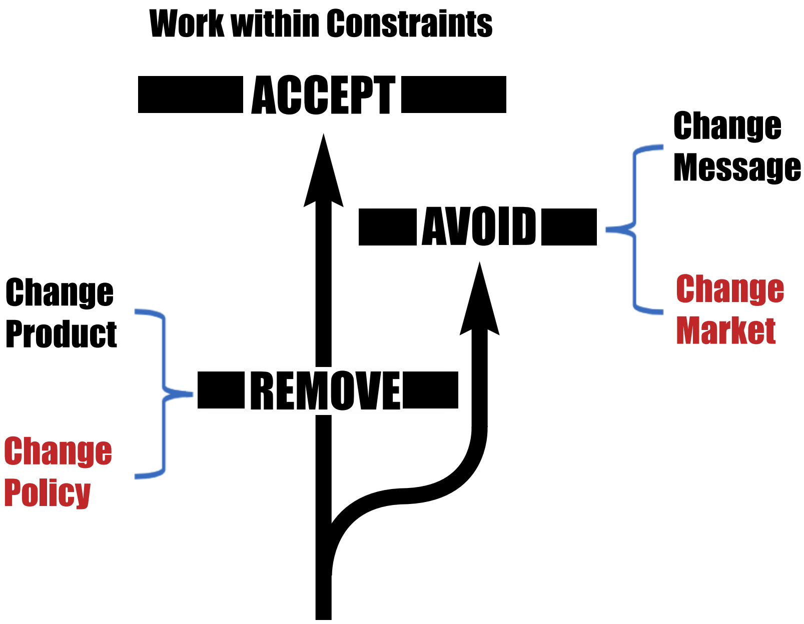

Figure 3: The options available for confronting the barriers to innovation

In the context of OSM, this translates into two options. Either to confront the political barrier head on and lobby / educate government about what the industry needs from them to secure their future, or to take the alternative route which would be to seek out and focus on that sector of the market for which OSM currently provides the most appropriate solution and represents the industry's best chance to gain a secure foothold within the current political and economic environment. That is effectively the decision taken by the 'New Entrants', those providers who have entered the market from non-residential sectors to take advantage of the housing industry's failure to capitalise on the potential benefits that OSM can offer those prepared to carve out a market sector defined by its appropriateness for this form of delivery (Wilmore, 2017). It is no co-incidence that the Farmer Review recognises this sector as where any innovation in our housing delivery will stem from.

Approaching the Housing Industry through the lens of Systems Thinking

The following section now attempts to approach this synergy from the opposite direction – Knowing what Systems Thinking can offer, in what form might it be of most benefit to the housing industry?

The first point to raise is probably that the construction industry is not intrinsically different to any other, but is an example of an increasingly complex, fragmented, adversarial industry that is, at the same time, constrained by a powerful status quo in how it considers its options going forwards – which would suggest it could and should be benefitting from Systems Thinking in some form or another.

What becomes clear from a deeper analysis of Systems Thinking is that there would seem to be a loose association between its evolving forms and the point at which the boundaries to the issue being addressed are drawn, certainly with respect to how the housing industry operates, and it is therefore from this perspective that this discussion starts.

At a company level, the immediate concerns tend to be relatively simplistic and related to short term targets, efficiency levels and bottom-line profit. In these instances, with little internal contradiction, the functionalist methodologies of early, Hard Systems Thinking provide a sound starting point, at least for understanding what that business needs in order to survive. But in order to capture the impact that competing businesses might have on any strategies put forward at this level, or how the business's customer base might respond to their offering, a more pluralist approach would be beneficial.

Moving outside the immediate confines of the supplier and its customer base, the 'housing delivery system' represents a broader boundary that includes the many other sectors whose input also needs to be considered – the legislative bodies, funding bodies, the various housing provider business models, and the design industry, in itself a multi-faceted sub-industry. To deal with these actors' conflicting motivations requires a more nuanced paradigm that considers how consensus and collaboration can be achieved where siloed thinking and adversarial business practices are currently the norm.

This now enters the realm of Soft Systems Thinking where the levels of complexity that must be dealt with constitute wicked problems that cannot be solved, only resolved, based on the facts as they present themselves at any one time, and from multiple subjective perspectives. The many ways that have been developed to tease out the real drivers behind embedded working practices can help bring about more enlightened solutions, but still only within the confines of the social and political environment in which the entire industry has to operate.

The next step within critical modernistic thinking accepts that there is not always a consensus viewpoint that can be reached, and the further the boundary is stretched to include this wider economic model, the more likely it is that alternative viewpoints and motivations will defeat the desire to resolve conflict and find consensus. The coercive models that have been developed to recognise this reality attempt to give a voice to those bodies, often defined as witnesses rather than participants, so as to rebalance the equation. In the housing industry, the buying public are those witnesses, often seen as little more than 'pawns in the game', certainly whilst there is an endemic shortage of housing. But even the government is beginning to look increasingly powerless in the face of an ever more entrenched and dictatorial speculative housing business model (Oldfield, 2015).

Perhaps the inevitable final step for Systems Thinking beyond this admission that not all conflict can be 'managed' out of the equation is the world view that questions the very nature of discourse and what constitutes an acceptable window for debate. As this process of boundary expansion reaches its global end game, the criticism of idealism distancing the whole purpose of the movement from its original practical roots grows in strength. But without the honesty that the post-modernist thinking brings to the equation, the equally valid counterclaim is that the answers that the systemic and critical permutations of Systems Thinking offer are blinkered in their failure to recognise the broader context of the environment in which we must all operate.

So where is the common ground within this pantheon of Systems Thinking methodologies, let alone the industries they hope to orchestrate into some form of consensual progress? Understanding the role that each paradigm was developed to perform is clearly an important part of this journey, as is recognising how the housing industry is structured within a hierarchy of ever more heterogeneous boundaries. Only with this knowledge can the appropriate methods be brought to bear on the problems being confronted, and a necessary compromise be sought between the practicality of short-term survival and the ideology of a longer-term purpose (figure 4).

Ultimately, this is an exercise in being honest about what a person, a business, an industry, a socio-political economy - a civilisation, expects to achieve and how best to go about that endeavour. But what this delivers must ultimately be a practical solution to the question being asked: how to avoid the barriers to innovation, and improve the product – our country's housing – for the client – the general public. And if any more proof were needed of how far short the industry is currently falling in terms of honesty within this debate, to afford our 'affordable housing' requires a household income upwards of £60 000, whilst our average salary is below £30 000. Clearly there are voices in some sectors that are not being heard.

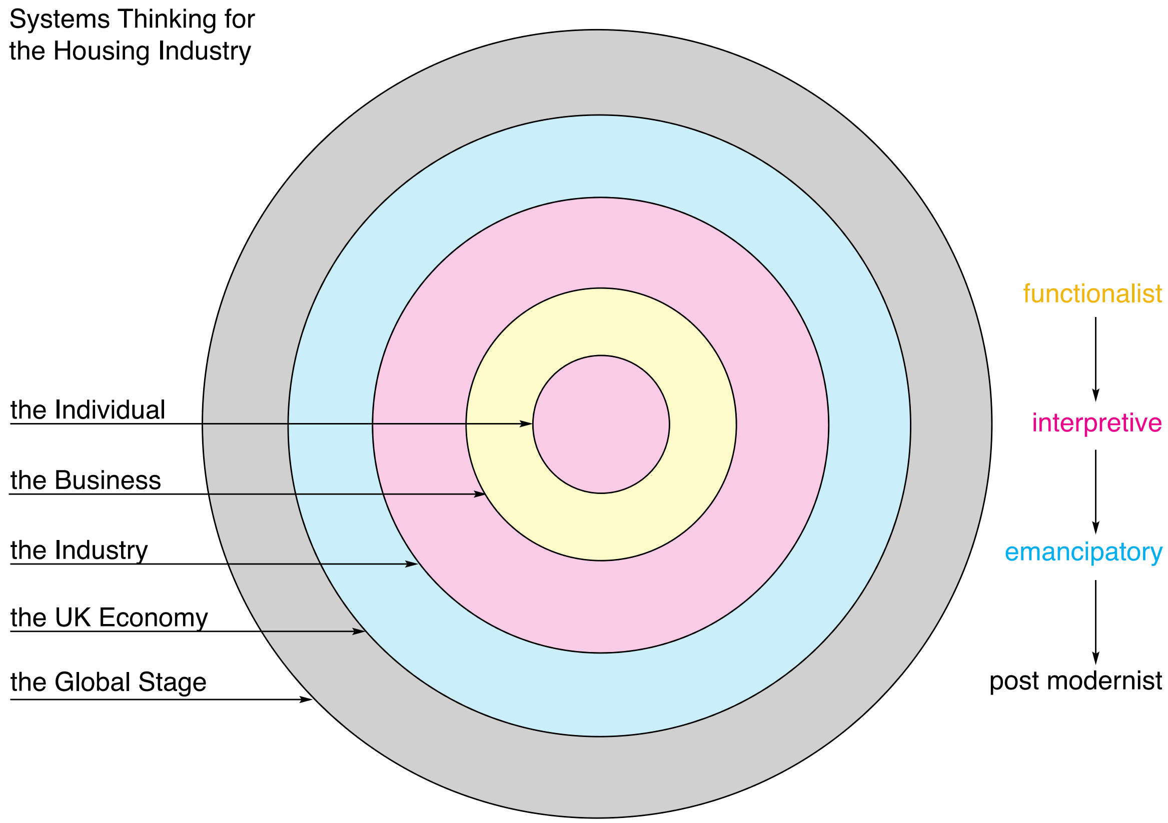

Figure 4: The relationship between paradigms and boundaries in the context of the Housing Industry

How to proceed?

The purpose of this paper has been to highlight the appropriateness of a Systems Thinking approach for resolving the issues being confronted by the housing industry. As common ground between the manufacturing and housing industries, off-site manufacturing and the production of volumetric housing has been used as a vehicle for showing just how such an approach might be beneficial. As is often the case with innovative solutions, the benefits to be gained – in this case a substantial shift towards the goals of the circular economy and more affordable housing – are well recognised, at least to those promoting the solution, but it is the barriers to adoption that are not being fully understood. To some extent these barriers are merely down to the message not being delivered in the appropriate language for the market being addressed. But this masks a more fundamental lack of knowledge within the industry of what motivates its different sectors. Without that knowledge, there is a danger that that message will never be in the right language and will never be heard, and this, it is suggested is at the root of the housing industry's crisis.

Certainly, when considering this common ground represented by off-site manufacturing, perhaps the most notable difference between the two industries is the housing industry's comparatively limited levels of collaboration, which only serves to show how desperately needed a more holistic approach is. The housing industry's siloed, linear thinking is preventing it from seeing the true nature of the problems being faced or the solutions that could help bring about meaningful change.

What the housing industry does have, however, albeit only partially adopted, is the vehicle for encouraging that collaborative environment to develop, in the form of BIM (Building Information Modelling). The first task of any process adopting a more holistic approach would be that of helping to explain the benefits of a common language underpinning the entire building process from concept design through to completion and beyond. Whilst BIM can provide this common language and help break down the barriers between those sectors and stages in the design process that need to better understand each other's perspectives, the current adversarial environment is preventing that essential interface from being fully adopted. The causal loop diagram in figure 1 depicting the cyclical failure of OSM is therefore only one of many reinforcing loops that exist within this industry that need to be recognised as such and broken with appropriate interventions. Again, as is the case in other disciplines, none of these loops exist in isolation, with all wicked problems being the symptoms of other problems, resulting in unsolvable conundrums that severely limit progress of any kind. But within the complexities that are known to exist, there is also a hierarchy of simple truths which is currently being overlooked that a Systems Thinking approach could use to promote its own benefits:

• The housing industry is paralysed by its own complexity, fragmentation and adversarial working practices that are preventing it from breaking free of its dysfunctional status quo.

• This cycle cannot be broken from within without those wanting change first reaching a consensus as to what is being proposed.

• That consensus requires a level of collaboration which in turn requires a deeper understanding of the industry's own sectors and what their motivations are within the broader housing delivery system.

• Reaching that level of understanding represents an undertaking that requires a decision-making process to be adopted by all those that have an influence over the decisions that need to be made, and leadership to enact that process.

There are many factors to consider here, including who will provide that leadership for change, what role government should or could play in encouraging that change, and where the financial catalyst for that change will come from, but of paramount importance is the industry first adopting a methodology that will help it recognise what those changes need to be. If Systems Thinking does hold the key to unlocking that decision-making process, either in its current form or as some hybrid solution, the proof of concept that the term Systems Thinking carries will help provide both the housing industry and government with the confidence needed to bring about such a change.

Using Systems Thinking to promote Systems Thinking

Evidence of past success only buys an introduction. To convince an industry that this will also help it find the answers to its own problems, it is probably necessary to provide the answers as well, or at least some plausible answers to show how the process works.

To paint a picture of how that might be taken forwards, the leadership needed to promote such a gear change in problem solving could come from the architectural profession, already chosen by the industry as the most appropriate party to promote and implement BIM as the 'common language interface'(Morrell, 2015). Government, already keen to promote manufacturing as the industry to emulate, should be fully behind the use of that industry's methodology as the way to transform housing's image, leaving only the often ignored but thorny issue of financing such a change to be resolved.

Change is slowest to materialise when there is no immediate cost saving involved. Most of the changes being discussed here are ones that have a social or an environmental benefit, both of which involve medium to long term paybacks, but with up-front costs. Without the stick of government legislation, innovation of this kind requires some other form of incentive, which it is suggested here could come from the growth in 'Impact Investment' – investment looking to actively make a positive social or environmental impact (Impact Investing Hub, 2018). Those businesses defined at the outset as the majority stakeholders with a vested interest in perpetuating the status quo, are not immune to investor trends, and if there is a growing trend demanding sustainable development, they will need to be seen to be investing a proportion of their research budgets in some socially or environmentally orientated field of activity. That cloak of respectability comes at a cost, in the form of lower returns on that proportion of their investment, which is potentially enough to provide those innovating businesses with the differential they need to compete against the prevailing market.

It is ironic that 'the public', seen throughout the industry as having little say or knowledge about the decisions being made on their behalf, if brought back into the equation might become the most important influencers of innovation. Even as the client of the housebuilders, they are belatedly finding their collective voice through social media and making their dissatisfaction heard (Kollewe, 2017). But as investors, they could be responsible for changing the emphasis on what is deemed acceptable in a social and environmental context. That influence is what will ultimately drive policy both within business and at a governmental level, as indeed it should.

This possible scenario is put forward here as an example of how such a holistic, emancipatory approach to complex problems can result in some equally complex but more balanced solutions that take into account all the barriers, many of which would otherwise get overlooked or side lined as unimportant or, even worse, unsolvable. Ignoring difficult issues does not mean they are no longer part of the equation - they will merely reappear at a later date after much time and effort has been expended travelling down a dead-end road. That is the current modus operandi of the housing industry that needs to be confronted, and this is one example of how a Systems Thinking driven solution could be used to promote Systems Thinking as the methodology for unlocking the industry's stalemate position.

Conclusion

There is much in this discussion to encourage a coming together of minds from the Systems Thinking community and the housing industry's many sectors of influence. There is also a proposition being made that the architectural profession is possibly best placed to act as the instigator of such a collaboration. Were the profession still in a position of power as the 'Master Builders', sat above the pyramid of work that construction entails, this might not have been the most appropriate route to introducing a methodology based on self-determination and collective decision making. But the architect's future role is now more likely to be one of 'Master Collaborator' sat firmly within the centre of that pyramid and able, if willing, to act as the catalyst for change that the industry knows is needed but finds itself unable to co-ordinate.

This is not a call for revolution, for some radical change in how the industry must operate, but a call for a more thought through approach to the problems being faced and how to deal with them – and finance them. The barriers to adoption for such an approach are no different to the barriers to adoption faced by the innovators this methodology hopes to create a path for. Proof of concept and the reduction in perceived risk that this brings is a major part of that process, and where such a campaign would need to focus its attention. In essence, the message being promoted is that whilst there still needs to be a radical vision to guide this process, this does not need to translate into radical policies, just small, well-directed, incremental changes that all move the industry in the same direction towards a commonly agreed goal.

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Using the Self-Organising Maps to distinguish between stress and non-stress state heart rate

Edward Bentley
Department of Computer and Information Sciences, Faculty of Engineering and Environment, Northumbria University, UK Edward.bentley@northumbria.ac.uk

Laurie Rauch
Department of Human Biology, Division of Exercise Science and Sports Medicine (ESSM), University of Cape Town laurie.rauch@uct.ac.za

Petia Sice
Department of Computer and Information Sciences, Faculty of Engineering and Environment, Northumbria University, UK petia.sice@northumbria.ac.uk

Paras Patel
Tees, Esk and Wear Valleys Foundation NHS Trust Newcastle upon Tyne, UK

Abstract

In this paper, use of a Self-Organising Map (SOM) is described to assess the level of physical stress caused by a rigorous programme of exercise known as Iron Man. A SOM may be produced directly from a data set without the need for pre-processing, enabling easy visualization of the properties of the set in the form of a two-dimensional plot or map. Physical stress affects the heart's action by reducing the degree of variability of the heart rate. If a time series of heart rate variability measurements is used to create a SOM, the trajectory of the series shown on the SOM after it has completed its self-training, as it is applied item by item, forms a measure of the stress level experienced by the subject. A comparison of the SOM trajectory taken prior to the Iron Man event with that taken afterwards enables a direct assessment of the stress level produced. Using this technique avoids the need to consider data obtained from other subjects. This study considers the direct representation of heart rate data via the

SOM and the participation in a particular exercise regime known to be stressful.

Keywords: iron man, heart rate variability, self-organising maps, and stress

Introduction

Recently there has been considerable enthusiasm for participating in extremely taxing sports such as the Iron Man triathlon, which comprises 3.86 km of swimming, 180.25 km of cycling and a marathon run of 42.20 km, completed as one continuous race. Work has been carried out to determine whether such exercise can cause temporary or permanent cardiac damage with conflicting results. La Gerche et al. (2004) found no markers of sustained damage 4.7 days after an Iron Man event. In contrast, a report of cardiac dysfunction after an Iron Man event involved a transient lowering of left ventricular contractility and altered relaxation, demonstrated by impaired diastolic and systolic left ventricular function for up to 2 days after the event (Whyte, 2008).

In view of the high demands of the event, Iron Man triathletes form a convenient group for studying the response of Physiological regulatory mechanisms to stress. In [König et al. 2007; Neubauer et al. 2008; Neubauer et al.2008; Reichhold et al 2008; Neubauer et al.2008; Reichhold et al. 2009; Reichhold et al. 2009] the resolution of recovery up to 19 days (including 5 blood samplings) after the Iron Man triathlon was examined in 42 healthy, male Iron Man competitors. Measurements were made of oxidative, muscular, cardiac, inflammatory and immuno-endocrine stress responses as well as genome stability. A significant systemic inflammatory response subsided rapidly, most likely due to counter-regulatory mechanisms and returned to baseline three weeks after the event. Similar results were observed for biomarkers of myocardial stress. On the other side, despite temporary rises in markers to measure oxidative stress, they returned to baseline five days after the event. At the same time parameters for the total antioxidative plasma capacity increased as response to the exercise. There was no long-lasting DNA damage following an Iron Man triathlon.

Another way to assess the extent of the cardiovascular stress in participants who have completed an Ironman race is to measure their heart rate variability (HRV), which reflects the heart's regulation by the autonomic nervous system (Porges, 1995). HRV is used as a measure of cardiovascular risk; if HRV reduces, one expects increased risks of cardiovascular disease and death from cardiac arrest (Thayer et al. 2010). On the other hand, favourable emotional states such as calmness and cheerfulness are linked with a rise in HRV (Geisler, 2010), and in general are associated with favourable emotionality (Oveis et al. 2009). By contrast, (Kemp et al. 2010; Kemp et al 2012) show that anxiety and depression are associated with HRV reductions.

What is Heart Rate Variability?

The time between successive heartbeats (R-R interval) changes each time the heart beats, this variation is known as HRV. It is mainly determined by changes in the heart's external regulation. HRV is determined by measurement of consecutive R-R intervals in ECG data, otherwise pulse pressure measurements may also be used. HRV is a measure of the heart's ability to respond rapidly to stimulation from unexpected circumstances. HRV has been analysed in both the frequency and time domains, and is a popular measure of cardiac health (Rajendra et al. 2006; Coats et al.1992; Tapanainen et al. 2002; Reinhardt et al. 1996; Cerati et al. 1991; Ravenswaaij-Arts et al. 1993). The regulation of heartbeat is achieved by the combined effects of two conflicting systems; the sympathetic nervous system (SNS), with its 'fight flight or freeze' responses, speeds up heart rate and muscular tension. Heart rate is slowed by the parasympathetic nervous system (PSNS), the 'rest and digest' response system which influence heart rate and contractility and promotes a generally relaxed state. The vascular circulation is neurally regulated by the rostro-ventro-lateral medulla (RVLM) in combination with peripheral afferent feedback to the hypothalamus via baro- and chemoreceptors and muscle afferents. The main determinant of HRV is the output of the vagal nerve providing a parasympathetic input to the heart. The presence or withdrawal of parasympathetic input is controlled by the brainstem cardiorespiratory network, by integrating cognitive processes, brainstem regulation and peripheral afferent input (Spyer and Gourine ,2009).

One may usefully consider HRV to be the variance between consecutive R-R intervals over a period of time calculated from continuous ECG recordings. Direct measurements of the R-R intervals and the differences between them can then be calculated. Further variables may be derived such as the SDNN (SD of the Normal to Normal R-R intervals, i.e. after removal of ectopic beats and noise), RMSSD (RMS value of consecutive R-R differences) and NN50 (the number of intervals of successive R-R intervals greater than 50 ms). These parameters represent predominantly parasympathetic activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology1996; Berntson et al. 1997).

Time or frequency domain measurements alone may be too insensitive to reliably detect changes in HRV, since heartbeats cannot be represented just as a periodic oscillator (Rajendra et al.2006; Huikuri et al. 2008). The SOM based approach does not appear to suffer from this drawback. The heart rates of healthy subjects appear fractal showing fluctuations, which are scale invariant over differing time series. (Tulppo et al. 2005).

Polyvagal theory

Polyvagal theory proposes that, through evolution, mammals have developed two vagal systems: a phylogenetic relic of amphibia and reptilian and an evolutional modification unique to mammals. The theory, constructed on established publications in neurophysiology, neuroanatomy and psychophysiology suggests that the two vagal systems are programmed to conform to different response mechanisms and may respond in contradictory manner. The theory includes target organ afferent and efferent pathways and strives to understand the influences and bidirectional communication between the heart and the central nervous system. It provides an important link from a correlative approach to a more integrative model, incorporating contemporary knowledge from neurophysiology and vertebrate phylogeny.

In this theory as developed by Stephen Porges (Porges, 1997;1998; 2011;2007), the model of regulation of internal processes and adaptation to environmental challenges, identifies four levels in a hierarchical structure:

Level 1: Maintenance of internal homeostasis: the successful regulation of internal processes is accomplished through neural feedback. To maintain homeostasis, interoceptors in the body cavity sense and transmit information to the brainstem; the brainstem interprets and regulates the internal organs.

Level 2: Integration of interoceptive systems with other sensory modalities and psychological process: in response to environmental challenges, homeostasis is compromised and the autonomic nervous system (ANS) responds by downregulating parasympathetic function and often but not always increasing sympathetic function; trade-off between internal and external needs for resources is mediated by the central nervous system;

Level 3: Associated with observable behaviours and regulation; and Level 4 with regulation and social engagement.

The effectiveness of the Level 1 and Level 2 processes can be evaluated by monitoring vagal activity and its impact on the rhythms of functioning of the heart. Level 1 activity of internal homeostasis can be evaluated through measuring HRV at rest or sleep. Level 2 activities (of adaptation to external environment) can be evaluated through assessing the change of vagal control on the heart as a measure of the ability to quickly adapt to environmental challenges. Responding to environmental challenges in healthy individuals is associated with removal of the vagal brake (downregulating PSNS) to allow for mobilisation of bodily resources via the SNS when an individual is under stress, physical or emotional, the ANS activates the so called 'fight-or-flight' response, which reduces HRV.

An individual's ability to transition between differing states of arousal is a function of the facility with which the ANS can respond to environmental challenges.

The data presented in this article is used to study the HRV in two different physiological states of athletes. To achieve that, for each subject their ECG was recorded just before and after completing an Iron Man event. From the ECG data, a MATLAB programme extracts the HRV data and then this is used to generate Self Organizing Maps, which indirectly compare the stress levels in the hearts of the participants before and after the event to examine the effects of the exercise.

Methodology

Heart rate variability analyses

The ECG activity before and immediately after participating in the Iron Man exercise was recorded from three electrodes, two placed subclavicularly bilaterally and one over the lower left rib just above the anterior superior iliac crest; the configuration known as Eindhoven's Triangle. An alcohol swab was used to clean the skin prior to attachment of the electrodes. The three electrodes were connected to a Biopac ECG amplifier set to band-pass filter between 0.5and 35Hz. All ECG traces were again off line band-pass filtered between 0.5 and 35Hz to reduce interference noise. The output was then examined to confirm that the QRS complexes and T waves were successfully identified. Noise and missed or ectopic beats were corrected by either enhancing R peaks to distinguish them from T peaks or by spacing beats. Undefined QRS complexes were corrected by replacing them with a previous adequately spaced QRS complex. The Iron Man subjects were tested during the Iron Man registration in a separate and relatively quiet room. Post-event the athletes completed the testing procedure again. This test was done as soon as the athlete reported to a temporary laboratory, which consisted of a minibus parked in a relatively secluded area behind the finishing tent.

Self-Organising Maps

Tambouratzis et al. (2002) showed that a Self-Organising Map (SOM), which is a form of Artificial Neural Network (ANN), could distinguish between a subject with left ventricular hypertrophy and a normal subject, using data obtained from measurements of blood pressure and heart rate. In the light of this work the current authors determined whether a SOM trained with HRV data only would be sufficient to distinguish between the before and after states of Iron Man subjects. The authors found that a SOM did distinguish between the HRV data taken before the Iron Man event vs. taken afterwards, suggesting that the HRV was altered by the stress of the exercise.

SOM is an ANN, which uses unsupervised, competitive learning. It is a useful tool that has been used in various discipline of research The SOM allows one to visualise and analyse data. The method transforms the original, possibly multi - dimensional, relationships between the items of data into, typically, a one or two-dimensional display. The SOM can reduce multidimensional data to a manageable form whilst retaining the input data topology.

SOM operation is discussed below with reference to Fig. 1.A full treatment of the theory is given in Kohonen (2001).

With reference to Fig. 1, the data to be studied forms a 'space' with typically two or more dimensions. A (typically) two-dimensional grid of 'neurons' or 'nodes' is set up in the software. The links joining the inputs and the nodes are given weights, a set of which corresponds to each node. Each neuron occupies a particular position on the 2-dimensional output space, and has a weight vector having the same number of dimensions as the input data set, which is mapped onto the grid of neurons. All neurons are allowed to relate to their neighbours by use of a neighbourhood function, which determines the topology of the eventual map. A training algorithm then varies the magnitudes of the weight vectors so that they encompass the input data set. The input data set is then applied one by one to the entire grid of neurons, and each data unit in turn is correlated with the neuron whose existing weight vector is closest (measured perhaps in terms of the 'Euclidean distance') to that of the data item being applied at the time. The weight vector of the 'similar' neuron is then modified to become closer to the corresponding values of the data item, and adjacent neurons within the array are modified so that their weight vectors are made similar to the data item, but to a lesser degree. The map becomes gradually organized as more and more members of the data set are applied. (Bentley et al. 2010).

To elaborate, each neuron 'i' starts with a weight vector 'mi', perhaps chosen at random. Data item 'x' is applied to all of the neurons in the grid simultaneously using weights 'wij'.

A comparison is then made between the data item 'x' and every 'mi', the location of the best match being given by: -

$$||x - Mc \,||= min_i||x - \; m_i \;|| \ldots .(1)$$

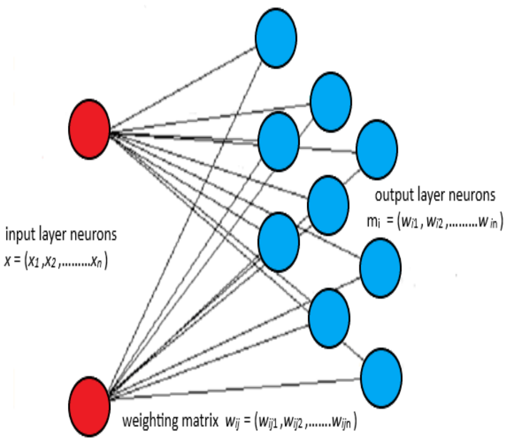
Where 'm_c' is the best matching neuron, known as the Best Matching Unit (BMU). The BMU weights and the weights of those neurons topologically adjacent to it in the grid are modified to more closely resemble the data item being applied, shown in Fig. 2.

Adjacent neurons in the grid as in Fig. 2 are modified by ('learn from') the data item 'x' and as successive data items are applied a global ordering is obtained.

After many cycles of application of the whole data set one by one, the learning process, with random initial values of *mi (0)*, converges to:

$$m_i(t+1) = m_i + h_{ci}(t)[x(t) - m_i(t)] \ldots .(2)$$

In this expression t=0,1,2, ... Represents a discrete time coordinate and h_{ci} *(t)* is known as the 'neighbourhood function', which decreases with time during training. To achieve eventual convergence the requirement is for h_{ci} *(t)* to tend toward zero when time tends to infinity.



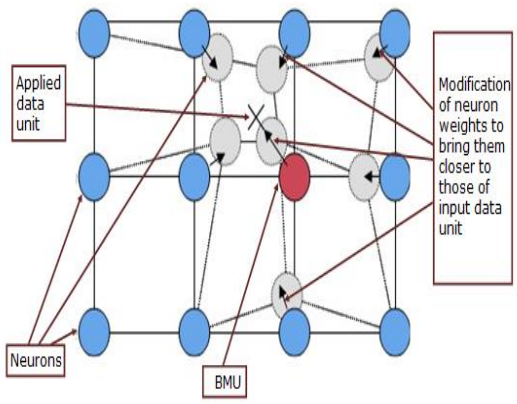
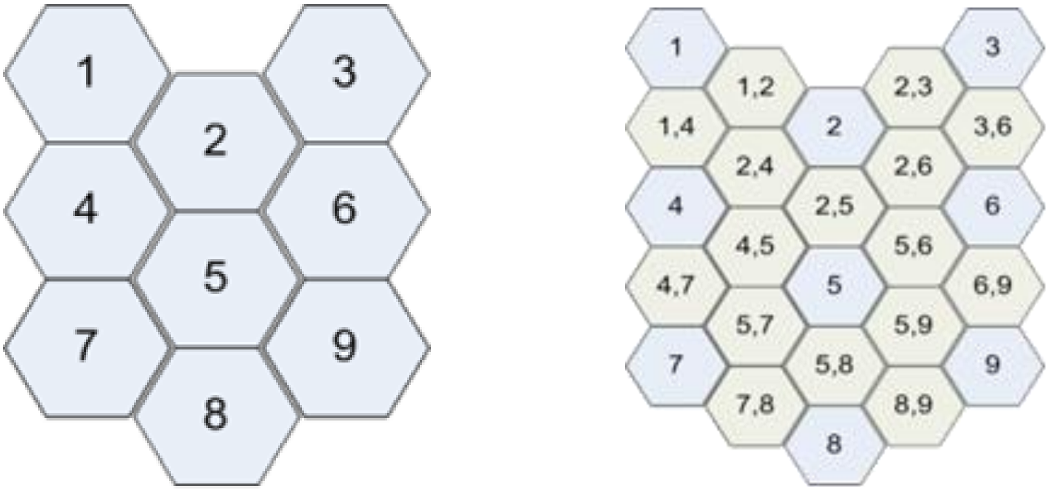


Figure 1: SOM structure and Figure 2: Modification of lattice in response to applied data item

In this expression t=0,1,2, ... represents a discrete time coordinate and hci (t) is known as the 'neighbourhood function', which decreases with time during training. To achieve eventual convergence the requirement is for hci (t) to tend toward zero when time tends to infinity.

Once the map is created, a convenient method of discovering patterns is to plot a greyscale image of the trained SOM in which the Euclidean distance between the neuron weight vectors determines the shade of grey.



(a) 3x3 SOM (b) 3x3 SOM with interpolated distance values

Figure 3: 3x3 SOM and interpolated distance values

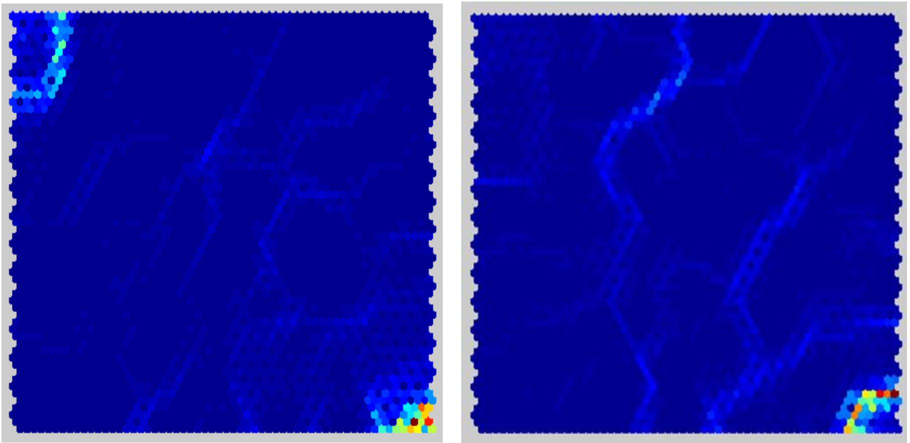
The average values of the distances between a node and its immediate neighbours, six in the case of a hexagonal structured Map, yield the values of the elements of a matrix known as the Unified Distance Matrix (U-Matrix). A 3x3 hexagonal map is shown in Fig 3(a). The corresponding U-matrix will then be a 5x5 matrix with interpolated elements for each connection between two neurons as shown in Fig 3(b). The interpolated {x, y} elements represent the distance between neuron x and y, {4,5} equals the Euclidean distance between neurons (4) and(5).

A light or pale colour in the U-Matrix display represents similar i.e. closely spaced neurons, dark shades neurons that are more distinct. Thus, contiguous areas of light grey represent areas (clusters), and the dark parts as inter cluster boundaries. A colour palette may be used instead of shades of grey. The U-Matrix helps to detect similarities and clustering, especially in high dimensional data sets.

SOM Configuration

For the present study, a 2D map was created to represent a participant's state pre and post Iron Man. To create the SOM, the SOM Toolbox - CIS is used in the

MATLAB environment.



(a) Pre exercise (b) Post exercise

Figure 4 U Matrix produced from HRV data for participant one

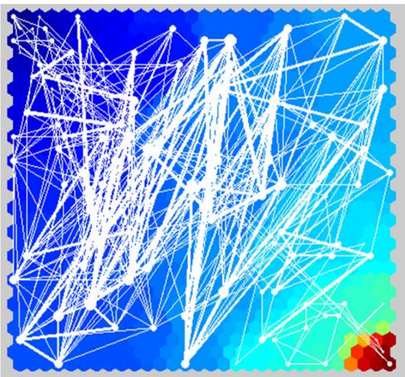
The commonly used hexagonally shaped neighbourhood was adopted providing equidistant sets of neighbours, which was found to give superior results when compared to the normal alternative of a square topology. HRV data was recorded from athletes with two different physiological states: before and after they complete an Iron Man Triathlon. The input data set comprised the HRV measured over a 6minute period, derived from the measured R-R times. When mapped the data formed clusters of similar HRV measurements. The trained map consists of 30 x 30 hexagonal topology neurons.

Results from SOM

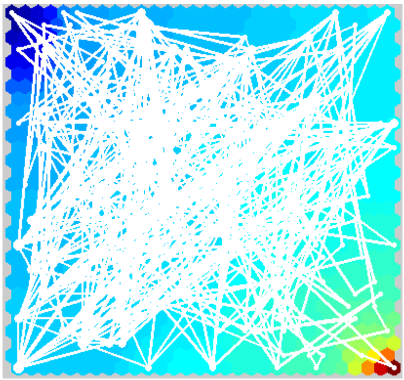
As may be seen in Fig.4 there is a noticeable difference between the U-Matrices for 'before' and 'after' the exercise for one of the athletes used for the study. Post exercise there are fewer clusters, demonstrating that HRV has been reduced by the exercise for the participant, since each cluster represent a similar level of HRV, so a smaller number of clusters implies less HRV.

Trajectories Map results

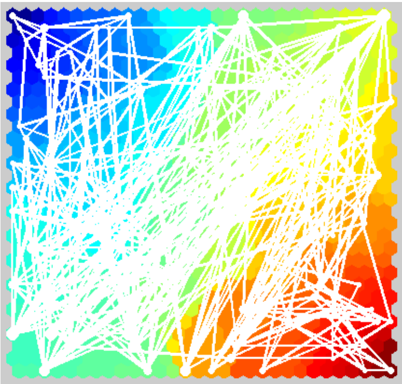
It is possible to generate the SOM, and then plot the trajectory of each successive data unit as it is applied to the trained map. The length of the trajectory represents the distance ‘travelled’ between successive BMUs. In this way, the variation in HRV can be directly observed. Figs 5(a-d) show the results of this procedure for two athletes; in each case the applied physical stress caused by the Iron Man exercise very obviously varies the trajectory, which becomes sparse. The applied stress due to Iron Man participation is seen to have the effect of greatly reducing the observed variability of the participant’s HRV.



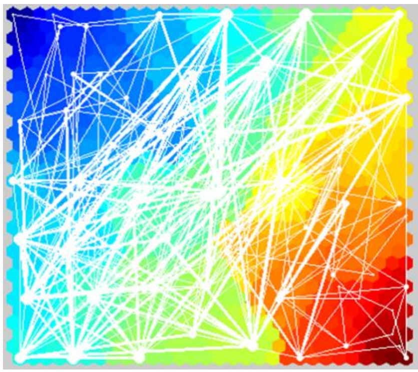
(a) participant 1 pre-exercice trajectory



(b) participant 1 post exercice trajectory



(c) participant 2 pre-exercise trajectory



(d) participant 2 post exercise trajectory

Figure 5 pre and post exercise SOM showing trajectories of participants 1 and 2

Conclusion

In this work, a SOM has been applied to data derived from subjects in two distinct physiological states. The differentiating power shown by the SOM approach using these results are similar to those obtained using traditional statistical techniques. The advantages of using SOM and a SOM trajectory mapping are: The SOM can be used to generate a trajectory as a measure of HRV, indicating both changes in HRV amplitude and variance; the resulting patterns are reminiscent of those arising from fractal mathematics; changes are easy to discern with a naked eye; the system is easy and quick to implement.

The use of SOM for trajectory mapping is not new in itself, but provides a valuable new insight into physiological measurement.

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How to save the planet - a systemic analysis

Dennis Sherwood
Managing Director, The Silver Bullet Machine Manufacturing Company Limited
info@silverbulletmachine.com

Abstract

Climate change is the most significant crisis facing mankind today. Most people believe the solution is to reduce greenhouse gas emissions, but although reducing emissions is a *good* thing to do, it is not the *right* thing to do...

...as validated by consideration of a causal loop diagram (Sherwood, 2002) of the planet-as-a-whole, based on James Lovelock's Gaia Theory (Lovelock, 2000), which represents the Earth as a single self-organising system, with various sub-systems interacting together through complex feedback loops.

An immediate inference is that reducing emissions slows down the rate at which the problem is getting worse. That is good, for it buys (a little) more time. But the fundamental problem is remains.

The causal loop diagram reveals something else too - how to solve the problem, once and for all. Reducing emissions and using renewables will help. But it is technology – "geoengineering" – that is the fundamental solution.

Man, Gaia and Climate Change

Please refer to https://docs.wixstatic.com/ugd/7c5491_ac07094be50b433dae3bff83f493b34f.pdf, where you will be able to download a sequence of annotated causal loop diagrams which tell the story far more vividly and succinctly than any words I could ever hope to write.

Keywords: climate change, causal loop diagrams, emissions, Gaia Theory and geoengineering

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Mirror of the Heart: real time monitoring of physiological state from a distance and artistic interpretation of heart rate data

Napat Saengthong
Department of Computer and Information Sciences, Faculty of Engineering and Environment, Northumbria University

Jethro Vernon
Department of Mathematics, Physics and Electrical Engineering, Faculty of Engineering and Environment, Northumbria University

Marianne Sice
School of Arts and Cultures, Armstrong Building, Newcastle University

Edward Bentley
Department of Mathematics, Physics and Electrical Engineering, Faculty of Engineering and Environment, University, UK Edward.bentley@northumbria.ac.uk

Petia Sice
Department of Computer and Information Sciences, Faculty of Engineering and Environment, Northumbria University, UK petia.sice@northumbria.ac.uk

HG Laurie Rauch
Department of Human Biology, Division of Exercise Science and Sports Medicine (ESSM), University of Cape Town, SA laurie.rauch@uct.ac.za

Abstract

Heart Rate Variability (HRV) is used as a systemic measure of the state of the autonomic nervous system. The polyvagal theory and experiments developed by Stephen Porges suggest that HRV is a valid measure relevant to physical, mental and relational homeostasis. Modern sensor technologies *provide the capability for non-invasive collection and immediate analysis of heart rate data and bio-feedback in real time. While there are many studies implementing Wi-Fi and Bluetooth as a physiological monitoring device, the LoRaWAN technology offers a longer-range coverage communication and low power consumption. Its configuration is flexible and able to be adjusted to work in the required environment. Thus, a prototype was created implementing a LoRaWAN technology to create a wearable device for collecting and monitoring heart rate, and 3-axis acceleration data from a distance.*

Visualisation and sonification of the data are used to make a distinction between states of the nervous system and explore the connection with perceived experience. This paper introduces an approach to the sonification and visual interpretation of heart rate data allowing for quick differentiation between autonomic nervous system states. The work includes a demonstration of the artistic expression of these states determined by artists Marianne Sice and Jethro Vernon and their research into the impact and relation of sound and colour to wellbeing. Sound and visuals are generated by hand coded programmes in Max MSP.

Keywords: LoRaWAN, HRV, heart rate monitoring, artistic interpretation of data, sonification.

Introduction

IoT technology is a mere two decades old. IoT is the interconnection between things to share and benefit from information gathered by end devices to increase the data value, monitor and control systems (Bolt, et al., 1981; Akyildiz, et al., 2002). IoT has been developed to perform many tasks, to provide convenience and solve problems. Thus, the type of communication for the system needs to be chosen appropriately. For example, in the system where end devices are remotely deployed without an energy source, energy efficiency needs to be carefully considered. In this case, sometimes the cost of replacing the new battery is more expensive than replacing the entire module (Lavric & Popa, 2017). Moreover, signal coverage is also important as wider coverage will cover more end devices and reduce the cost of additional stations.

Today, there are many technologies developed to work with IoT, such as cellular evolution (4G/5G), WiFi, Bluetooth and LPWANs, where 5G cellular evolution and LPWAN are the technology that consumes low power and provides wide area coverage (Navarro-Ortiz, Sendra, Ameigeiras, & Lopez-Soler, 2018).

IoT-Based Health Monitoring System

There are several studies that implemented IoT technologies to develop health monitoring equipment. Many types of wireless technologies have been used to create real-time virtualization for health carers to monitor their targets. Mdhaffar, et al., 2017, designed IoT-based health monitoring via LoRaWAN to monitor patients with chronic diseases in rural areas. In rural areas where each sensor node has to be separated from the other, wide coverage area technology is required. The data is collected and sent to the doctor, the authors defining this architecture as IoT4HC (IoT-based for healthcare system). From the drive test results, LoRa gateway can cover an area of 60 km^2 rural areas and 734 metres in dense urban areas. Concerning power consumption, node devices can stay up to 10 days, which is ten times lower than using cellular GPRS technology (Mdhaffar, Chaari, Larbi, Jmaiel, & Freisleben, 2017).

Moreover, wearable physiological sensors have been used to make LAN-based real-time monitoring vests tested in high gravitational force environments and wearable respiratory monitoring to measure tidal volume in exercise (Akcivi, 2003; Caretti, et al., 1994). The implementing of a physiological monitoring system for firefighter activities was examined in the study by Smith, et al. (2014). The firemen wore physiological status monitors (PSM) with personal protective equipment (PPE) during the experiment to compare the accuracy with the standard device. BioHarness 3 devices – the commercial device introduced by Zephyr Technology Limited – were used in the experiment to collect, store and send the heart rate and respiratory rate data. According to the specification sheet of BioHarness, this device can transmit the data up to 10 metres and has a battery life of up to 35 hours (BIOPAC System, Inc., 2015). The result shows that a PSM-shirt can give accurate results (Smith, Haller, Dolezal, Cooper, & Fehling, 2014). While the devices in Smith study used Bluetooth to transmit the data, M Potirakis (2016) used Wi-Fi to provide the connectivity for the device (M Potirakis, et al., 2016). The physiological status monitoring system proposed by M Potirakis, et al. (2016) uses

Arduino and sensors to monitor temperature, respiration rate, ECG, 3-axis acceleration. Moreover, the Wi-Fi signal in this study could reach up to 38 metres in indoor conditions (M Potirakis, et al., 2016).

LPWANs and LoRaWAN

LPWANs or Low-Power Wide Area Networks are an alternative type of technology designed to be compatible with IoT, providing better energy efficiency and wide signal coverage. LoRa, SigFox, RPMA, and NWave are examples of LPWAN technologies. LPWAN technologies mostly utilize unlicensed frequency bands, so-called ISM (industrial, scientific and medical) bands, where authorisation to operate on these bands is not required.

LoRa is the LPWAN technology introduced by Semtech Corporation. Its physical layer, LoRaWAN, uses CSS (chirp spread spectrum) modulation, which makes the signal energy spread wider, and consists of chirps. The chirps allow the signal to propagate throughout a long distance and be able to be demodulated by the receiver, even when the signal is weaker than a noise floor up to 20 dB. PHY (Physical layer)'s parameters, including spreading factor (SF), bandwidth, coding rate, carrier frequency and transmission power, can be configured to adjust the communication performance as the Table 2 (Cattani, Boano, & Römer, 2017). Table 1 shows the comparison between LoRaWAN and other communication technologies. Thus, LoRaWAN claims that it has the greater link budget beyond other standardized technologies, resists interference, including multi-path effects and multi-path fading, and has good receiver sensitivity, longer battery life, and longer coverage area (Mdhaffar, et al., 2017). However, the cost of using spread spectrum and low power consumption will result in inefficiency spectral management and data rate. Hence, to implement LoRa in a project, the developer needs to consider the matter carefully.

Feature	LoRaWAN	Narrow-Band	LTE Cat-1 2016 (Rel12)	LTE Cat-M 2018 (Rel13)	NB-LTE 2019(Rel13+)
Modulation	SS Chirp	UNB / GFSK/BPSK	OFDMA	OFDMA	OFDMA
Rx bandwidth	500 - 125 KHz	100 Hz	20 MHz	20 - 1.4 MHz	200 KHz
Data Rate	290bps - 50Kbps	100 bit/sec 12 / 8 bytes Max	10 Mbit/sec	200kbps – 1Mbps	~20K bit/sec
Max. # Msgs/day	Unlimited	UL: 140 msgs/day	Unlimited	Unlimited	Unlimited
Max Output Power	20 dBm	20 dBm	23 - 46 dBm	23/30 dBm	20 dBm
Link Budget	154 dB	151 dB	130 dB+	146 dB	150 dB
Batery lifetime - 2000mAh	105 months	90 months		18 months	
Power Efficiency	Very High	Very High	Low	Medium	Med high
Interference immunity	Very high	Low	Medium	Medium	Low
Coexistence	Yes	No	Yes	Yes	No
Security	Yes	No	Yes	Yes	Yes
Mobility / localization	Yes	Limited mobility, No loc	Mobility	Mobility	Limited Mobility No Loc

Table 1: Comparing specifications of LoRaWAN to those of other technologies (Lora-Alliance Technical Marketing Workgroup 1.0, 2015)

Cattani, et al.(2017) evaluated the performance of LoRa by placing the LoRa with different setting – including spreading factor (SF), bandwidth, coding rate, carrier frequency and transmission power – in three scenarios; indoor with obstacles , outdoor with direct line of sight , and underground covered by a metal manhole. the result shows that the fastest PHY setting provided the highest efficiency even in the worst-case scenario.

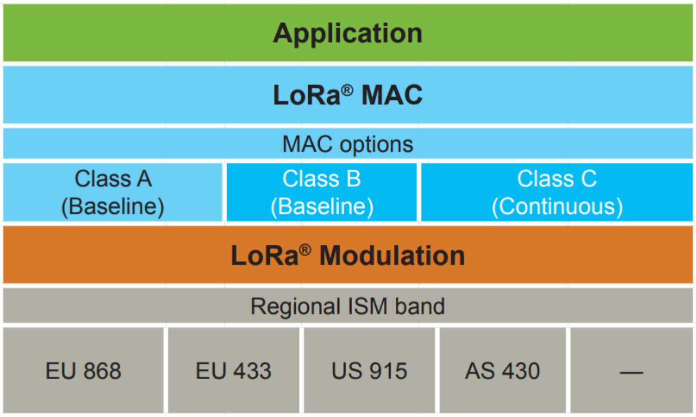

Figure 1: LoRa Layer Architecture (Lora-Alliance Technical Marketing Workgroup 1.0, 2015)

Setting	Values	Effects
Bandwidth	125 to 500 kHz	Higher bandwidths allow for transmitting packets at higher data rates (1 kHz = 1 kcps) but reduce receiver sensitivity and communication range.
Spreading Factor	26 to 212 $\frac{chips}{symbol}$	Bigger spreading factors increase the signal-to-noise ratio and hence radio sensitivity, augmenting the communication range at the cost of longer packets and hence a higher energy expenditure.
Coding Rate	4/5, . . . ,4/8	Larger coding rates increase the resilience to interference bursts and decoding errors at the cost of longer packets and a higher energy expenditure.

Transmission Power	-4, . . . ,20 dBm	Higher transmission powers reduce the signal-to-noise ratio at the cost of an increase in the energy consumption of the transmitter.

Table 2: Summary of LoRa's configurable settings and their impact on communication performance (Cattani, Boano, & Römer, 2017).

Setting ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SF	7	7	7	9	7	7	9	9	7	9	9	12	9	12	12	12	12	12
CR	4/5	4/8	4/5	4/5	4/8	4/5	4/8	4/5	4/8	4/8	4/5	4/5	4/8	4/8	4/5	4/8	4/5	4/8
BW (kHz)	500	500	250	500	250	125	500	250	125	125	125	500	125	500	250	250	125	125
BR (kb/s)	21.87	13.62	10.93	7.03	6.83	5.47	4.39	3.51	3.41	2.2	1.76	1.16	1.09	0.72	0.58	0.37	0.30	0.18

Table 3: LoRa settings that used in Cattani's experiments (Cattani, Boano, & Römer, 2017)

Heart Rate

The human heart rate (HR) is an integrated cardiovascular characteristic of importance because it could be a predictive of early mortality (Zhang, et al., 2014). For example, during firefighting activities, the characteristic of cardiovascular strain is altered by the products of combustion (e.g., heat, smoke). Heart rates (HR) increase and the rise in HR responses to firefighting varies tremendously, depending on the type of work the firefighter is doing and multiple other factors, such as stress. Alterations in other cardiac variables are likely to be even more important in describing the cardiovascular risk associated with firefighting (Smith, DeBlois, Kales, & Horn, 2016). Heart Rate alone cannot be an indicator of risk state of a person as heart rate is also sensitive to movement. If, however the heart rate variable is coupled with accelerometer measure to identify a fall, heart rate that does not go down may indicate a physiological risk. Further analysis of the pattern of change of heart rate may be needed to identify a risk (Prinsloo, et al., 2011).

Fall Detection

When a person falls, the more severe that fall and the longer the time the person lies helplessly on the ground, the longer will be the period of hospitalization (Thilo, Hahn, Halfens, & Schols, 2018). Thus, detecting the fall could be essential in creating the opportunity to support the user(wearer of the device) as quickly as possible.

Tan & Tinh (2014) developed fall detection by using a 3-dimensional accelerometer with posture recognition. The remote end-nodes with the fall detection sensors are attached to an elderly patient and send out the data using a GSM/GPRS system. The system consists of two main modules, posture recognition and fall detection, cooperatively working to determine the fall event and eliminate fail decisions. The accelerometer generates three numbers, including the acceleration from the x, y and z axes. These number are used by both modules. The posture recognition module averages the sample every 1 second. These averaged numbers are used to decide and classify the posture by the Boolean algorithm. Postures are classified into 4 postures, including walking, standing, lying and null. The fall detection module uses the currently sensing numbers to compare with the one second later sensing number to find the difference (Dn). The formula used in the fall detection module is $D_n = A_n - A_{n-1}$, while A_n is the acceleration vector of 3 axis equals to $\sqrt{A_x^2 + A_y^2 + A_z^2}$. Then, Dn will be used to compare with the threshold to determine if the fall occurs. Finally, both results from the two modules will be used together to make the final decision in order to minimize false detection (Tan & Tinh, 2014). Thus, this project has also attempted to provide acceleration vector values for further study to be able to create fall detection.

IoT has been used in many applications and sectors, such as agriculture, education, public health, and commerce. Health monitoring systems have been implemented to support treatment and in life protection. There are many types of communication that can provide the connectivity for IoT devices, each of which has its advantages and disadvantages, depending on the requirements and conditions of that application. LoRaWAN has characteristics that potentially suits to the monitoring system. Combination of LoRaWAN and physiological parameter could lead to the monitoring system with wide coverage and low power consumption.

Design Construction

This project required both hardware and software to deliver a functional prototype. The hardware and software that were used in this project are shown in the following.

Hardware

Arduino UNOs (Price: 7 GBP) was used as a microcontroller for the device.
Dragino Shield (Price: 20 GBP) was used as a transceiver module, providing long range communication based on LoRa technology. Essentially, this shield is a hardware component connected on top of the Arduino board. It has a built-in RFM95W. RFM95W modulate data with LoRa modulation (Dragino, 2017).

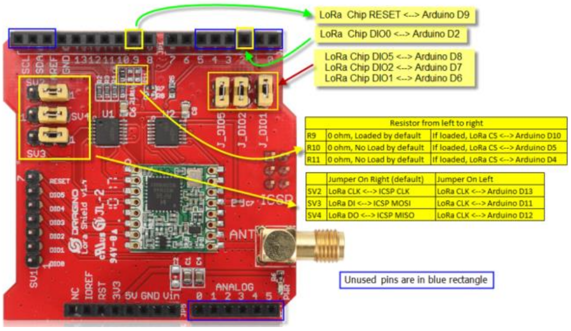

Figure 2: Dragino Shield (Dragino, 2017)

A Pulse Sensor (Price: 3 GBP) was used to capture heart rate and inter-beat interval. The pulse sensor uses photoplethysmography as a main technique. The sensor responds to the changes in light intensity of the blood stream under the skin and converts the signal to the voltage level. When using a Pulse Sensor with Arduino UNO, a sample rate of 500Hz and inter-beat interval resolution of 2mS can be given.

Figure 3: Pulse Sensor (AliExpress, 2015)

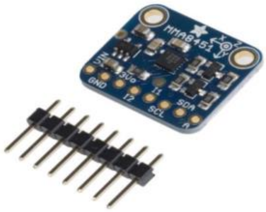

Figure 4: Adafruit MMA8451 Accelerometer (RS Components Ltd., 2013)

Adafruit MMA8451 (Price: 7 GBP) was used for monitoring motion and posture. This can detect motion, acceleration in 3 axis, tilt and orientation.
LG01-P (Price: 57 GBP) was used as the gateway for the system. It can communicate to Lora-nodes by LoRa wireless and communicate to the pc or server by Wi-Fi based on 802.11 b/g/n standard. Thus, the 868 MHz-band antenna was used.
9V battery (Price: 4 GBP) was used as a power source for the sensor node.

Software
Arduino IDE was used for programming the Arduino boards and LG01-P gateway. Arduino IDE also provided Serial Monitor and Serial Plotter, which were used in the testing process and result visualisation.

Putty was used as the terminal for the data visualisation
Microsoft Excel was used as a spreadsheet platform to show and compare the results from the testing.

Block Diagram

The main components of this system are sensors, Arduinos, gateway and database. , The sensors include pulse sensor and accelerometer. These sensors are contained in the small plastic box worn on the user's body to monitor the user and send to display to the supervisor if the user is in risk condition or has shown abnormal behaviours. Arduino 1 is the master device and has the accelerometer attached to it. It does most of the task, including directly collecting the data from the accelerometer, collecting data from Pulse Sensor, by request from its slave (Arduino 2), and then managing these parameters before sending the data out by RF95W module. Then the data travels wirelessly to the gateways and is received by the RF95W module in the gateway. Finally, the gateway will reassemble into readable information the data received and upload this to the database by Wi-Fi or LAN. At the database, the information will be displayed in real-time through the serial monitor and stored in the text file.

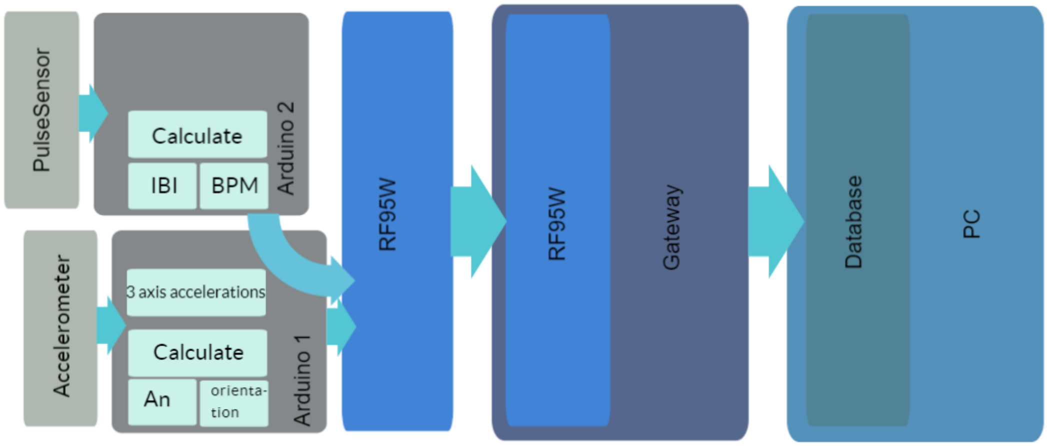

Figure 5: Block diagram of the physiological monitoring system

Prototyping

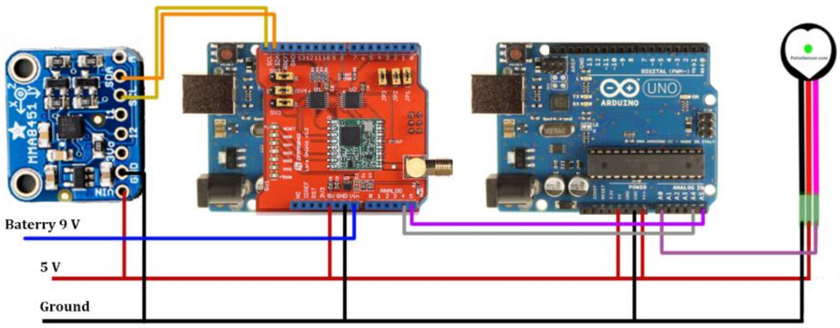

Figure 6: Wiring Map

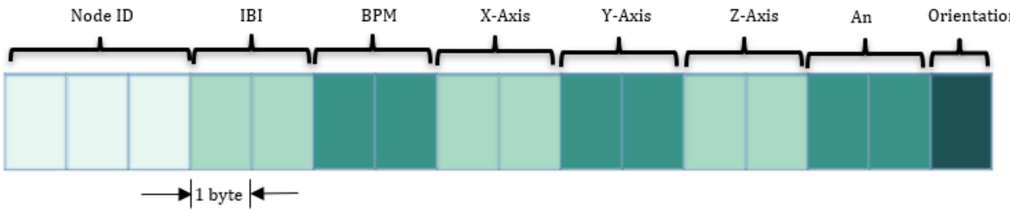

Figure 7: The buffer structure

```
15:41:44.709 -> Listening on frequency: 868.00
15:41:44.768 -> ===========================================================================
15:41:44.909 ->         time     RSSI:    IBI:     BPM:     x:       y:       z:       An:      o:
15:41:44.951 -> ___________________________________________________________________________
15:41:46.936 ->         13422    -32      430      92       1874     196      -2563    45       6
15:41:48.084 ->         14569    -28      526      86       1508     810      -2645    49       8
15:41:49.223 ->         15716    -36      266      89       542      110      3130     60       4
15:41:50.372 ->         16863    -39      1462     89       1554     1482     3008     45       6
15:41:51.518 ->         18010    -37      1330     83       3126     1182     1858     63       2
15:41:52.666 ->         19156    -49      800      86       1918     2480     2520     42       2
15:41:53.813 ->         20303    -36      488      89       1926     2482     2534     44       2
15:41:54.961 ->         21450    -35      488      89       1930     2464     2488     44       2
15:41:56.108 ->         22597    -30      362      0        1936     2468     2540     44       2
15:41:57.254 ->         23744    -29      362      0        1920     2482     2524     44       2
15:41:58.401 ->         24891    -30      600      0        1930     2470     2558     32       2
15:41:59.553 ->         26038    -30      362      0        1926     2466     2506     45       2
15:42:00.696 ->         27185    -30      362      0        1934     2464     2504     44       2
15:42:01.843 ->         28332    -30      362      0        1922     2464     2488     44       2
15:42:02.989 ->         29478    -31      362      0        1938     2464     2502     45       2
15:42:04.142 ->         30625    -30      600      0        1926     2476     2512     45       2
15:42:05.287 ->         31772    -31      1072     55       1914     2462     2504     42       2
15:42:06.433 ->         32919    -30      1150     55       1932     2450     2502     44       2
15:42:07.580 ->         34066    -31      458      61       1916     2468     2500     42       2
15:42:08.731 ->         35213    -32      870      68       1928     2464     2496     45       2
```

Figure 8: The user interface

Firstly, a 3-axis accelerometer was connected to Arduino 1. The Vin of MMA8541 was connected to the 5V output pin of the Arduino 1. The SCL and SDL pins of MMA8541 were connected to the SCL and SDL pins on the Arduino respectively. Secondly, the signal pin of the Pulse Sensor was connected to A0 and Vin was connected to the 5V output pin of the Arduino 2. Using only one Arduino was the design in the first prototype, but after the testing process the results showed that the information from Pulse Sensor was inaccurate. By observation on the output signal, the signal was disturbed by the other tasks – correcting data, calculating average and sending data to the gateway. Thus, another Arduino was necessary. As a consequence, the Arduino 2 was included in this prototype. Two Arduinos can communicate with each other through wires as master and slave. Analog pins A4 and A5 of both Arduinos were connected so the data could be shared upon request. Finally, all the GDN pins of both sensors and Arduinos were wired together. The wiring map is presented in *Figure 6*.

The parameters, including timestamp, RSSI, IBI, BPM, acceleration on x-axis, acceleration on y-axis, acceleration on z-axis, acceleration vector and orientation, are stored in the buffer as shown in *Figure 7*. The user interface shows the information in the form of a table. The columns show timestamp, RSSI, IBI, BPM, acceleration on x-axis, acceleration on y-axis, acceleration on z-axis, acceleration vector and orientation, respectively. The value of the 3-axis and orientation can be used to determine the wearer's posture. The user interface is shown in the *Figure 8*.

Delay time Measurement

Data exchange in wireless system usually has some delay time between sending and receiving. The aim of this task, the delay time measurement, is to make an assessment regarding this delay time. In this task, the node device was placed in a different location. This experiment took place in a building. The node device was connected to a computer to display the data logging to show the sending time on each floor of the building, 10 floors in all, while the gateway remaining placed on the first floor. Each floor had a ceiling height of 2.3 m. The data at each location were collected for a minute. The difference between time of sending the data at the node device was used to compare with the time of data arriving at the gateway. *Figure 9* shows how the experiment was performed.

Figure 9: Delay time and penetration ability experiment

Penetration Ability Measurement

This task aimed to measure the penetration ability of this LoRa-based device since Semtech claimed that LoRa technology has high noise resiliency. The gateway was placed on floor 0, while the node device was moved and measured the RSSI on each floor from 0 to 10. The RSSI (Received Signal Strength Indicator) is a measurement of the power strength of the radio signal at the receiving point, the higher value indicating higher signal strength (Sauter, 2010). In others word, the results will represent the signal strength at the gateway that numbers of the ceiling, from 0 to 10, were blocking the transmitting path between gateway and node device. Besides this, the number of packets that arrived at the gateway and lost packets were considered because it is possible that the packet loss was increased owing to the number of the obstacles.

Coverage Measurement

The main advantage of LoRa technology is the extremely long range of the coverage area. CSS modulation technology in LoRa provides noise immunity for the system. Thus, this task aimed to measure the coverage range of this system in an urban area. The coverage range is affected by several factors, such as the number of obstacles, type of material of the obstacle, transmitting power, quality of antenna (antenna gain) and LoRa Setting. This prototype used wire-antenna with 2 dBm antenna gain. The LoRa setting was configured as 14 dBm transmission power, spreading factor at 7, bandwidth of 125 MHz and coding rate as 4/5. As stated in section 2.4, each setting has both advantages and disadvantages. However, this experiment aimed to examine the coverage ability in an urban area where the signal travelled through buildings and trees. Thus, the transmission power was set to 14, which is the highest value allowed, following the Federal Communications Commission (FCC) rule (Semtech, 2018). Decreasing the spreading factor will sacrifice the coverage but will reduce time on air. Thus, the spreading factor was set to 7 to decrease time on air or delay to provide the real-time monitoring. Moreover, to increase the noise resilience in an urban area, the bandwidth was set to the lower setting at 125 MHz. The gateway was placed 4 metres above the ground.

Battery Lifetime Measurement

In this task, the gateway was programmed to show the timestamp every time that the gateway received the packet from the node device to the variable. The battery that powered the node device was a 9v battery with an 800 mAh electrical capacity. Then the programme would print the latest ‘timecount’ to monitor, as shown in Figure 10.

```
15:25:38.921 ->         37076   -23     362     0       136     -2603   554     59      1
15:25:40.098 ->         38223   -23     362     0       186     -2613   614     59      1
15:25:41.216 ->         39370   -23     362     0       168     -2627   548     59      1
15:25:42.365 ->         40517   -23     362     0       154     -2597   548     59      1
15:25:43.509 ->         41664   -23     362     0       162     -2607   546     59      1
15:25:48.527 -> Timeout at
15:25:48.543 -> 41664
15:25:53.564 -> Timeout at
15:25:53.578 -> 41664
```

Figure 10: The program printing the 'timecount' value

Results

Delay Time

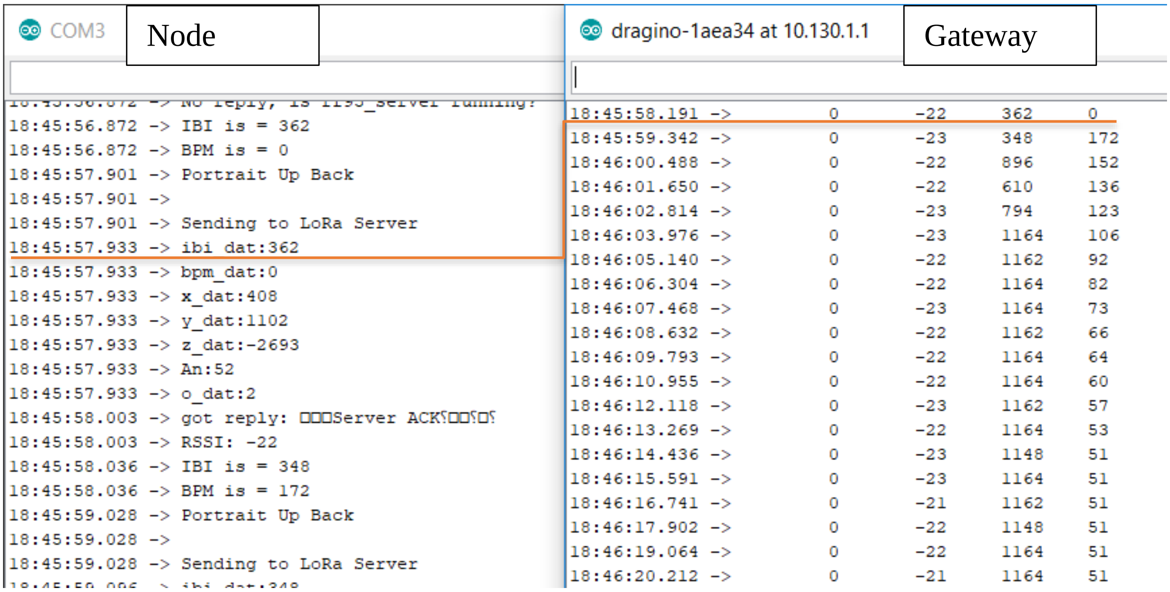

Figure 11: Example of the delay time measuring method

Number of ceiling	Timestamp [s]		Delay time	Packet Received	Packet lost	Success Rate [%]	Average RSSI [dB]
	Receiving	Sending					
0	57558.191	57557.933	0.258	53	0	100.00	-22.28
1	59115.899	59115.610	0.289	53	0	100.00	-75.04
2	59323.541	59323.257	0.284	54	0	100.00	-84.39
3	59434.695	59434.399	0.296	54	1	98.11	-89.92
4	59535.956	59535.650	0.306	45	2	95.45	-91.16
5	59650.557	59650.247	0.310	54	0	100.00	-93.35
6	59795.542	59795.233	0.309	54	0	100.00	-94.85
7	59908.758	59908.438	0.320	50	1	98.00	-96.22
8	60028.927	60028.627	0.300	53	0	100.00	-94.68
9	60186.353	60186.035	0.318	51	1	98.00	-99.14
10	60308.916	60308.614	0.302	53	1	98.11	-95.25

Table 4: Delay time and penetration ability experimental result

The data were collected as shown in *Figure 11*. The picture on the left-hand side is the serial monitor displaying that the data are being sent at the node device, while the picture on the right-hand side is the serial monitor displaying the data that are being received at the gateway. From this example, it can be seen that the sending time and receiving time are different.

Table 4 shows all the results from this experiment on each floor. Sending time and arriving time were converted into timestamps to be able to calculate the difference in sending time and arriving time. Figure 12 plots the delay time against the number of the ceiling. As can be seen, there was a significant increase in the delay time when the number of the blocking ceilings increased. As seems reasonable, the more ceilings blocking the transmitting path and the greater the distance, the more time the signal needs to travel to the destination.

Delay Time vs Number of Ceilings

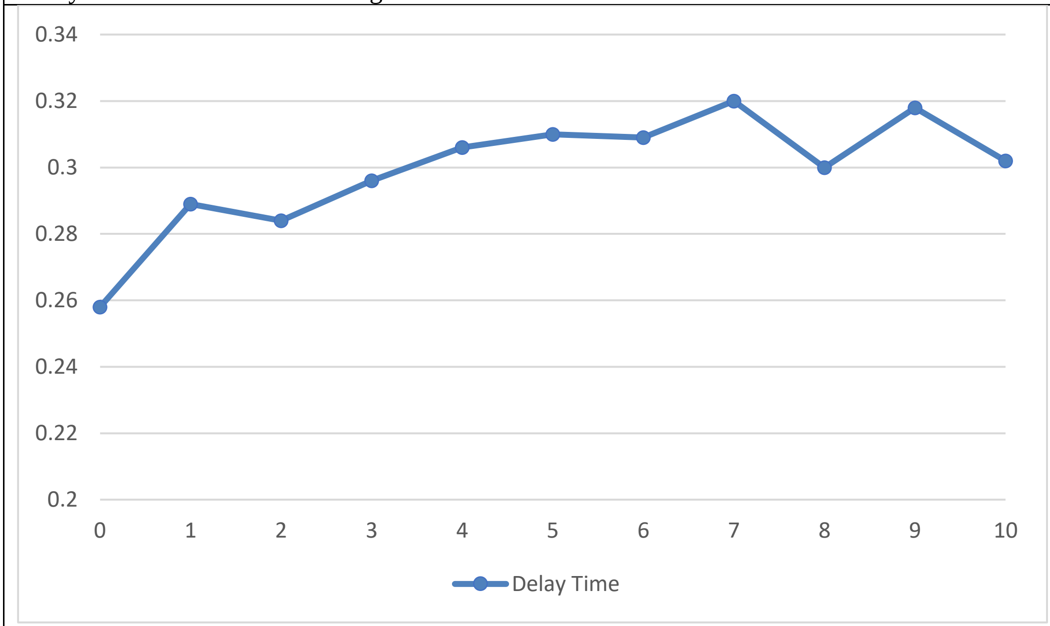

Figure 12: Delay time on each floor

Penetration Ability

Figure 12 shows the RSSI that the gateway received the incoming signal from the node device placed on each floor. As expected, the RSSI value dramatically decreased on the 4 floors. Then the RSSI values slightly declined and touched -100 dBm on floor 9. However, regarding the packet sending success ratio, shown in Figure 13, there was no significant change in data. In that case, even the RSSI dropped to -100 dBm when there were 9 ceilings blocking the transmitting path, the packet sending success ratio still as high as 98 per cent. The researcher believes that the signal could be sent further than over 10 floors.

RSSI

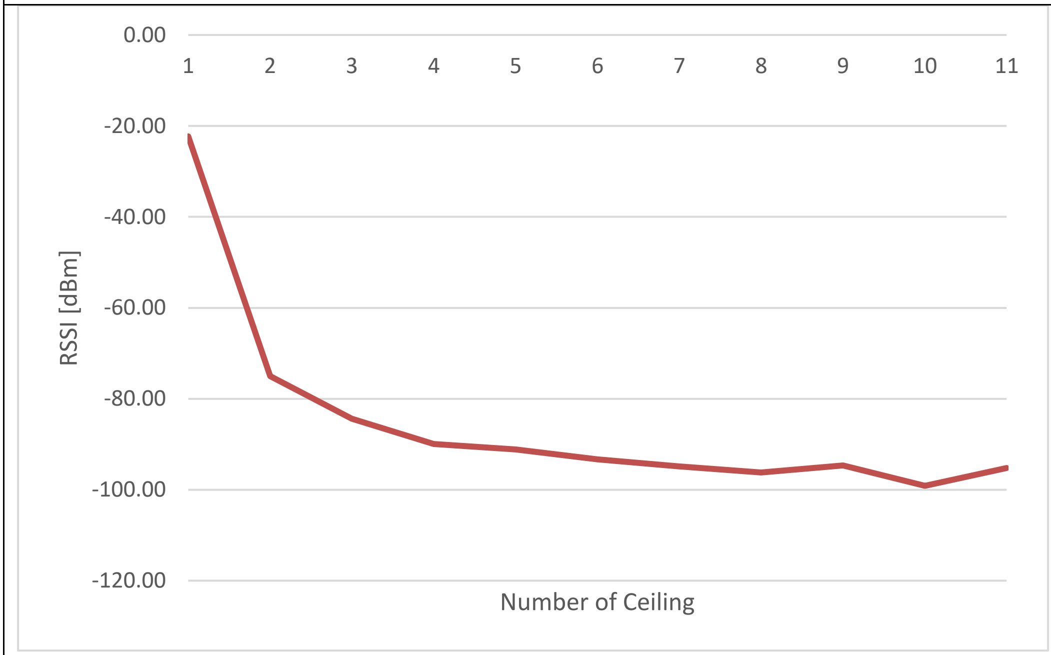

Figure 12: RSSI on each floor

Success Rate of the Packet Arrived at the Gateway

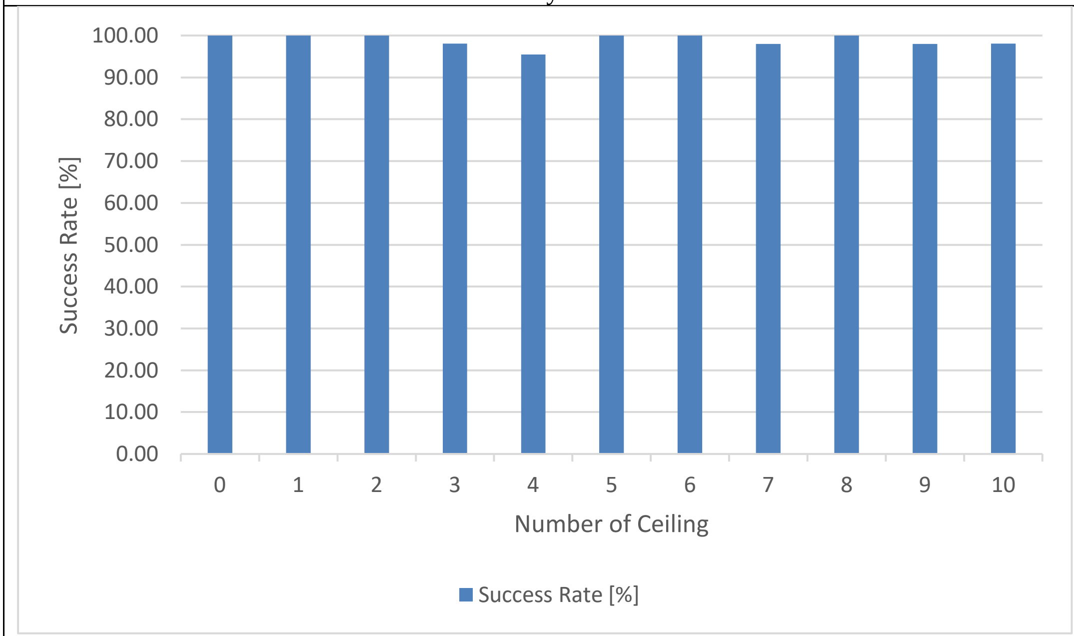

Figure 13: Comparison of packet sending success ratio on each floor

Coverage area

Figure 14 shows the testing route from the Google Map. The route was from A to D, where the start point to the stop point had a displacement distance equal to 650 metres. Additionally, D point was the place where the packet lost 100 per cent – the gateway was unable to receive any data from the node device. As a result, the coverage range of this system was only 650 metres in an urban area, close to the result from Mdhaffar's study that the signal can reach up to 734 metres (Mdhaffar, et al., 2017). However, as already pointed out, the coverage range can be affected by many factors, including antenna gain, number of obstacles and the height of the gateway. In this experiment, the gateway was placed indoors and only 4 metres above the ground, while Mdhaffar had placed the gateway 12 metres above the ground.

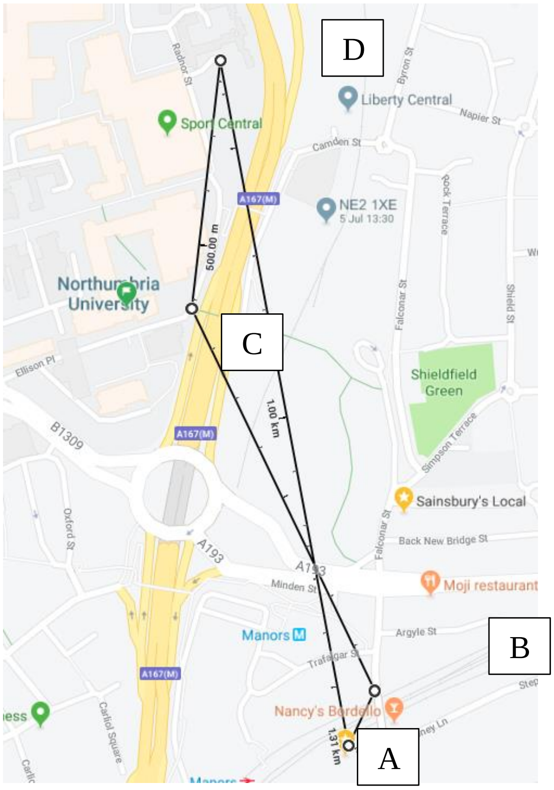

Figure 14: The testing route

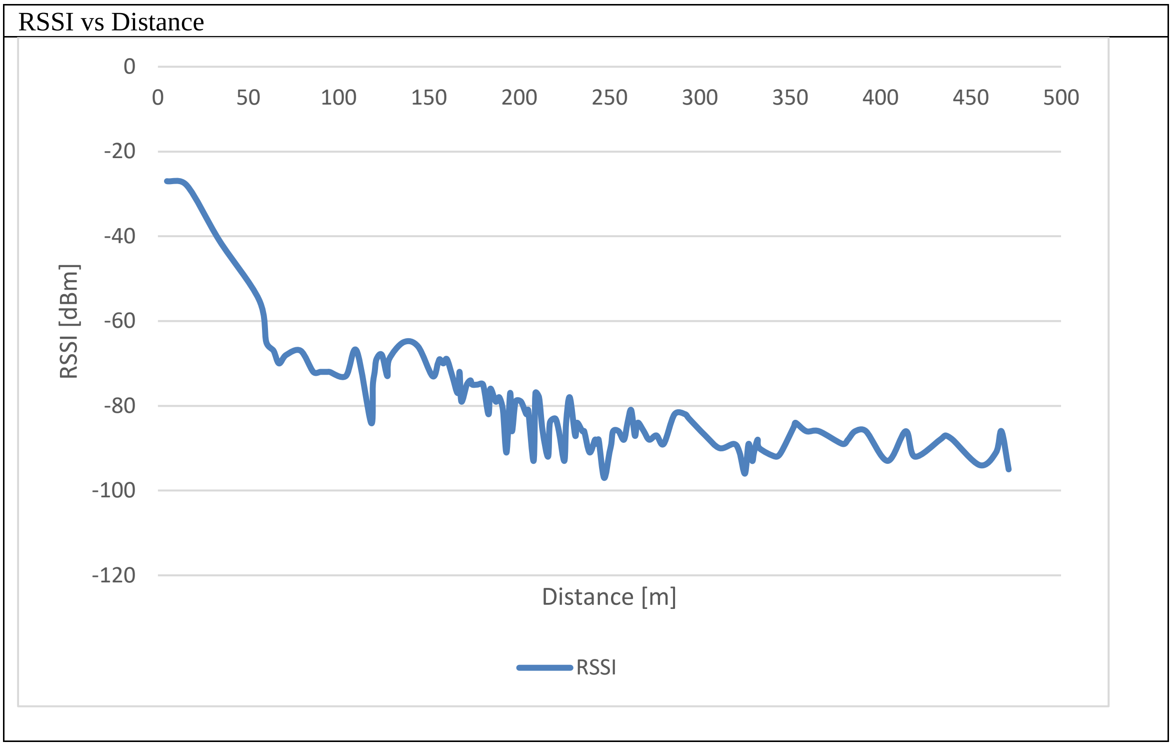

Figure 15: RSSI at the gateway

Battery Lifetime

Devices	Current Consumption	Unit	Number of Devices	Current Consumption	Unit
Arduino (Arduino, n.d.)	0.02	mA	2	0.04	A
Pulse Sensor (World Famous Electronics llc)	0.004	mA	1	0.004	A
MMA8854, min (Semiconductors, 2017)	0.000004	mA	1	0.000004	A
MMA8854, max (Semiconductors, 2017)	0.000165	mA	1	0.000165	A
Dragino shield, min (Dragino, 2017)	0.0002	mA	1	0.0002	A
Dragino shield, max (Dragino, 2017)	0.12	mA	1	0.12	A

Table 5: The current consumption of each component

The experiments have been done 3 times. The results are 28934330, 35237701 and 23956789 ms, which is the average of 8 hours 27 minutes. To illustrate the calculation, Table 5 shows the current consumption of each component in the node device. Thus, the summations of the current usage are as following:

Total maximum possible current consumption	0.044204	A
Total minimum possible current consumption	0.164165	A

Where the Battery lifetime can be calculated by:

$$BatteryLifetime = \frac{BatteryCapacity}{CurrentConsumptionoftheLoad}, \left[\frac{mAh}{mA}\right]$$

Thus,

Maximum possible battery lifetime	18.0979097	hrs.
Minimum possible battery lifetime	4.87314592	hrs.

As a result, a battery of 800 mAh capacity can last this device 8 hours, which is in the range of the calculation above. This is also close to the average between the maximum and minimum values. *Table 5* shows the Arduinos and the Dragino Shield had the most effect on the battery lifetime. Dragino Shield's current consumption varied from 0.0002 to 0.2 mA, depending on the mode of RF95W module. In other words, the more frequently that the data were transmitted, the greater the current consumption.

Experiment with user interface: representation of heart and heart rate variability data for developing intuitive awareness of physiological state

Heart rate (HR) has become easily accessible for both specialist (interested in the use of HR monitoring and analysis for clinical purposes) and for the general user to monitor and regulate their autonomic nervous system, physiological coherence, and performance. The LoRaWAN technology offers a longer-range coverage communication and low power consumption which allows one to access Heart Rate data from a considerable distance too, as shown in the development of the prototype and outcome of testing in the previous sections.

The representation of the data is of significant importance in enhancing the user understanding and monitoring of their physiological state, as well as empowering them to intervene where regulation or self-regulation response is needed. For the general user, interested in monitoring and self-regulating their physiological state for maintaining health and/or enhancing performance, it is important to have an interface which allows for the development of intuitive knowledge and interpretation. Current interfaces focus on presenting the information in terms of text and numbers (average HR, HR over time, and heart rate variability statistical and frequency analysis).

What is heart rate variability?

The time between successive heartbeats (R-R interval) changes each time the heart beats, this variation is known as HRV. It is mainly determined by changes in the heart's external regulation. HRV is determined by measurement of consecutive R-R intervals in ECG data, otherwise pulse pressure measurements may also be used. HRV is a measure of the heart's ability to respond rapidly to stimulation from unexpected circumstances. HRV has been analysed in both the frequency and time domains, and is a popular measure of cardiac health (Task Force of the European Society of Cardiology, 1996). HRV is a valuable piece of data when it comes to assessing an individual's quality of life. Yet sitting and watching a graph can often be difficult to understand and not very interesting! This is why, earlier this year Vernon and Sice worked together to build the system 'Mirror of the Heart' to demystify HRV data and makes it easy for the individual to understand.

'Mirror of the Heart' uses the programme Max MSP (a coding programme often used by musicians and sonic programmers) to transform this data into audible sound. Connecting Max MSP creative DAW system Reason, Vernon and Sice M. were able to then design the sound and aesthetics. In addition they were able to visualise this data - so that one could not only hear their HRV but they could also see it. This was made possible through a sonic responsive camera tool (ref. Gustavo Silviera) which reacts to sound and its respective frequencies and adjusts the image in front of the camera to these frequencies. Red colours pick up peaks (i.e. heart beats) and blue colours represent low HRV frequencies.

When presented at the UKSS conference in June 2019, the heart rate data that was used came from data collected from participants in the Iron Man triathlon – pre and post run collected by Laurie Rauch of the University of Cape Town, South Africa. Physical stress affects the heart's action by reducing the degree of variability of the heart rate (HRV). Sonification and visualisation of the pre and post iron man data has the potential to allow for intuitive distinction between state of physical stress and state of relaxation. Data collected from the LoRaWan prototype, was also used to experiment with artistic interpretation using sound and visual. Vernon, Sice and their team are currently, however, working to make this a live data collection in order to have the most benefit for the user/viewer.

A brief overview of the Max MSP approach

The Max MSP patch first extracts data from a csv file storing it in a coll (Justin G). All data can be accessed in a coll with specific addresses. For example: address i = 1 will access the first data point. The number of notes played per heartbeat can be altered by the user setting the number of addresses to increment every trigger. The trigger interval is set in milliseconds, this sets the playback speed by setting the time between musical notes.

In Max MSP each midi keyboard note has a numerical value, the standard range of notes C1 to B4 have the numbers 36 to 83. To convert the heart rate data to this scale the minimum and maximum of the data must be retrieved, this is used to calculated which midi note is to be played.

$$Midi\ Note = \frac{(data[i] - data[\mathrm{min}]) \times (83 - 36)}{data[max] - data[\mathrm{min}]} + 36$$

where i is the is the current data point.

The heart rate variability is calculated by counting the samples between each peak in the data. To emphasise the HVR in the audio output, the value of the HVR is added to the Midi value. This Midi value is then sent via a virtual midi port to music software ‘Reason’. Using a virtual Scales and Chords device in Reason the notes are mapped to a select key and scale. These chords or single notes can then be played through a synthesizer and be listened to by the user.

Conclusion

The evidence presented in this study has shown that LoRaWAN technology can be applied to a real-time physiological state monitoring system. The prototype was able to measure physiological parameters, including IBI, BPM, acceleration on x-axis, acceleration on y-axis, acceleration on z-axis, and acceleration vector and orientation. The results also show that the main factors affecting the signal strength were obstacles in the transmitting pathway. However, the coverage range could still reach up to 650 metres, surpassing the other comparable technologies – Bluetooth and Wi-Fi. This device can also last for 8 hours, while always transmitting the data. While the LoRaWAN has the limitation in term of low data rate, this study ensures that it can be used to provide the connectivity for physiological state monitoring in real-time with acceptable delay. The researcher believes that LoRaWAN physiological state monitoring system can be used in many sectors, such as medical, emergency and entertainment services. The representation of the data is of significant importance in enhancing the user understanding and monitoring of their physiological state. The use of sonification and visualisation of physiological parameters has the potential to enhance the intuitive awareness of the user.

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Autopoietic Management of Behaviour, Reflection, Awareness and Innovation in a circular economy

HG Laurie Rauch
Department of Human Biology, Division of Exercise Science and Sports Medicine (ESSM), University of Cape Town, SA laurie.rauch@uct.ac.za

Petia Sice
Department of Computer and Information Sciences, Faculty of Engineering and Environment, Northumbria University, UK petis.sice@northumbria.ac.uk

Edward Bentley
Department of Mathematics, Physics and Electrical Engineering, Faculty of Engineering and Environment, University, UK Edward.bentley@northumbria.ac.uk

James Uhomoibhi
School of Engineering, Ulster University, NI j.uhomoibhi@ulster.ac.uk

Abstract

Autopoietic theory defines a 'living' system as an autopoietic system, i.e. a self-generating system capable of reproducing and maintaining itself. The internal dynamics of the 'components' of an autopoietic system both generate and sustain the global processes, while the global processes constrain and govern the interactions of the individual components in a reciprocal relationship. In organisms with a nervous system the rules of interactions within the component neuronal networks are in reciprocal relationship with the overall activity of the autopoietic entity. Reciprocal in that what the living autopoietic system senses is a function of how it behaves and how it behaves is a function of what it senses.

Furthermore, in an embodied and situated human autopoietic system or entity, global autopoietic processes are 'governed' by two control centres, *a 'mammalian' brain and a 'primate' brain. While the mammalian brain is hard wired to respond to internal and environmental stimuli to maximise the here and now (physical) survival of the human autopoietic entities, the primate brain enables the embodied and situated human autopoietic entity to act responsibly within the context of the challenges presented by day to day advancements in information technologies (mental) and the increasing impetus to move from linear (here and now) to circular (anticipatory) economies. The primate brain thus enables human autopoietic entities to function in the ever more digital societies and circular economies developed by modern society, while the mammalian brain enables human autopoietic entities to survive in the here and now.*

The influence that mammalian brain governing of the here and now local neural networks associated with eating behaviour has on primate brain governing will be used as an example of the importance of alignment between the mammalian and primate brains of human autopoietic entities to successfully embrace the ever more circular economies of the future.

Keywords: mammalian brain, primate brain, wellbeing triangle, motivated behaviours, relationships.

Introduction

Developing an adequate leadership capability to allow for socially responsible action is of critical importance in the current climate of swift changes and within the context of globalisation, communication opportunities and challenges presented by day to day advancements in information technologies (Vyas 2013, Zeleny 2014) and it is of particular relevance to the move from linear to circular economies. There is thus a need to rethink the phenomenon of leadership to reflect the more subtle levels of reality that deals with the quality of consciousness and awareness, all of which determine the quality of experience and intention and, therefore, the quality of behaviour and action.

Leading, as used in everyday language, is linked to the ability to guide and to direct oneself and others. It is related both to an individual's 1) cognitive capacity, an ability to learn to 'see' clearly, conduct 'appropriate' choices & actions; and 2) self-regulatory capacity to modulate automated behavioural responses. What 'appropriate' means in this context very much depends on what a person can 'perceive' to be of prime importance (cognitive) and how they act it out (behaviour). The theory of Autopoiesis (Maturana and Varela 1980) suggests that the development of cognitive ability is a continuous process of 'becoming' that is determined by our biological embodiment and by our co-existence with other autopoietic entities in a common environment. This paper interprets the insights of Autopoiesis in terms of developing a 'clearer' understanding and involvement in leading ourselves and others in creating the life we desire, i.e. articulating the factors that contribute to developing a leadership capability.

Autopoiesis

There exists a large body of work by two Chilean Biologists: Humberto Maturana and Francisco Varela, usually referred to as Autopoietic theory (Maturana and Varela 1980). This theory concerns the dynamics of living systems, asking the questions: What is a definition of a living entity? What does it mean to be alive?

Maturana and Varela define a living entity as a system that produces itself, i.e. a system whose output is itself. An autopoietic (living) system is defined as 'a network of processes of production of components that produces the components that: through their interaction and transformations continuously regenerate the network of processes that produced them; …' (Maturana and Varela 1980).

Autopoiesis is basic to the living individual. What happens to the individual is subservient to its autopoietic organisation, for as long as it exists the autopoietic organisation remains invariant. What this means is that its identity, and therefore its emergent global properties, are generated through a process of self-organisation within its network of components. However, we must also realise that this process of self-organisation is conditioned by a two-way process of local-to-global and global-to-local causation, i.e. we need to consider the mutual embeddedness of component dynamics, autopoietic entity and its environment. This dialectic relationship between local and global levels is described in autopoietic theory as 'reciprocal causality'. For example, in organisms with a nervous system, the rules of interactions within the neuronal network are in reciprocal relationship with the overall activity of the autopoietic entity. To a very large extent, behaviour is a regulator of perception. We enact our world rather than recognise one (Sice and French 2004; Sice and French 2006). In an embodied and situated human system, global autopoietic processes are essentially 'governed' by two control centres, a mammalian brain and a primate brain. While the mammalian brain is hard wired to respond to bodily and environmental stimuli to maximize the 'here and now' survival (our day to day enacting or behaviour); the primate brain enables the embodied and situated human individual to anticipate future events (cognitive) to thereby perform more optimally in society. This suggests that the process of self-organisation in organisms with a nervous system is better described as a three-way process of local-to-global, global–to-global and global-to-local causation. The influence that the mammalian brain's global regulation - over here and now neural networks associated with eating behaviour - has on primate brain governing will be explored below as an example of global-to-global causation.

First-person vs. third person perspective

Our understanding of experience suggests that while experience is clearly a personal event this does not mean it is private in the sense of some kind of isolated subject that is parachuted down onto a pre-given objective world. The senses do not perceive 'the world', instead they are participating parts of the mind-world whole (Harung et al. 2009). Consequently, the 'separation' of first-person vs. third person accounts is misleading:

> *…so called third person, objective accounts are done by a community of concrete people who are embodied in their social and natural worlds as much as first-person accounts. The line of separation between rigour and lack of it is not to be drawn between third and first-person accounts, but rather on whether a description is based on a methodological ground leading to a communal validation and shared knowledge. (Depraz, pp. 120)*

Our first-person perspective is the domain of the primate (cognitive) brain, while our third person perspective (our behaviour that can be objectively measured) is the domain of the mammalian brain. The key factor that will facilitate a healthy corporate environment is 1) that the first-person cognitive perspectives of each individual broadly aligns with the corporate vision and goals and 2) that the first-person cognitive perspectives of each individual aligns with their own third person behavioural (enacting) perspectives. It follows, therefore, that the process of leadership must be in harmony with this view of the creation of reality, based on a perspective of 'the self', both individually (1^{st} person) and collectively (3d person).

The working environment must allow the expression and growth of the individual and collective 'self'. Moreover, it becomes apparent that the core processes of leadership will be deeply intertwined with the capability to cultivate awareness: the use of one's 'self' to sense and bring to the fore that which 'wants to emerge'.

The theory of autopoiesis proposes that the quality of human experience, cognition and action, are determined by the interplay between the internal dynamics (biological processes) and the environment (social and other) of an active situated human agent, and thus offers an alternative perspective to interpreting and enacting leadership capability (Maturana and Varela 1987, Sice and French 2006). Leadership appears as both deeply personal and inherently collective and may be defined as shaping 'life-enhancing' conditions (Sice et al 2013). This requires focus on the 'common good' for the individual human agent to flourish (Georgantzas 2015, Maturana and Varela 1987). From the perspective of autopoiesis and theory of complex systems, the phenomenal domain of human enterprises is realized through the network of interactions between the human actors (Large et al. 2015, Maturana and Varela 1987). Such networks through the interactions of local agents are capable of spontaneous self-organization, to produce emergent patterns of behaviours of the network without any prior comprehensive, system wide blueprint for the evolution of the system (Sice and French 2006). The immediate local 'intentions' of the interacting human actors are continually emerging in a context.

The premise of this paper is that the quality of 'intentions' and quality of 'interactions' are interlinked, and effective leadership is distributed and impacted by both the structure of the system and its emergent properties, i.e. trust, wellness, sustainability, as well as, by the individual intent, morality, creativity and motivation. Research into conditions and models of governance that promote collegial decision making also implies that both quality of awareness, emotional intelligence and morality of individual actors, as well as the structure of the interactions, will need to be attended in parallel for catalysing leadership (Georgantzas 2015, Zeleny 2010).

This paper also brings into focus the 'embodied' aspect of leadership (Stake 2010). Behaviour is interlinked with both biological processes and responses to environmental triggers (Sice and French 2004). It is thus important to take into account measures of the 'invisible' aspects of cognition that are impacted by the function of the nervous system, i.e. Heart Rate Variability (HRV) (Prinsloo et al.

2013a, Tanaka M, McAllen 2008), cortisol profile (Rutters et al. 2009), skin response (Zhang et al 2013), etc.

The Three Dimensions of Human Experience

Effective attention to human experience requires the capabilities of reflection and awareness. Practices of developing the capabilities of reflection and awareness at personal and collective level need to address the three dimensions of human experience: physical, mental and relational (Varela 1995)

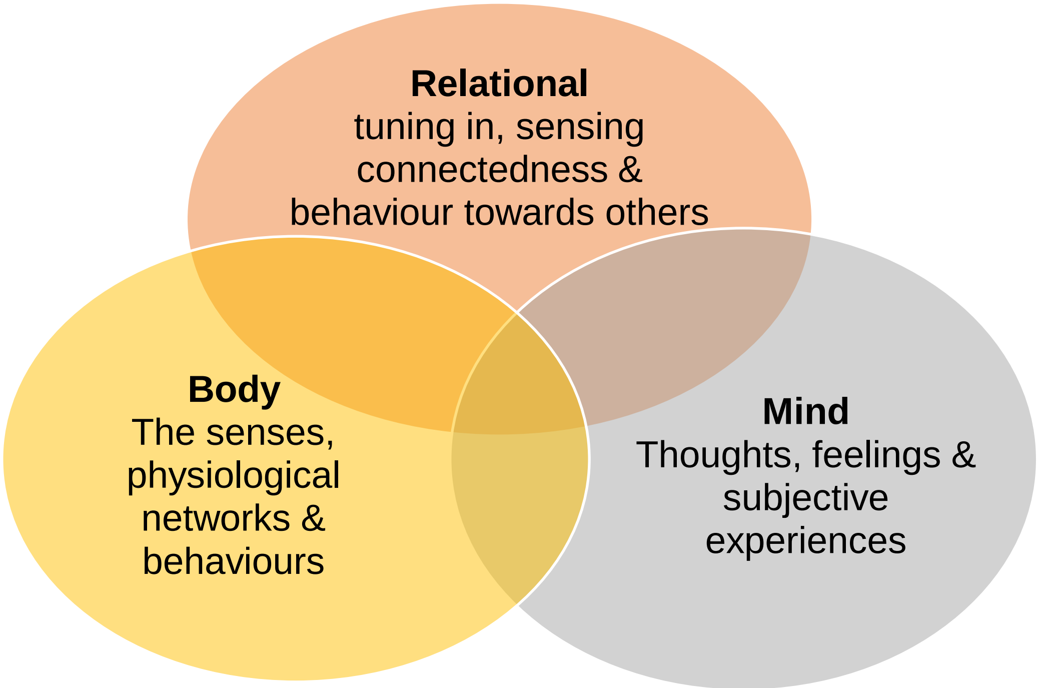

Figure 1: The Three Dimensions of Human Experience constituting our 'reality'

Reflective capability is associated with effective reflection on experience that can lead to insight and adequate interpretation and thus action. Our actions can be either 'voluntary' or 'motivated'. A voluntary action is prompted by specific tasks we set for ourselves (e.g. writing a letter, attending a meeting, doing banking, etc.) that is directed by our primate brains (Rauch et al. 2013a). Our primate brain also enables us to reflect on things, both on those things happening in and around us, and more importantly, on how we behaved when we were confronted by the things happening in and around us. A motivated action or behaviour, on the other hand, is prompted by subcortical behavioural programmes that we can complete 'without thinking' (e.g. taking food from the fridge when hungry, running away from a vicious dog, kissing a boy/girlfriend, etc.) that is directed by our mammalian brains (Rauch et al. 2013a, Rauch et al. 2019).

Mammalian brain versus primate brain

Human autopoietic entities essentially have three 'brains', a reptilian brain (directing vital functions), a mammalian brain (directing behaviours) and a primate brain (directing cognitions and voluntary actions). The reptilian brain is highly tuned to environmental and bodily stimuli to maintain bodily homeostasis. However, to stop the human autopoietic entity from being completely ruled by senses like a lizard, the reptilian brain is enveloped, and forms an integrated part of, the mammalian brain that co-ordinates behavioural responses via hard wired neuronal circuits (Naumann et al 2015) to maximize here and now survival. In turn the mammalian brain is enveloped, and forms an integrated part of, the primate brain, which allow a measure of control over mammalian brain automated behaviours (Nimchinski et al 1999). Furthermore, the primate brain is also able to govern/override the reptilian brain vital functions, e.g. breathe holding to swim under water, but only up to a point. The primate brain cannot override the hard-wired reptilian and/or mammalian brain indefinitely as this would threaten here and now survival. Nevertheless, the primate brain can anticipate and plan for the future, but only if these future plans don't threaten here and now survival. The mammalian brain essentially has only 3 types of hard-wire behavioural programmes, defensive, ingestive and reproductive (Swanson 2000), each of which confers a specific state on the enactive situated agent. When the defensive behavioural programme (Fight and Flight) is switched on the enactive experience is stressful, when the ingestive neuronal programme (Rest and Digest) is switched on the enactive experience is relaxing.

Mindful awareness

Awareness capability is associated with enhancing personal experience through cultivating the qualities of attention and intention to allow for being fully present in the moment, operating from the space of non judgement, while observing with open mind and open heart and open curiosity. The state of awareness is determined by the quality of intention and attention to our experiences in the present moment:

these include the experiences of our senses and body sensations, the activity of the mind, our thoughts and emotions, as well as the connective/relational experience of being connected with others, nature and all there is (Sice et al. 2008). While our attention is mediated via top down primate brain processing, our intentions include bottoms up ‘state’ components (Fourie et al. 2011). For example, when the mammalian brain’s hard wired defensive behavioural programme is switched on the top-down primate brain processes have little/no control over bodily responses and the default behavioural response is individual survival rather than collective altruistic behaviour.

Heightened awareness is different from reflection. While reflection allows for assessing our experience (after the experience has taken place), heightened awareness is the ability to enhance our experience by intentionally directing our attention to fully listening to and witnessing (noticing) the body, mind and relational experiences in the present moment. In Western translation a heightened state of awareness is often referred to as ‘Mindfulness’. This terminology is widely accepted in the West, where the state of ‘mindfulness’ is defined as an opposite to ‘mindlessness’, i.e. where we are engaging/functioning on autopilot, downloading our mental models, assumptions and prejudices rather than witnessing present experience. Jon Kabat-Zinn (2003) provides an operational working definition of mindfulness as

> *“The awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment”.*

Three key elements of the definition are: intentionality, present-centeredness, absence of judgment. (Davidson and Begley 2012). It is important to stop here and reflect that the distinction that we make in terms of physical, mental and relational/connective dimensions (Figure 1) are important in terms of directing attention and developing interventions, however, we cannot separate these dimensions from each other in our experience. In effect the dynamics of the mutual connectedness of the physical, mental and relational could be redrawn in related but hierarchical fashion Figure 2. If the base of the wellbeing triangle (physical and mental dimensions) is out of kilter, the relational/connective dimension will also be out of kilter

We choose to use the metaphor of the cameraman (Siegel, 2010) to explain the aspects of awareness practices that need to be observed. To allow for clear and accurate image the cameraman needs to take care of: 1/opening the lens of the camera to allow for a full view; 2/ stabilising the camera (using a tripod) to avoid blurring the image. Similarly, opening the lens of awareness requires attention to all aspects of experience: sensory perceptions, body awareness, awareness of mental activity such as thoughts, feelings, attitudes, beliefs, intentions, etc. and relational awareness of our connectedness with others, with nature, with our planet, etc.

The picture of our reality will still be blurry if we fail to stabilise the camera of awareness. Stabilising the camera of awareness requires *openness, observation and objectivity*. Siegel (2010) refers to these three fundamental components as the three legs of the tripod that stabilise our awareness lens (in his work Siegel uses the word mindsight instead of awareness). When the lens of our awareness is stabilised, the details come into focus. We see with more depth and precision. Openness implies that we are open and accept what is, without any preconceived ideas or attitudes of how things 'should be'. We let go of expectations and receive things as they are. Openness allows us to recognise restrictive judgements and release them from our mind. Observation allows us to place ourselves in a larger frame of reference where we observe ourselves even when we are experiencing an event.

Self-observation could promote the capacity for observing/tuning in with open mind, open heart and open will (Scharmer, 2010). Objectivity recognises that our awareness (subjective) is separate from what we are aware of (feedback signals). Our thoughts, feelings sensations, etc. are just what we are aware of at the moment and not our true identity. Self-observation allows us to detach ourselves from our habitual responses and to take steps to align our primate brains with the behavioral programmes hard wired in our mammalian brains. Intention, which is heavily influenced by bottoms-up affect, determines the direction of attention. The intention of 'seeing and feeling reality' more clearly, and continuously enhancing our awareness and reflection capability making sense of reality, requires the integration and alignment of the mammalian brain behavioural state regulation with the primate brain directing of attention in monitoring body sensations, mental activity and relationships.

It is important to clarify that our understanding of mindfulness as paying attention to our experiences and behaviours as it unfolds is not only connected to present moment sensations but to accepting and witnessing our present moment experiences and behaviours that may involve some or all aspects of experience, i.e. sensations, bodily states (Fight & Flight, Rest & Digest, Tend & Befriend), mental activity (thoughts, feelings, memory, intentions, beliefs, attitudes, etc.) and relational experience (connectedness to others, to our planet, to nature, etc.) (Siegel, 2012)

Wellbeing Triangle

Brain-body, Mind and Relationships are all aspects of one reality and need to be considered together, where the body provides the biological structure for hosting human experience, and the mind is *embodied*, and relational processes regulates the information and energy flow in the embodied brain and in the relationships with others, the environment and between the primate and mammalian brains. (the term 'embodied brain refers to the whole nervous system, not just the brain in the skull).

Figure 2: successful and healthy work environment

1. The physical domain with brain-body biological structure & processes, nervous system, energy flow and five senses is the preserve of the Mammalian brain.
2. The mental domain with mind/cognition, awareness, reflection is the preserve of the Primate brain.
3. The relational domain with universe, nature, human connections, people and language is the preserve of how well the Primate brain aligns with the

> Mammalian brain, i.e. is the productivity goals (KPIs) set by the Primate brain in line with the heart felt intensions of the Mammalian brain?

The mutual connectedness of our physical, mental and relational domains is crucial, as is the hierarchical nature of this mutual connectedness. An individual whose mammalian brain defensive behavioral programme (Fight & Flight) has been activated will have little/no primate brain control and by extension will have little/no control over his/her relationsips and connectedness with other people and with society as a whole.

Motivated Behaviours

The 3 types of behavioural programmes subsumed in the mammalian brain, defensive, ingestive and reproductive behaviours, provide automated behavioural programmes that ensures fulfillment of the 3 main biological needs, safety, nourishment and propagation of the species (Swanson 2000). Habitual responses take root when the primate brain 'hijacks' the innate mammalian behavioural programmes to fulfil non-biological needs such as switching on the ingestive behavioural programme instead of the defensive behavioural programme to cope with stressors. This response was seen in a group of women who had lost more than 5% of their body weight and had kept it off for more than 12 months when compared to a group of women who had never weight cycled (Rauch et al. 2019). The habitual Eating Restraint score on the validated 51-item Three Factor Eating Questionnaire (TFEQ) of all the participants was compared to their heart rates during a stressful cognitive test. Higher scores on the TFEQ is indicative of greater degrees of dietary restraint, disinhibition and hunger. While there was no correlation between habitual Eating Restraint scores and heart rates recorded during a cognitive stressor in the group of women who had never weight cycled, in the group of successful weight loss maintainers there was a significant correlation ($\boldsymbol{r} = 0.62$, $\boldsymbol{p} < 0.01$, Rauch et al 2019).

In the group of successful weight loss maintainers, the women with the lowest habitual Eating Restraint scores (≤ 6) had the highest heart rates during the cognitive stressor and the women with the highest habitual Eating Restraint scores (≥ 12) had the lowest heart rates during the cognitive stressor (85 ±5 vs. 68 ±8 bpm, $p < 0.0005$, Fig 3). This shows that those successful weight loss maintainers who were able to dampen their fight and flight responses during a cognitive stressor had a greater habitual ability to restrain themselves from overeating. This suggests that the primate brains of these women had adapted to 'dampen the activation' of their mammalian brain defensive behavioural program during cognitive stressors to prevent them from succumbing to over indulging. Restrained Eaters had previously been found to succumb when allocating cognitive resources to an attention-demanding task that overstretched their ability to monitor dietary restraint (Wallis and M Hetherington 2004).

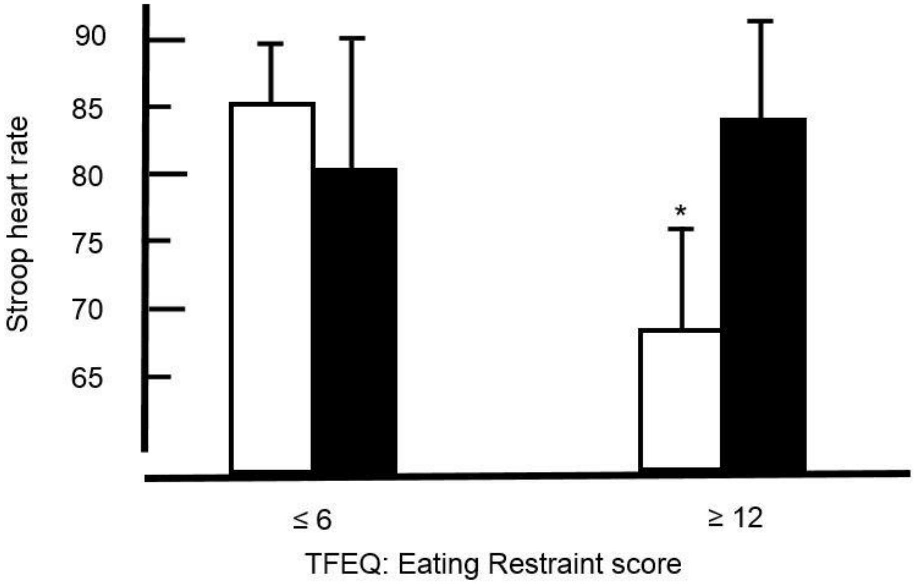

Figure 3: Stroop Task heart rate versus habitual Eating Restraint score on the Three Factor Eating Questionnaire.

White bars are the heart rates of women who have successfully maintained weight loss; black bars are the heart rates of women who have never weight cycled. * P < 0.0005.

It may well be that this hard-wired mammalian brain ingestive behaviour programme was 'high-jacked' by the primate brain of those women who had lost weight and were taking steps to keep it off as evidenced by the significant correlation between their habitual Eating Restraint scores and their stressor mediated heart rates (Rauch et al. 2019). I.e. the habitual eating behaviour in these women are closely linked to their fight and flight responses (as indexed by heart rates) when under pressure, but there is no such correlation in women who have never weight cycled. Once a habitual response is hardwired in the primate brain it becomes ever more difficult to correct, because the brain reward circuitry (with attendant downregulation in e.g. dopamine, serotonin, cortisol, etc. neurotransmission) adapts to the habitual responses and it soon becomes a full-blown conditioned response (Rauch et al. 2013a).

Awareness and locomotor movement

Sense perceptions from sight, hearing, touch, smell, taste and bodily sensations (interoception from the gut, heart, etc.) provides us with dimensions of experience that we need to bring into our awareness and reflection while exploring and seeking insight. The intention is to bring into focus embodied and relational experience, being open to what is emerging, sensing and observing with acceptance and detachment. Crucially, a calm (Rest & Digest) state is conducive to quietening the primate brain enough to become aware of the myriads of subtle bodily and societal feedback signals. From that space we develop the capacity to integrate our awareness into richer and deeper experience from which insight is born. Siegel (2012) divides the exploration of experience into a wheel of awareness consisting of four segments: sensory input, body sensation, mental activity (mental models, images, beliefs, thoughts, feelings) and relationship to the outside environment (people, nature, artefacts) that provide us with a structure for managing and integrating attention. In turn this provides us with the ability to notice and seek integration of our two brains, nervous system, mental activity and our relationships (Siegel 2012).

Research from neurobiology (Daniel Siegel, Richard Davidson, Francisco Varela) cognitive science and mindfulness (Jon Kabat -Zinn) and epigenetics provides evidence that contemplative, i.e. *awareness development* practices such as meditation, the Wheel of Awareness, Mindfulness, etc., lead to the development of the pre frontal cortex of the brain, vertical (gut, heart and cortex) and horizontal (left, right brain hemisphere) integration of the brain and the development of qualities of emotional balance; response flexibility (pause before you act); insight (linking past with present experience and future possibility); empathy and compassion for ourselves and others; morality (what is appropriate from the perspective of the common good) intuition (non-rational way of wisdom and knowing). Neurobiological research further provides evidence that locomotor movement 'from the spine' can be employed to facilitate synchronous action between the primate and mammalian brains (Rauch et al 2013b) and to recover the brain reward circuitry (Rauch et al 2013a, King et al 2018).

Conclusion

Human beings can be seen as self-generating autopoietic systems 'governed' by two control centres, a 'mammalian' brain and a 'primate' brain. Although the primate (cognitive) brain allows individuals to relate to the concept of a circular economy, the mammalian brain is unable to adapt to the behavioural changes required to work harder (paying more for food and goods produced in a circular vs. linear economy) for the same reward given that the mammalian behavioural programmes, that drive fulfilment of biological needs, are hard wired.

In order for an embodied and situated human to be 1) a healthy wellbeing system, 2) a high functioning productive member of society and 3) have good relationships with fellow workers in the highly competitive, innovative and digitally advanced circular economies of today, the 'here and now' mammalian brain and the 'anticipatory' primate brain must work in tandem.

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TOWARDS BUILDING AN INTELLIGENT SYSTEM BASED ON CYBERNETICS AND VIABLE SYSTEM MODEL

Akinola Kila
School of Computing, University of Portsmouth, UK.
akinola.kila@port.ac.uk

Dr Penny Hart
School of Computing, University of Portsmouth, UK.
penny.hart@port.ac.uk

Abstract

It aims to revisit some notable ideas in cybernetics namely, Stafford Beer's viable system model (VSM) and Ross Ashby's Law of requisite variety. In the paper we will discuss the philosophical underpinnings and theoretical standpoints of these ideas and their relevance to the management of a complex engineering organization.

The approach adopted combines cybernetics and systems thinking to explore the key parameters to building an intelligent system. We take an Intelligent system to be ~~a~~ viable and one that can learn and adapt to the changes in its environment.

CSTP-NASRDA [Centre for Space Transport and Propulsion – National Space Research and Development agency] is used as an example to explore how a complex engineering organization can become viable enough to cope with the dynamics and complexities that confront management. The more complex an organization gets the more complex it is to manage hence, the more organization we have to put in. In this paper, a model for an intelligent system is built, based on Stafford Beer's viable system model and Ross Ashby's contribution to cybernetics.

Keywords: system, organization, intelligence, viability, Viable Systems Model, and cybernetics

Introduction

To remain viable an organization needs to have capacity to adapt to new situations. This capacity for adaptation is normally associated with the strategic levels of management in an organization (Espejo & Harnden, 2006). In exploring this field of study, we ask the question; how can policymakers increase the likelihood that everyone in the organization will contribute, to the best of their abilities, to the decision-making process necessary for an effective organization? (Espejo & Harnden, 2006, p.83).

In this paper, we use the Centre for Space Transport and Propulsion; one of the activity centres of National Space Research and Development Agency (NASRDA-CSTP) as an example for building an intelligent and viable system model. CSTP-NASRDA is Complex engineering organization with a strict engineering environment for scientists and engineers (highly systematic and reductionist in its approach); this work therefore, suggests that, a systemic perspective can help reduce complexities and improve the way decision processes operate/are made.

We discussed system thinking as a basis for justifying cybernetics as an advantageous systemic approach to our situation of interest. However, in order to reaffirm the importance of critically informed research, the application of cybernetics to problem definition or situation of interest was used. The purpose of this paper is to introduce VSM as a recommendable and useful model for complex engineering organization's management; directed at making it a viable system. VSM is a product of cybernetics; ''the science of control and communication of complex and dynamic systems (living system, machine or organization) (Wiener, 1962). Cybernetics has evolved over the years with notable contributions from Warren McCulloch, Walter Pitts, N. Weiner, Donald Hebb, Ross Ashby and Stafford Beer (Abraham, 2002) (Beer, 1995)(Wiener, 1962)(Espejo & Harnden, 2006). Stafford Beer however, contributed to cybernetics by introducing it to management, which became the basis for the model he described as viable systems model (Beer, 1995) (Beer, 1979). It also moves towards building a model based on Ross Ashby's law of requisite variety and Stafford Beer's viable system model to help CSTP-NASRDA adapt to the changing environment (Ashby, 1958; Beer, 1995; Espejo & Harnden, 2006; Schwaninger, 2019).

We begin by exploring the situation of interest or problem space, which is a complex engineering organization. ‘’Problem definition is often considered a project’s most important and difficult phase’’ (Stephanie, 2012). The definition of the problem space is a critical phase of a research because, the ontological perspective has to be met with a corresponding and appropriate epistemology, which all together shape the approach of inquiry and methodology. A complex organization is that which has multiple processes that interact with the changing environment and requires simultaneous management. In a bid to meet this requirement, we explore key parameters to building an intelligent system that possess considerable amount of viability and can adapt to the changing environment. ‘An intelligent system is that one that learn and adapt to be viable’ (Nora, Slimane, 2018; Schwaninger, 2019). After the exploration of this key parameter, we move to building an intelligent system model to help management cope with the dynamics and uncertainties associated with a complex engineering organization.

Objective
To reaffirm the importance of critically informed research: An intro to cybernetics; systems thinking and their philosophical underpinnings.

Critical evaluation of problem definition or situation of interest.
To revisit cybernetics and VSM as useful tools to building an intelligent system/organization.

To synergize the contribution of Ross Ashby’s Law of requisite variety and Viable System Model (VSM) for the development of a cybernetic model specifically for complex engineering organization such as CSTP-NASRDA.

Systems thinking and cybernetics in perspective

Systems thinking is also about interconnectedness (Stowell & Welch, 2012). Its basic building blocks can be subsumed as ‘Emergence, Hierarchy, Communication and Control’; therefore, if the management of an engineering organization adopts this framework of reasoning, then, it becomes possible to improve decision making and resolve problems without causing adverse resultant effect elsewhere within the organs of the organization (Stowell & Welch, 2012).

Cybernetics however is a type of systems thinking as it is also about interconnectedness and thinking in a systemic way (Dorfman, Meyer, & Morgan, 2004). The interconnectedness and interdependence of all living systems, phenomena, organization, and behavioural patterns is the central principle of cybernetics. Systems thinking and cybernetics unequivocally view all the entities and subsystems within the system as interconnected and that an effect on one will ultimately have a resultant effect overall. This line of reasoning is an improvement on the classical science of cause-and-effect because it is a holistic approach (Dorfman et al., 2004). Nevertheless, cybernetics is subsumed into different orders: first order cybernetics focuses on an 'observed system' while the second order cybernetics is about 'observing system', which also takes into account the observer (Baron, 2007). Simply put, the first order is similar to the classical science approach while the second order according to Von Foerster is considered to follow a non-classical scientific rational (Foerester, 1974; Lepskiy, 2018). The third order cybernetics is what can be referred to as the point where it overlaps with systems thinking as it combines first and second order cybernetic approaches dealing with the self-reflexive-active environment (Lepskiy, 2015). Cybernetics has however evolved over the years with major contributions from Walter McCullock, Warren Pitts, N. Weiner, Ross Ashby and Stafford Beer (Beer, 1995). We now have management cybernetics, medical and biomedical cybernetics; cybernetic knowledge of neural networks etc. (Pekker & Novikova, 2014; Smurro, 2018). However, this paper focuses on management cybernetics.

Origin of cybernetics and its important to building an intelligent system

The origin of cybernetics can be traced back to Aristotle; the structure of knowledge itself and the principle of non-contradiction, which then evolved to become syllogism (the basis of reasoning). Aristotle's law of non-contradiction explains that you cannot be 'A' and 'Non-A', however, you can be something between 'A' and 'Non-A' (Beer, 1979, 1995; Stanford Encyclopedia of Philosophy, 2015).

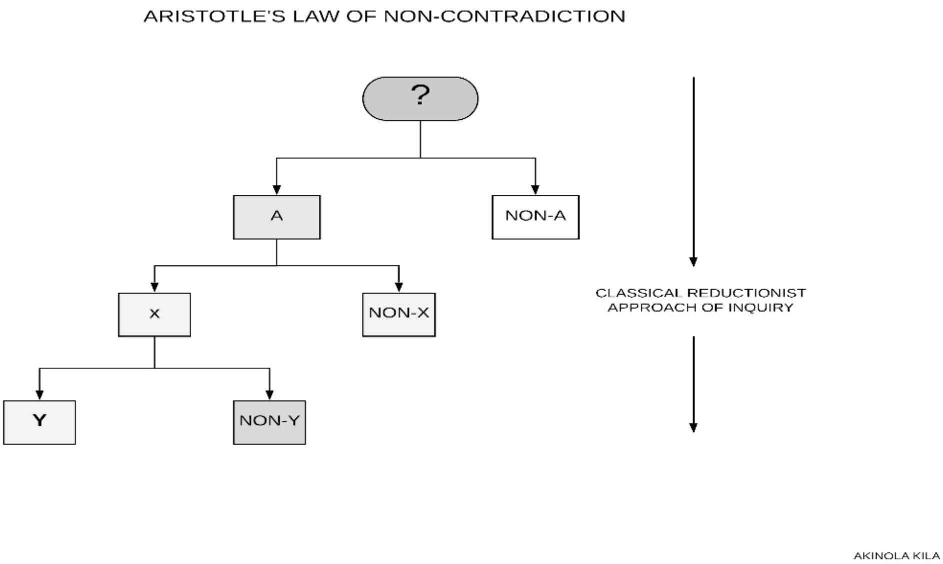

Figure 16 graphical illustration of law of non-contradiction

The figure 1 above looks like a family tree and that is what a reductionist approach means from the law of non-contraction.

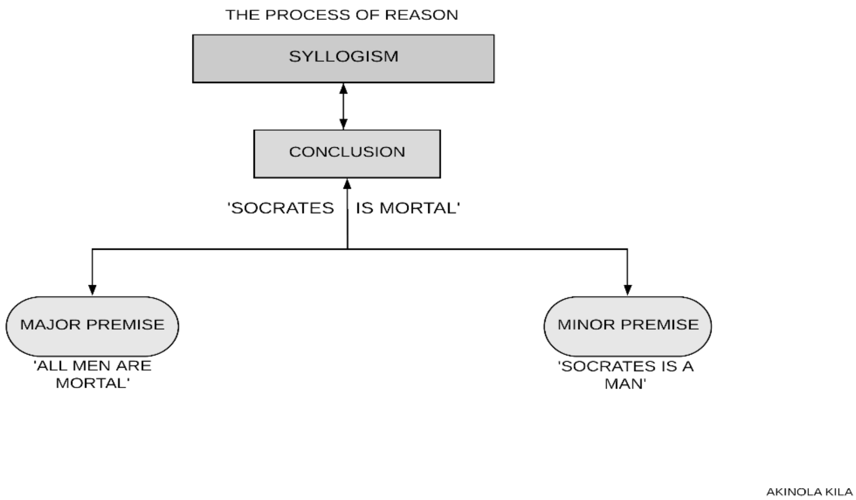

Figure 17 graphical illustration of syllogism

This develops again with Aristotle with syllogism as the process of reason just as shown in figure 2 above; which as to do with making conclusion based on major premise and minor premise. The classical one for example is ''All men are mortal'', and a minor premise, ''Socrates is a man'', we then deduce that ''Socrates is mortal''. This became the basis of reason and classical science; it is what we refer to as a reductionist approach of inquiry.

However, in building an intelligent system, one must seek to explore non-reductionist approaches like cybernetics for a process of reasoning that perceives thing in a holistic way; with a better reception to handling complexities and uncertainties. This approach has already emerged in different fields of study, such as in physics 'relativity and uncertainty' and in biology 'autopoiesis'(Beer, 1995).

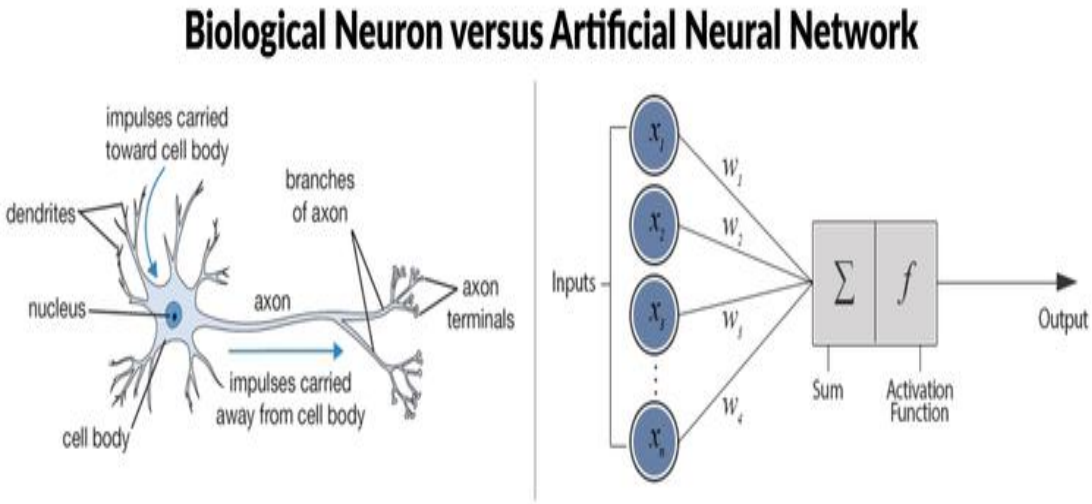

Figure 18 showing evolution of neural network from biological neuron

As shown in figure 3 above, one of the earliest Cybernetician was Warren McCullock, who was also a Neurophysiologist. In 1943, he developed a neural network circuit from studying how neurons in the brain works with his friend Walter Pitts (Mathematician) (Abraham, 2002). The diagram illustrates how neurones receives input via the dendrites; processes it in the nucleus by adding a neuro-transmitter, it then gets transmitted via the axon that converts it back to an electric signal which outputs through the axon terminals that connect to multiple dendrites of other neurons or to a muscle for effective action through the central nervous system. This biological phenomenon became the basis of neural network design and method of taking in multiple inputs and processing it with an 'activation function' before outputting it. Contribution was also made to this work by Donald Hebb who explained by pointing out, how neural networks are strengthened anytime they are used. A conceptual framework that is fundamental to how the human brain learns. If two nerves are activated at the same time, he argued that the connection between them is enhanced (Hebb, 2002). This evolution of neural network from biological neuron is a cybernetic framework of thinking that has also enhanced the pursuit of artificial intelligence.

It is therefore appropriate to describe cybernetics as an interdisciplinary subject of interconnectedness and a super-science of system's control and communication. A science of purposeful system and effective organization

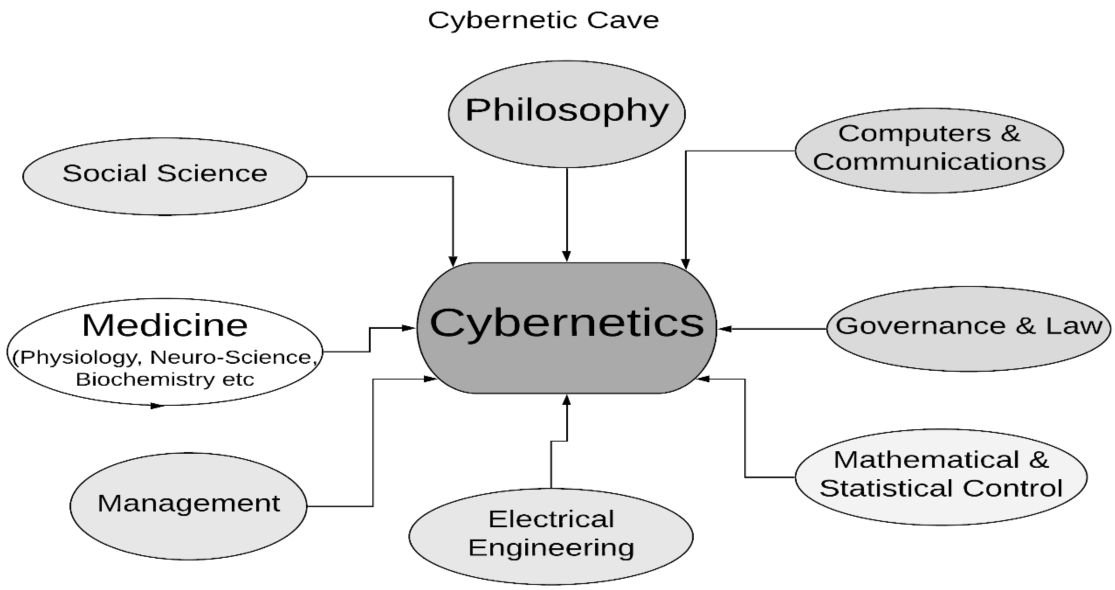

Figure 19 Cybernetics and different disciplines of influence

Figure 4 above shows different disciplines of study that have influence on cybernetics and also where cybernetics can be applied. Cybernetics is the approach that made the digital age possible (Beer, 1995). Beer illustrates that cybernetic answer is structural (Beer, 1995, P.21); that the structural architecture and arrangement of semi-conductors is what is responsible for the computational power of computers' processor and RAM management; not just because it is silicon-based semiconductor. On the same basis, the structural arrangement of amino acids in the DNA of a living cell is what is responsible for its genetic powers and not just because it is protein.

Some of the key definitions of cybernetics can be summarised below:
''Cybernetics was defined by Norbert Wiener to be the field addressing communication and control in animal and machine'' (Wiener, 1962).
''Ashby indicates that cybernetics can be applied to many systems including biological organisms, anthills as functioning societies, and economic systems. He wrote "Prominent among the methods for dealing with complexity is cybernetics"(Ashby & Young, 1961).

Heylighen and Joslyn write: "Cybernetics is the science that studies the abstract principles of organization in complex systems. It is concerned not so much with what systems consist of, but how they function. Cybernetics focuses on how systems use information, models, and control actions to steer towards and maintain their goals, while counteracting various disturbances'' (Heylighen & Joslyn, 2001). The focus on control that is organic; which can also be modelled for systems stability, viability and improved productivity of a purposeful system is the basis of Stafford Beer's viable systems model (VSM). VSM specifically provides basic structural configuration for viability. With VSM, an organization is set to be viable only if it commands a set of management subsystems, functions and interrelationships of which they are defined precisely. Just as Meadow right quoted ''Stop looking for who is to blame; instead start asking, what is the system? (Meadows & Wright, 2008)''.

The contribution by Stafford Beer to cybernetics in his design of the VSM was as a result of understudying the sympathetic nervous system of human being and its viability, which can then be modelled for management in an organization. This concept of cybernetics with emphasis on structural arrangement was introduced to management for effective control and enhance viability of organization (Beer, 1995). VSM however, focuses on system structure as a computable function of purpose.

Beer's viable system model in focus

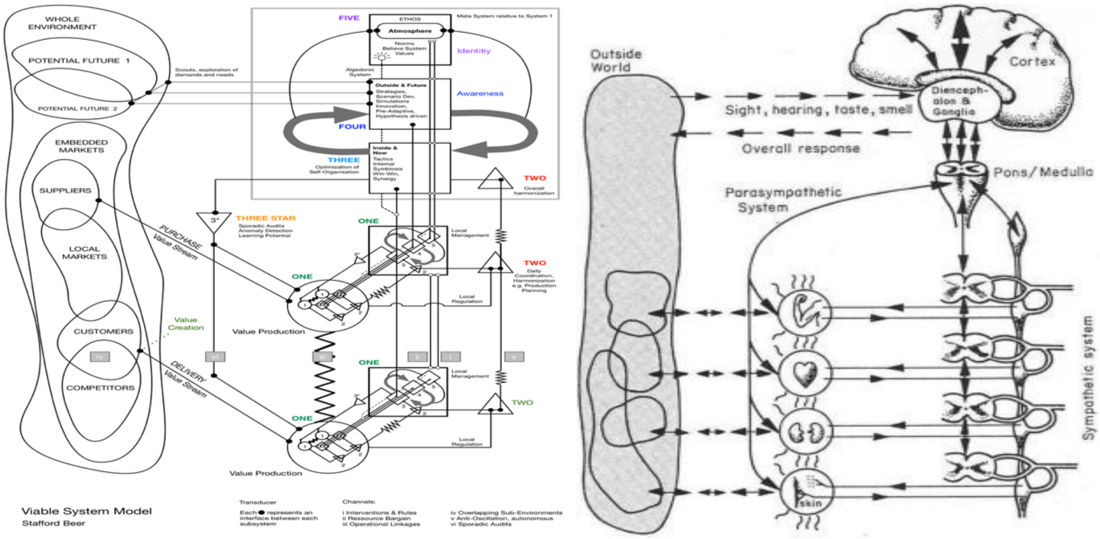

Figure 20 VSM and Sympathetic Nervous System

The figure above is a graphical representation of Beers viable systems model (VSM) for a customer-based production company based on human's sympathetic system (Schwaninger, 2019). This model is based on the assumption that current system's structural control is 'benign', which means localised. The word 'Benign' itself is inimical to viability (Beer, 1995, p.21). It is inspired as a reflection of the human autonomous nervous system; because it is capable of operating without any conscious intervention just as the case of VSM (Beer, 1995). The study of the sympathetic nervous system shows how different parts of the brain controls all the organs within the body; at the same time interacting with the outside world simultaneously, just as shown in the image on the right in figure 7.

Critique of VSM

In the literature on VSM applications, rarely any account of failures have been published, nevertheless, the practical applications and ease of use have raised some discussions(Jackson, 2005; Schwaninger, 2018). However, the model conveys a conceptual framework for design and diagnosis of organizations viability with respect to the principles of decentralization, participation, autonomy and ultimately democracy. The model possesses a methodological rigor: It offers a well-grounded and justifiable structural framework for dealing with complexity (Schwaninger, 2018).

Beer himself reflected upon some of the perceived limitations of VSM. How the theory is affected by the notion that the basic parts of a social organization involves purposeful people with free will, rather than organs or cells with no free will. Beer addressed this with the principle of recursion as the organizational maxim (Espejo, Harnden, 1989; Schwaninger, 2018). Simply put, the viability; cohesion and self-organization of the firm, divisions and subsystems are structured recursively and they are driven by a social rule of conduct which is called the autonomy of purpose (Beer, 1995).

In our research to building an intelligent system model for CSTP-NASRDA, we discovered that that the theoretical understanding and application of Ross Ashby's law of requisite variety was pivotal and not just the duplication of Beer's VSM. We also explored where necessary the law of cohesion by Beer in designing the model for variety attenuation and management.

Key laws to building viable and intelligent system model

For a system to be considered viable, it must be capable of independent existence. However, nothing is capable of absolute independence as every individual/system still needs something from its environment (Beer, 1995; Espejo, Harnden, 1989). Hence, the viability we are trying to achieve is not absolute but reasonable enough, in order to achieve an intelligent system that can survive on its own, for a considerable period of time before any major action is taken. There are two key laws we considered in this work to building a viable system which can be subsumed into:

- Ross Ashby's law of requisite variety: which states that only variety can absorb/nullify variety; also, we cannot effectively control everything within a system, hence we choose what to control effectively (Ashby, 1958; Stowell & Welch, 2012; Young, 1961).

- Law of cohesion by Stafford Beer: which states that in a viable system, just as much variety attenuation is needed to maintain a balance within the system (Beer, 1995; Espejo, Harnden, 1989).

It is worthy to note that, 'variety' in relation to Ashby's law of requisite variety is the option/variables presented at any time by the situation of interest or controlee; and it is directly proportional to complexity. This means that the more the variety, the more complex it is to control the system. Variety or complexity must then be met or absorbed by options presented by the control system/mechanism. This was elucidated by Ashby's statement that says 'all processes of regulation are dominated by the law of requisite variety; and that if a certain quality of disturbance is prevented by the a regulator from reaching some essential variables, then that regulator must be capable of exerting at least that quantity of selection'(Ashby, 1958; Stowell & Welch, 2012). Ashby further explained that if we choose to control everything within the system, it would not be effective; hence, we should choose what to control effectively (Ashby, 1958).

However, in order to demonstrate the building of an intelligent system for effectively managing complexities based on the laws above, we explored the organizational structure of Centre for Space Transport and Propulsion, which is one of the centres of National Space research and Development Agency (CSTP-NASRDA); generally called the Nigerian Space Agency and overseen by the National Space Council of Nigeria.

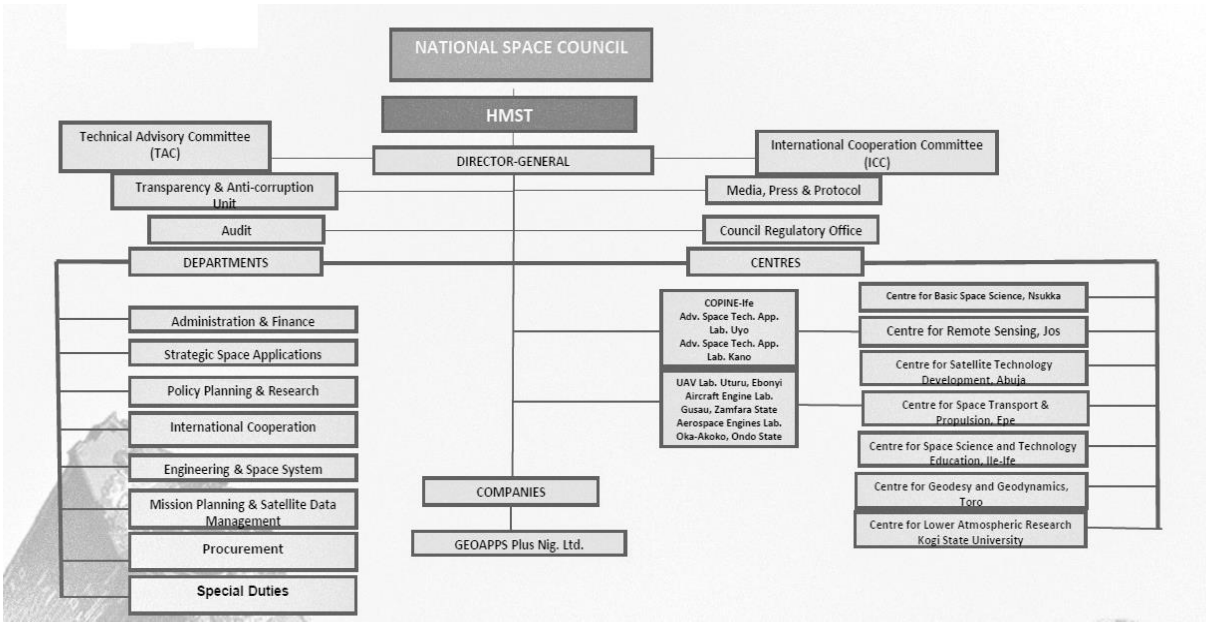

Figure 21 Current NASRDA's Organogram

Figure 6 above is an organogram that shows the current hierarchy-based structure of NASRDA and CSTP as one of the activity centres.
We viewed this centre (CSTP) under the lenses of VSM and Ashby's law of

The purpose of CSTP is research into rocketry and unmanned aerial vehicles (UAV); and its primary activities, which we can also refer to as internal environment can be subsumed into four main processes and sub-systems namely:

- PROCESS A – PROPULSION SUB-SYSTEM
- PROCESS B – STRUCTURES SUB-SYSTEM
- PROCESS C – AVIONICS SUB-SYSTEM
- PROCESS D – DESIGN & COMPUTATION SUB-SYSTEM

Furthermore, the existing structure of this organization as shown in figure 8 below; is a reminiscent of the reductionism-like family tree explained earlier in this paper in the Aristotle's law of non- contradiction.

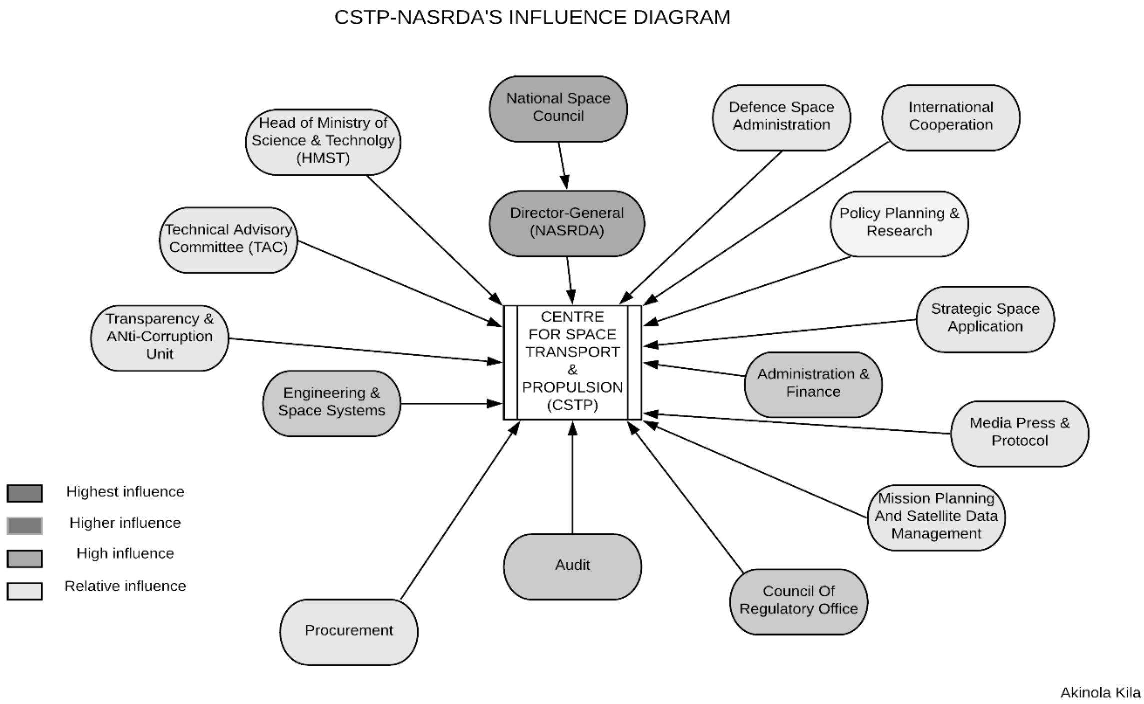

Figure 22 Showing CSTP-NASRDA influence diagram

Nevertheless, the sources of complexity in an organization like this are external environment; internal environment and policy (Espejo & Harnden, 2006). Hence, the reason for the introduction of key structural filters and control mechanism to manage these complexities and effectively control the sub-systems respectively, in order to make the system viable. Notably, we are only exploring one of the centres of NASRDA known as Centre for Space Transport and Propulsion with key interest in its environmental boundary and the influences exerted on it.

For further investigation into CSTP-NASRDA's boundary, we drew an influence diagram to show for illustration as shown in figure 9 below:

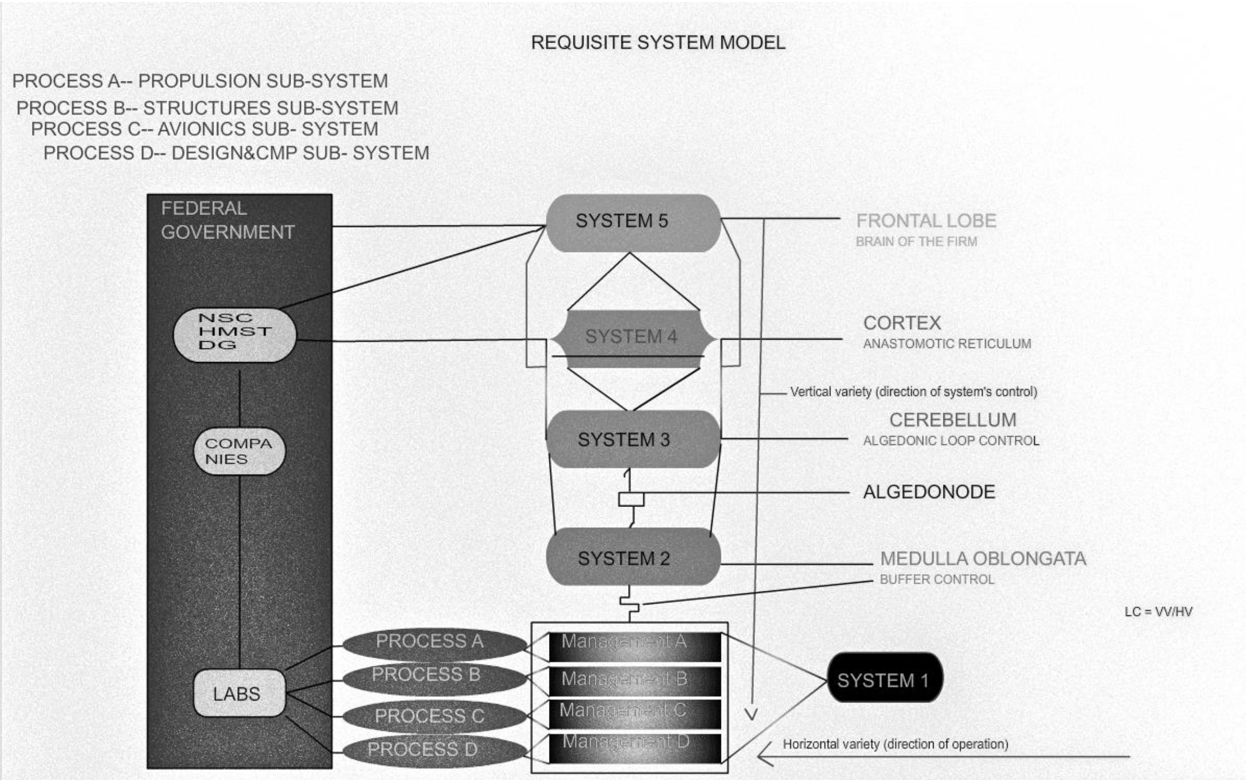

Figure 23 intelligent system model for CSTP-NASRDA

Figure 7 above shows other entities within NASRDA which are outside the system boundary of CSTP but have influences on it. There is a colour coding from highest influence to the relatively low influence. We proceed to building an intelligent model specifically for CSTP within its NASRDA's environment.

Intelligent system model for cstp-nasrda

The above diagram (figure 8) shows the graphical representation of the key structural filters and control systems for CSTP-NASRDA. In this model, we began by identifying the key components within the system. We have the environment; process and the management. These three components make up the primary structure of each sub-system within CSTP-NASRDA. For process A, the lab is an example of the environment and management A is the control mechanism for the process. Correspondingly, the produce: Environmental Variety; Process Variety and Management Variety. This is where the problems are generated, and this is why we designed 'system 1' to attenuate this complexity. However, for consistency of lexicon in this paper, the measure of complexity in cybernetics is called 'variety' (the number of possible states of a system (Beer, 1995)). We can deduce from our epistemology that variety of management is lower than the variety of process (meaning that management cannot simply know everything happening, hence cannot effectively manage it), also process variety is lesser than the environment variety (Shown in figure 9 below), the variety of each management is less than that of the corresponding process and environment respectively.

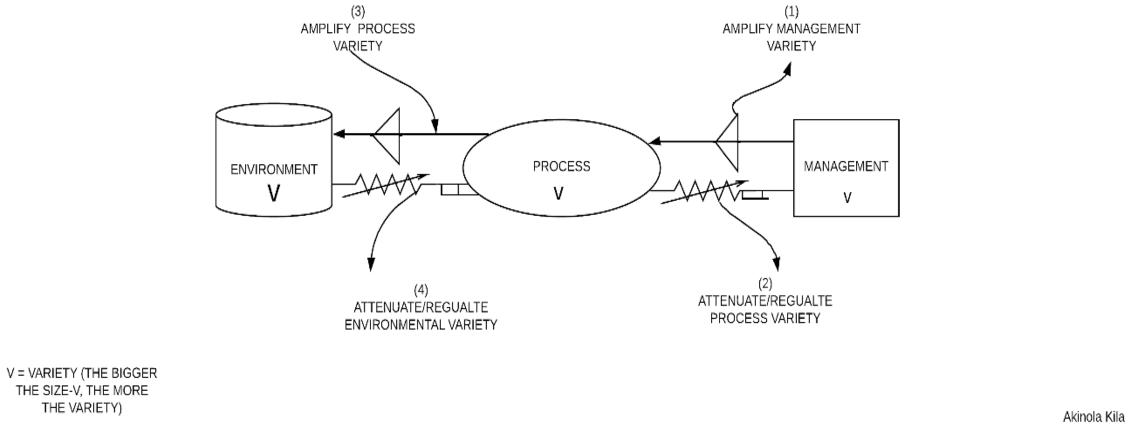

Figure 24 illustration of variety attenuation and amplification

In the above diagram, we showed how we can amplify/attenuate management's variety to meet the process variety and how the process variety can be amplified/attenuated to meet the environment's variety respectively. More so, management needs to increase its variety in a bid to meet the process variety for example by providing training schemes, putting up health and safety measures. At the same time, the process variety needs to be controlled and decreased with an attenuation mechanism. Respectively, the process variety has to be increased to meet the environment's variety; for example, increasing the advertising/media presence, market or laboratory research (Beer, 1979, 1995).

This control system helps the management regulate the processes within an environment. Managements A – D have to communicate with processes A – D; and the processes have to communicate with the environment with regards to what they do. Also, there is a return loop where the environment returns communication to the process and then it reports back to the management (eg. We are doing what you asked us to do). It is worthy of note at this point that, the old reductionist managerial way of measurement, which was largely regarded to as the four 'Ms' namely: Men, Materials, Machinery and Money; we have now reclassified it as 'complexities' (Beer, 1995). The holistic and uniform commodity underlying the common problems of the four 'Ms' is regarded as complexity in this organizational management. Simply put, the more complex it gets the more complex it is to manage, hence the more organization we have to put in. This model is devoid of this exponential variety by introducing corresponding system's control.

Furthermore, we aggregated the key sub-systems process in the model to illustrate their interconnectedness with both their management and the environment. The control systems which we have designed is explained below:

At this point, we introduce Ross Ashby's law of requisite variety that states 'only variety can absorb variety'; the explanation and modelling we have been making earlier in system 1 is an organization of Ashby's law of requisite variety. It is like law of nature, either we organize it or not, it will exert itself. Hence the need to organize it in order to prevent chaos (Ashby, 1958; Beer, 1995). When variety is constantly generated, by Ashby's law, the situation will always absorb the variety one way or the other. So, what we tried to do in system 1 is to organize the system by getting requisite variety beforehand in other to manage imminent complexities generated from varieties to prevent chaos (Beer, 1995).

System 1

The procedure we explained above is a building block of a complex organizational system, which its environment, processes and management are interconnected. We also showed how to manage variety and prevent chaos. As shown in figure 11, these are the sub-systems/divisions of CSTP-NASRDA. It is not a hierarchy, sub-systems A to D can be placed whichever way. In system 1, we are introducing viability to the four sub-systems. Before we explain how this works, there is need to define what a viable system means. A viable system is that which is capable of independent existence. Not that anything is capable of absolute independence existence, because every entity and systems will always need something from its environment; however, we are referring to a significant amount of independence that would make it viable. Even if a part of the system is having problem, it would not be detrimental to the whole before addressing it.

System 2 (Medulla Oblongata)

What we have explained in system 1 in relation to managing variety, can be considered as the introduction of horizontal variety in other to have requisite variety in managing the horizontal interactions between management, process, and the environment. Because managing horizontal variety can be a difficult task to maintain; there is need to generate a vertical variety to create balance in the sub-systems' management and improve their viability. We have tagged this the 'Buffer control' because, just like in chemistry, we use buffers to balance the pH level – from either being too acidic or basic to neutrality. There are also catalysts or enzymes in natural sciences that serve similar purpose of balancing rate of reactions but do not necessarily partake or get involved in the process of reaction.

However, we refer to system 2 as the medulla oblongata because it is at the lowest part of the brain which houses the control centres for the heart, lungs etc. it is primarily responsible for autonomous function within the body such as, breathing, sneezing, heart rate monitoring, etc. (Hornby & Turnbull, 2010). It is what houses our buffer control of autonomous system in this model. What we are doing with the buffer control it is to an extent, taking and given variety away from management of the sub-systems which might seem inefficient; hence the need for a cohesion and synchronization of these stages. This is the stage where we require Beer's law of cohesion that states '' in a viable system, just as much variety attenuation/reduction is required to keep the identity of the whole intact''. Therefore, for a viable system to be balanced it requires as much variety attenuation both horizontally and vertically. Law of cohesion = VV/HV (vertical variety/horizontal variety). To reiterate, the purpose of the model, is to make each subsystem viable and at the same time interconnected with the whole; hence these principles and laws are universal to the management of each system control. In addition, the variety attenuation and cohesion we are using especially in system 2, to balance oscillation within system one is not an oppressive control, but a strategic division of managerial task and the encouragement of the autonomy of a purposeful system. The purpose of the system must be the driving motivation/force of this intelligent system. To become a viable system, requires service of purpose, just like in autopoiesis. However, the main reason why this strategic and dynamic system's control is vital is to prevent the pathology of management that can arise when sub-system tend to seek absolute viability (Beer, 1995).

In addition, in a bid to minimise the reduction of varieties; and because of the massive amount of varieties constantly generated in complex organizations like this or just because of how inconsistent humans can be there is need for system 3.

System 3 (Cerebellum)

The rate of change within the system control can be inevitable, hence the need for system 3. We can simply describe this stage of management control as crises management. This phase of the system control does not have the luxury of time to think as the emergent varieties generated within the system has to be met immediately by Ashby's law (Beer, 1995). For example, there is an unsolicited visit of the press to the organization demanding key information about the processes or system 2 simply broke down and there must be an instantly response. We refer to system 3 as the Cerebellum because it is the part of the brain that regulates muscular activities and respond to stimuli (Hornby & Turnbull, 2010). System 3 must also be in considerable awareness of the happenings within the processes.

System 4 (Cortex)

System 4 takes charge of varieties, which are not in crisis or require emergent response. It is in constant interaction with the system boundary/environment. It syncs the flow of information between the organization; its environment and entities that have influences of it within its boundary. It is worthy of note that the outside world to the whole system is more than the sum of the system's environment; and there is an emerging future in the environment that the system constantly needs to be aware off. So, imbedded in the system's environment, there is both the present and future environment which is emerging, and an intelligent system must be aware of it. In order for us not to be trapped by Aristotle's law of non-contradiction, where we have to then either be system 3 or 4, we designed a loop around them for continuous information synchronization. This loop (from System 3) was referred to by Beer as the 'Algedonic loop' (Beer, 1995). An organization that does not balance this loop can lose its viability. This is the stage where it balances investment in relation to future plans. The loop between system 4 and 3 is what will actually make the system intelligent enough to adapt to ever dynamic/changing environment/world. System 4 is what we regarded as the cortex because, just as in the autonomous nervous system, it is capable of operation without conscious intervention (Beer, 1995; Hornby & Turnbull, 2010). It is also what Beer refers to as the anastomotic reticulum (cross connection between vessels or network (Hornby & Turnbull, 2010)) in his book 'Brain of The Firm' (Beer, 1995).

System 5 (Frontal Lobe / Brain of the firm)

The role of system 5 which happens to be the final system control is monitor and maintain the balance within system 4 and 3 known as the loop for adaptiveness for dynamic environment. We refer to system 5 as the frontal lobe because it is at the end of the brain just behind the forehead which the primary role is to coordinate behaviour, personality, voluntary behaviours and learning (Hornby & Turnbull, 2010). This final control system is what is responsible or policy formulation and also expresses the identity of the organization. It is the final part of the brain of the firm.

Sensorium for transfer function and decision making

See following Fig.

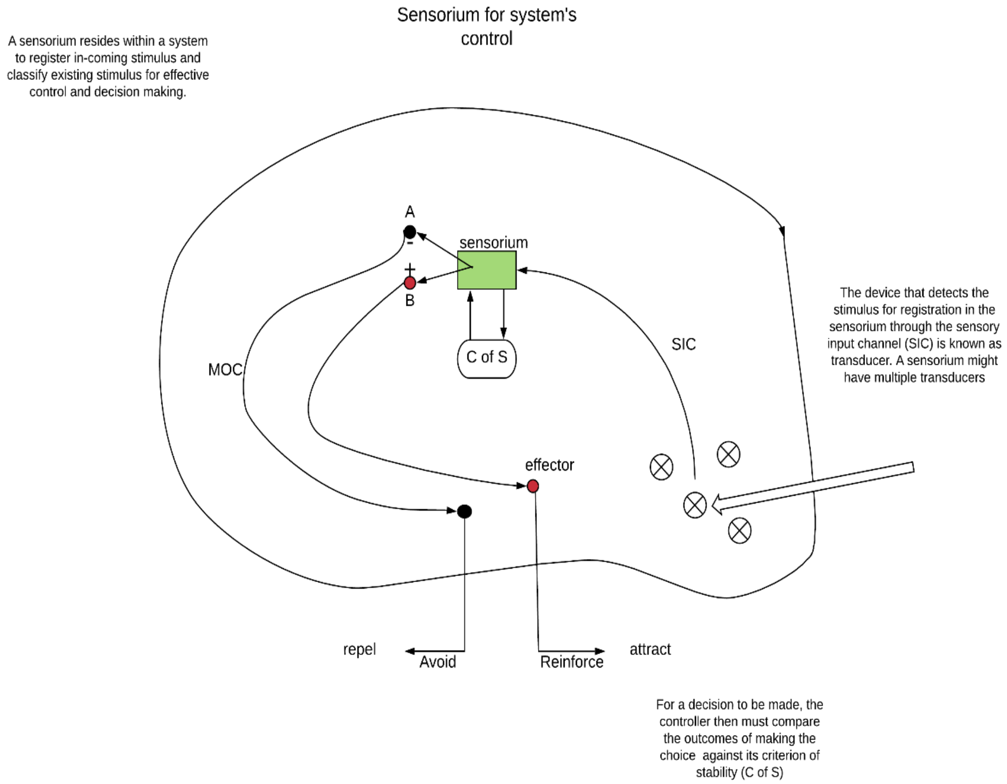

Figure 25 Illustration of sensorium for transfer function and decision-making

The sensorium resides within a system to register in coming stimulus and classify existing stimulus for effective control and decision making (Beer, 1995). The sensorium is a cybernetically inspired means of addressing transfer function and decision making without having to mathematically model it. Every system must possess a form of sensorium to become stable. In this case we have a transducer; which is a device that detects the stimulus for registration in the sensorium input channel (SIC). A sensorium might have multiple transducers connected to a single sensorium. When a stimulus is detected, it goes through the sensory input channel (SIC), into the sensorium; and for a decision to be made, the controller then must compare the outcomes of making the choice against the criterion of stability (C of S). This then gets passed out via the motor output channel (MOC) as an effector to either be repelled; reinforced or maintain neutrality as the case may be (Beer, 1995).

Conclusion

This model has shown that an intelligent system must be viable centralized or decentralised system; that they have to be fused and approached in a systemic way that intelligently connects all the organs within the system just like in the autonomous nervous system which is capable of operation without conscious intervention.

However, the focus of this work is not just to build an intelligent system that is viable enough to adapt to the ever-dynamic environment/world. It is also not just about independence or autonomy of sub-systems in terms of absolute freedom, because that will result to chaos but to encourage autonomy of purpose with effectively dynamic control mechanism. We aim to reduce some of the mathematical tools of reductionist approach which includes differential calculus. When we first started thinking in cybernetics about the nature of intelligence, we can write differential equations such as in the case of control engineering or neural networks that varies the output over the input: $f(p) = O/I$. However, in a social-technical system, either studying the way cells behave in the brain as a neuro-physiologist or behavioural patterns of humans as a psychologist; we simply cannot quantify a transfer function. The structure of a viable model for a social-technical system is a computable function of purpose (Beer, 1995). It is a model designed specifically to handling human affairs.

In conclusion, with the advent of social media; internet of things and artificial intelligence; we have had massive distribution of information and organizations; as a result of this, more complexities are being generated. The question then beckons, can VSM be of used in addressing this situation?

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Using Systems Thinking as an aid to project evaluation in the private, public and voluntary sectors

Karthik Suresh
Project Management Consultant
k.suresh@jayamony.co.uk

This paper details a set of case studies from projects in the private, public and voluntary sectors in using and applying some or all of the components of Soft Systems Methodology (SSM) to make clear the commercial case for a proposed opportunity to the participants considering whether or not to work together. The application of SSM consists of exploring the situation using rich pictures, mapping problematic areas, understanding the transformation required from the proposed activity and capturing the implications using the tools of SSM, including CATWOE, root definitions and conceptual models, and using the resulting outputs to inform and support a debate about the actions that might be desirable, feasible and justifiable on an economic basis. The results from these case studies show that SSM can successfully help participants better understand problematic situations and identify the areas that either need improvement or, equally importantly, stand in the way of coming to an agreement on the best way to proceed. The implications of these findings is that SSM can be a useful way to identify what is worth doing and help to make clear the main obstacles that must be addressed before the project can go ahead and, as a result, make it easier to get economic value from a potential opportunity or avoid wasting time and resources in pursuing an opportunity that is likely to be come up against insurmountable obstacles due to the nature of the problematic situation underpinning the proposed opportunity.

Keywords: catwoe, conceptual models, Soft Systems Methodology, project evaluation, rich pictures and root definitions.

Using Systems Theory to Highlight How Handicrafts Such as Railway Modelling Could Help Prevent Dementia

David Powell
Gateways, Bledlow Road, Saunderton, Princes Risborough, Buckinghamshire HP27 9NG
Email: david.powell@waitrose.com

Abstract

Currently, dementia research concentrates on diagnosis, clinical treatment and patient care. There is little research into prevention other than through immunisation. Empirical evidence suggested a new direction for dementia prevention research. Namely, identify social groups appearing to avoid dementia and look for common relevant characteristics and railway modellers could be one such group. This paper describes a survey of 1,100 members of 20 UK model railway club which highlighted a significant difference between the number of dementia cases forecast and the small number reported. The analysis highlighted two key common characteristics: engagement in a hobby involving cognitive dexterity, and participation in social groups with a common interest.

Applying systems theory showed that the significant characteristic of the hobby is the wide range of non-repetitive handicraft skills involved so that railway modellers continue to exercise the neocortex area of the brain, keeping it healthy. This limits or delays atrophy of the neocortex cells, more commonly known as Alzheimer's disease, the most common form of dementia. This research highlighted that a lifestyle incorporating participation in a complex handicraft pastime could help to prevent dementia, especially when reinforced by enjoyment and membership of a social group.

Keywords: Alzheimer's disease, cognitive dexterity, dementia, handicrafts, lifestyle, railway modelling, social groups, and systems theory

Introduction

The catalyst into researching the health benefits of complex handicrafts was not from concerns about dementia. It was concern about the future of railway modelling, given the hobby's aging and dwindling numbers, and ensuring viable trade support and sustaining the its informal network of clubs and societies. Although conversations about the hobby's prospects included stories of cancers, heart problems and other age-related illnesses, a recurring feature was the little or no mention of railway modellers with dementia. This led to a paper circulated in 2015 to the dementia research community which suggested identifying social groups that appeared to avoid dementia, such as railway modellers, to look for relevant characteristics. This proposal failed to have any impact. However, the 2015 Warley National Model Railway Exhibition provided an opportunity to collect data and resurrect the idea. Before going into the detail of the data collection, its analysis and the findings, this paper reviews: railway modelling, dementia and current dementia research.

Railway Modelling

As with most other handicrafts, railway modelling has never had the status, funding and recognition enjoyed by the arts. This predominantly male pastime is enjoyed by a wide cross-section of society from pop-stars to postmen brought together through researching, making and operating aspects of rail transport in miniature. As with most other pastimes, the time available is constrained by the demands of work, family and other commitments. Being a hobby, where access is voluntary, one of the main reasons for staying involved is the enjoyment the pastime brings. Those modelling in 1/24th scale or larger are usually described as scale model engineers; those working in smaller scales are referred to as railway modellers. This research concentrates on the latter.

Creating models of rolling stock, track formations, signals, buildings and scenery etc. requires physical dexterity, mental concentration and good eyesight using a variety of tools and materials. Techniques involve: scratch building from basic materials; construction from kits of partially prepared parts, and modifying the products of manufacturers such as Hornby Hobbies Ltd. (Hornby, 2019) As summarised by Marriot (2015) in his book *Railway Modelling Skills*, these techniques involve a wide range of handicraft skills. In his modelling encyclopaedia, Payne (1996) recommends at least 30 types of hand tools as a basic modelling tool-kit; many, such as files, in multiple shapes and sizes. Materials used include metals, plastics, card, wood, paints and adhesives, etc. In addition, the finished models may be presented as working dioramas, or layouts; where their operation requires significant concentration and dexterity.

Participation in railway modelling is by individuals, informal groups of friends or in structured clubs and societies. Some of the larger clubs offer formal and informal training in aspects of railway modelling. Sharing an interest in railway modelling has led to an informal network of model railway clubs in the UK to exchange ideas and share techniques. The layouts appear at model railway exhibitions organised by the clubs. Most clubs are based on a geographic town or area, many with their own premises, and membership can range from a handful to over 100. In addition, there are specialist societies, usually national and often with large memberships. They cater for special interests, such the Scalefour Society for those working to precise standards in 4mm to the foot, including an exact track gauge of 18.83mm. (Scalefour Society, 2019) Unlike the USA's National Model Railroad Association, there is no formal national UK association of model railway clubs. The nearest equivalent is the Chiltern Model Railway Association (CMRA) founded in 1965 by clubs centred on Hertfordshire to deconflict exhibition dates. Since then it has grown to some 150 clubs across the country representing over 9,000 modellers. (Chiltern Model Railway Association, 2019)

Dementia

Dementia is a term for a range of symptoms associated with memory decline and the loss of other cognitive skills severe enough to reduce a person's ability to perform everyday activities. (Earlstein, 2016) It is caused when a weakened brain is damaged by disease. If body parts remain unused for prolonged periods they deteriorate and are exposed to infection and the risk of disease, the process of atrophy. The most common form of dementia is Alzheimer's disease. This is caused by neurodegeneration of the brain, in particular atrophy or weakening of the neocortex from the loss of the neurons and connections between the brain cells. (Earlstein, 2016) The neocortex accounts for about 76% of the brain's volume. It is involved in functions such as sensory perception, generation of motor commands, spatial reasoning, conscious thought, and language. (Dubin, 2013)

An Alzheimer's Society report, *Dementia UK, 2014*, on the future social and economic impact of dementia concluded that there were some 850,000 people with dementia in the UK and Northern Ireland. (Alzheimer's Society, 2015) This was expected to rise to over 1 million by 2025 and 2 million by 2051. According to the Alzheimer's Society's *Facts for the Media* (2019), current estimates for UK dementia costs are in the order of NHS £4.3 billion and social care services £10.3 billion. Although often considered a risk only facing the elderly, there are over 42,000 people under 65 with dementia in the UK, and this proportion is increasing. An Office of National Statistics (ONS) report on Mortality Statistics indicated that dementia and Alzheimer's disease remained the leading cause of death in 2017, with 12.7% of the total and increasing. (Office of National Statistics, 2018)

Dementia Research

The key stakeholders in funding UK dementia research include the Alzheimer's Society. The research they sponsor covers five main areas: understanding the underlying causes; improving diagnosis; searching for a cure; clinical trials of new treatments, and improving care. (Altzheimer's Society, 2019) This research agenda reflects significant investment and influence from the pharmaceutical sector seeking profitable dementia related products and the health care sector looking for more efficient ways of caring for the condition. The only significant research which can be described as prevention relates to investigating genetics and immunisation. (Altzheimer's Research UK, 2019)

Meanwhile, a Mayo Clinic study recognised that participation in arts and crafts and socializing in middle and old age may delay the development of the thinking and memory problems which often lead to dementia. (Roberts, Pankratz & Mielke, 2015) The *Crafts and Creative Activities* section of the Alzheimer's Society's website now incorporates these findings as advice to help people with dementia to live well and reduce loneliness. (Altzheimer's Society, 2019) However, there appears to have been no research into which crafts could be most beneficial or why. This is the research path being explored in this paper.

Field Research

This research, into the dementia prevention benefits of railway modelling, was revived by an opportunity to interview representatives of 20 model railway clubs participating in the Warley National Model Railway Exhibition held at the National Exhibition Centre (NEC), Birmingham, over 28-29 November 2015. Although an individual initiative, this research incorporated published research ethics guidance and protocols. (Economic and Social Research Council, 2015) The NEC research method comprised:

Interviews
The interviews were with representatives of UK model railway clubs with their own club information stand or operating a layout at the Exhibition. The clubs covered a triangle from Cleveland in the north to Great Yarmouth in the east and Weymouth in the south west.

Conduct of interviews
The interviews were informal. As well as the purpose of the survey, care was taken to establish that the interviewees had a reasonable knowledge of their club's past and present membership. The data collected about each club comprised membership numbers and cases of dementia, if any, in their current and past membership.

Sample population
The data collection had a target of the interviews representing a combined club membership of at least 1,000 railway modellers. Assuming a normal distribution, this would provide a 95% chance of the survey result being within 3% of the total category value. (Niles, 2006) In the event, the combined membership was some 1,135 with an average individual club membership of 57. This was in the same order as the CMRA with an average of some 60 modellers in its 150 affiliated clubs. (CMRA, 2019)

Dementia occurrences

As the interviewees knew or had known their fellow members, present and past, as friends and colleagues, there were recollections of members suffering, and in some cases lost, through illnesses such as stroke, heart or cancer related etc. However, the interviews produced a total of only 3 club members with dementia.

Demographics

The Scalefour Society made available their 2015 research. This recorded 1,900 members with an average age of between 64 and 65. The bulk of their membership was spread 10 years on either side of the average. Railway modelling is often accompanied by enthusiasm for railways in general. Commercial data from a railway enthusiast magazine publisher indicated that their market sector was shrinking and the average age of their readers in 2015 was 65. This reinforced an assumption that half the NEC sample was likely to have been aged 65 and over, the age range most at risk of dementia.

Other ideas and views

Several interviewees offered ideas on why dementia may be absent. A recurring theme was social engagement through club membership and participation in activities, such as putting on exhibitions, and building and operating club layouts, as well as enjoyment, friendship, strong goal seeking and self-motivation, sometimes to the point of obsession by some modellers.

Analysis

The Alzheimer's Society report, *Dementia UK 2014*, forecast dementia effecting some 14.7 sufferers per hundred in the UK for the 65s and over age group in 2015. (Alzheimer's Society, 2015) In the absence of individual details, applying the Scalefour Society demographics suggested that half the sample, about 560, were at risk. This should have resulted in reports of as many as 80 cases of members and ex-members suffering from dementia in the sample compared with just the 3 cases reported.

It is accepted that, because of the circumstances, the NEC data collection was simplistic. Ideally, the data on dementia should have come from medical records. Furthermore, for the survey, the time frame was unclear as it was based on known cases in recent memory. Moreover, there was no allowance for membership churn, and the research could be challenged over the extent that a survey of model railway club members reflected the wider category of railway modellers, many of whom may not have been members of a local model railway club.

There was also the problem of proving negative causality. (Green, 2012) It could be argued that because of their condition, dementia sufferers would be unable to join a model railway club. However, the community-based nature of the clubs sampled meant that there would have been knowledge of what happened to members after leaving through ill-health or for other reasons.

Although the data can be challenged in terms of detail, it did highlight that for this group of some 1,135 model railway club members, there was a significant difference between the number of dementia cases forecast and the small number reported. This reinforced the original hypothesis that UK railway modellers did appear to be avoiding dementia to a significant degree when compared with the wider UK population. In the absence of any other data, this justified going on to analyse why this could be happening.

Common Characteristics

The significant common characteristics of the social group railway modellers identified in the NEC survey were:

Avoiding dementia
Members of model railway clubs did appear to be avoiding dementia compared with forecast arisings for the UK population in general.

Dexterity
Railway modelling required fine motor skill (dexterity) to coordinate small muscles and produce movement, usually with synchronisation of hands, fingers and eyes. (US National Library of Medicine, 2019).

Limited engagement
Being a hobby, many tools and techniques were used by railway modellers only occasionally during modelling sessions and most only at specific stages in modelling.

Railway Modelling and Dementia Prevention

To help to understand how railway modelling could be preventing dementia, the analysis included generic systems theory concepts such as subsystems, feedback loops, clockworks and connectivity; as well as aspects of Total Systems Intervention (TSI) including using metaphors (Flood & Jackson, 1991) and Soft Systems Methodology (SSM). (Checkland, 1981)

With systems theory the observer looks at the situation holistically. (Checkland, 1981) In this analysis the human body became a purposeful organisation, a system to make and operate model railways. This conceptual system had three main subsystems:

The maintenance subsystem
This comprised interconnected elements for specific bodily functions. E.g. lungs extracting oxygen; a digestive element extracting minerals, and the heart and associated blood vessels delivering oxygen and minerals to the body parts and recovering waste. These were primarily internal self-regulating elements, or involuntary functions. Even during sleep, they continued to function. In systems terms, such elements could be described as clockworks.

The production subsystem
This comprised the elements involved in making and delivering and the system's product, the models and the layouts. Unlike the maintenance subsystem, the manufacturing subsystem had significant interaction with the system's environment. This interaction used the hands and had access to an extensive inventory of craft tools and materials to create models and layouts.

The control subsystem
Mental concentration was the main activity in the control subsystem. This made use of the brain and the sensors (sight, sound, touch, smell and taste) to analyse data and make decisions, including initiating the required fine motor control of the hands. Data collection ranged from strategic research inputs to plan the model making to tactical sight and touch feedback control inputs e.g. the progress of a knife stroke. These inputs then set up the feed forward and feedback control of the fine movements of the hand and fingers, even for what appeared to be a simple activity, e.g. to take control, start, continue and stop a modelling knife making a

single cut in a material. Unlike clockworks, hand operations shut down during sleep, apart from involuntary movements. However, some environmental sensors, in particular sound, remained active during sleep.

Schwerin (2013) has described how dexterity requires considerable cortical space. In the systems model this became a metaphor of two overlapping functional areas in the control subsystem. These were, the front office and the back office, as found in many customers facing service organisations. The main outer mass of the brain cells, the neocortex area, formed the core of the control system's front office. This area was responsible for the higher mental functions including perception, behavioural responses and general movement. (Dubin, 2013) This was where the model making and operating processes were actively planned and managed, and from where control decisions over the handicraft skills were initiated and, in the absence of any intensive practice or repetition, repeated.

The control subsystem's back office included the reptilian limbic area. In operation, after a hand, finger, thumb movement had been repeated a large number of times over a relatively short period, either as a response or as an action, the appropriate muscle motor control passed from the front office to the back office. The transfer process applied to repetitive tasks ranging from simple dexterity such as tying a shoelace, to complex scenarios, such as learning to add a concerto to the pianist's concert repertoire.

Railway modelling involves a wide range of techniques. However, there is only occasional need for repetition of a technique over a short period. Consequently, in the notional model making and operating system, model making and operating continues to depend on the control subsystem front office neocortex for managing dexterity techniques, as they rarely migrate to the back office. This continues to exercises the neocortex, deferring or preventing its atrophy, Alzheimer's disease. This is why railway modellers do appear to avoid dementia while other social categories associated with dexterity, such as professional musicians, do not. (Kuusi, Haukka, Myllykangas, Järvelä I, 2019)

This interpretation added to the findings of Roberts et al., (2015). They had reported how crafts engage the mind and thereby may protect the neurons, or nerve cells, the building blocks of the brain, from dying, stimulate growth of new neurons, or may help recruit new neurons to maintain cognitive activities in old age.

An important contribution to the analysis came unexpectedly from a story, retold by a friend and musician, and attributed to the guitarist Jean ‘Django’ Reinhardt (1910-1953). Allegedly, Reinhardt’s teaching concentrated on the importance of practice in his neocortex to limbic retraining strategies. Reversing this story highlighted that it could be the absence of repetition which ensured that most handicraft techniques stayed with and continued to involve the neocortex.

The analysis also gave new insights into unexplained dementia related research findings. A characteristic of many complex handicrafts is being seated; this is to give the hands stability. This leads to a lack of exercise and increased body mass index (BMI). This would go some way to interpreting the findings of the Oxon Epidemiology team’s unexplained statistical relationship between avoiding dementia and higher than average BMI. (Qizilbash, Gregson, Johnson, Pearce, Douglas, Wing, Evans & Pocock, 2015)

Finally, the analysis showed the need for a term to differentiate between practice-based dexterity, e.g. that of a concert pianist, and dexterity continuing to demand active concentration for fine motor control, e.g. railway modelling. For this research, the combination of concentration controlling complex hand, finger and thumb movements adopted the term cognitive dexterity.

Group Dynamics and Enjoyment

The NEC research involved members of model railway clubs. As well as providing opportunities for skill transfer and encouragement, the Mayo Clinic studies had already identified how socializing may delay the development of problems leading to dementia. (Roberts, et al., 2015) However, many railway modellers do not belong to any social group. Also, there are other categories which do combine dexterity and social group interaction, e.g. musicians and orchestras, but still go on to suffer from dementia. (Kuusi et al., 2019) This raised a question: how significant are social group dynamics a factor in preventing dementia over and above just engaging in complex handicrafts such as railway modelling? Similarly, in common with other hobbies, how significant in energising the neuron activity associated with cognitive dexterity is the enjoyment and individual motivation observed in railway modellers?

One route to answering such questions would be to improve personal medical records to include details of the individual's pastimes. In systems terms this would be recording not just how the system, the body, was behaving and being maintained, but would take more cognisance of the system output, namely also what it was being used for?

Application to Other Pastimes

This research has concentrated on railway modelling. This was where the phenomenon was first noticed and the supporting data collected. However, there are many other pastimes which involve complex handicraft skills, where involvement is spasmodic and the hobbies are associated with group interaction and enjoyment. As well as other model making genres e.g. model boats and model aircraft, these could include those pastimes involved in preservation, restoration and operation in the heritage aircraft, ship, vehicle and railway conservation sectors. The operation of the items being restored and maintained often involves handicraft techniques appropriate to the period of the original design and construction of the item. Furthermore, the industrial heritage conservation sector requires working with other volunteers involved in specific projects. A typical example is the restoration and operation of trams at Crich in Derbyshire. (Crich Tramway Village, 2019)

Acquisition Time Lines

Another unknown is the time line needed to acquire complex handicraft skills if they are to be effective in preventing dementia. With dementia being identified at much younger ages than in the past (Pritchard, Mayers & Baldwin, 2013), model railway clubs could be besieged with potential early stage dementia sufferers in their 50s when involvement in the appropriate handicrafts should have been taken up much earlier, even being reintroduced in secondary education.

Alternatively, as the Mayo Clinic studies (Roberts, et al., 2015) have identified, there are benefits in introducing handicraft skills to defer the acceleration of the disease after diagnosis of the early onset of dementia. However, this could introduce significant practical management challenges, in combining health and safety of the public and duty of care of early stage dementia volunteers, especially in situations such as when industrial heritage sites are open to a paying public.

Medical Records

An attempt to involve a GP practice and pilot including hobbies in patient medical records failed as there was no space left for additional data. However, another avenue could be optician records. These can be paper based (usually hand written) or held electronically, e.g. Vision Express and Specsavers. As well as details of general health, unlike medical records they do include detailed notes on occupation, sports and pastimes. (Royal College of Optometrists Guidance, 2019) This data is collected to ensure that the glasses and contact lenses prescribed will meet an individual's lifestyle requirements. Manual records are held for 7 years after the last eye test, and then destroyed as confidential waste. Electronic records are deleted on advice of the death of the client.

Rise of Dementia and the Demise of Craft Skills

Research by Pritchard, et al., 2013, indicated that the numbers of dementia and other neurological deaths in people under 74 was rising and dementia was being detected in under 55s. Furthermore, this increase was highest in the 10 largest Western countries. The study team were unable to identify any one factor to explain the increases; however, the significance of complex handicrafts such as such as railway modelling in appearing to prevent dementias could provide one possible answer.

Before Meccano gave way to the simpler, and quicker, Lego building blocks, for many now over 60, childhood included activities such as these iconic nuts and bolts based engineering building kits; these required acquiring significant cognitive dexterity. Leaving school often meant apprenticeships in manufacturing or operations and developing dexterity skills to use equipment. Meanwhile, most cars and household goods could still be serviced and repaired by the user. In the 21st century, it is almost impossible to even change a headlight bulb on a modern car, and it would probably invalidate the warranty if one could.

As Tonya Reiman argues in her essay *The Opposable Thumb - Evolution's Gift to Humankind*, it was the hand and in particular the opposable digit, the thumb, which facilitated human evolution as primitive Stone Age craft skills advanced to the complexity demanded by 20th century pre-computer technology. (Reiman, 2013) Much of this has now been overtaken by a world dominated by computer technology at work, in the home and even for socialising. A scenario exacerbated by item replacement and the demise of handicraft intensive manufacture and owner maintenance.

This recent technology shift has removed exposure to many complex skills requiring cognitive dexterity. Today's engineers are trained in computer aided design (CAD) and computer aided manufacturing (CAM). Hand skills are limited to simple repetitive techniques such as touch typing and key-board interface operation. Moreover, voice activated and dictation software are further eroding the need for cognitive dexterity, except for a fortunate few, such as railway modellers, whose life style choices still embrace complex handicraft-based pastimes.

Initiatives Following NEC Research

The NEC findings were included in an article on the hobby's health benefits published in the *Railway Modeller*, a monthly magazine, circulation 41,000. (Powell, 2016). The feedback from home and abroad included support for the dementia prevention proposition. This feedback encouraged a revision of the 2015 submission to include the NEC findings. This was recirculated to the dementia research establishment in July 2016, but to no avail.

Since then, there have been unsuccessful attempts to influence other relevant dementia research teams by suggesting, where appropriate, including pastimes in their research parameters. However, much of the current research is based on processing medical records, and these exclude patient pastimes. Furthermore, even when only recently started and detailed surveys involving interviewing individuals could have included pastimes, the research protocols had been signed off as part of the funding process, and could not be amended.

Where there have been openings to promote the idea that involvement in complex handicrafts could help prevent dementias, seminars and lectures have been given to U3A groups and model railway clubs, and further articles written in specialist hobby magazines.

Most recently, 4 years since the idea was first raised, the opportunity was taken to give a paper on the proposal, that complex handicrafts could help prevent dementia, at the 2019 UK Systems Society Annual Conference at Bournemouth University on 24 June 2019.

Lessons from Rejection of 2015 Proposals

The failures of the 2015 and 2016 submissions were revisited using systems approaches to failure (Bignell & Fortune, 1984) to attempt to establish why they were rejected or ignored. From a systems perspective, the main external dementia research drivers were shareholder profit through improved efficiency in dementia care and new pharmaceutical products. This highlighted the dominance of the pharmaceutical and care sectors in resourcing, funding and influencing dementia related research. However, it was noted that one of the major participants, Pfizer, had pulled out of research into Alzheimer's related drugs, because of lack of progress towards developing suitable profitable products. (Dilts, & O'Brian, 2018) Therefore, there was little activity or interest in dementia prevention research, other than immunisation. Furthermore, any moves to stabilise or, ideally, reduce significantly future dementia numbers could be contrary to the business objectives of some dementia research stakeholders.

The other issue highlighted was that, unlike industry and business, where differentiation and innovation were significant environmental system inputs for survival and success, UK academic research was primarily a closed loop system based on existing research pathways. In particular that new research proposals, possibly leading to a PhD, should contribute to the chosen university's research standing. (Phillips & Pugh, 2015) New research proposals were expected to incorporate endorsement from experts already working in that field, and reflect existing research, peer-review activity, potential supervisors' interests and research department structures. This should then result in the findings from the proposed research being published in relevant journals and the work cited by other current and future researchers in that specific field, and shared at specialist field conferences and seminars. The primary system objective and the research selection process would therefore appear to be to maximise academic recognition through publication.

The proposed new approach to dementia research had failed to attract attention because it did not fit into either the primary objectives of the dominant business sectors or the main academic dementia research pathways.

Opportunities for Further Research and Action

The 2015 data collection and its subsequent analysis, raises unanswered questions beyond the resources of the current solo 'kitchen table' part-time researcher. In descending order of priority, these include:

Credibility. How to engage the wider academic community for this research to proceed? The only leverage is the potential to be involved in a scenario with forecasts of 1 million UK sufferers by 2025 and current annual costs of some £15 billion. (Alzheimer's Society, 2019) If the link between complex handicrafts and preventing dementia is to move on, it may need to engage researchers working in other fields, e.g. the social, political and economic related disciplines.

Data Sources. Until medical records include information on patient pastimes, an unanswered question is where and how to access data to identify potential dementia prevention characteristics? Solutions could include gaining access to ophthalmic patient records and repeating the NEC process with other modelling genres, e.g. model boat building which has its annual Model Boat Show in November.

Involvement Timelines. What period of involvement in a handicraft is needed to acquire an effective level of dementia prevention? Furthermore, which relatively complex handicrafts could be introduced to provide remission against further deterioration after early stage dementia is identified?

Group Interaction and Enjoyment. Compared with the non-club member modeller, what is the relative importance of group interaction in preventing dementia?

Interest Surge. Although modelling clubs and heritage engineering projects are covered by in-house training and sharing experience, this may not cope with increased demand, as handicraft skills disappear from modern technology training. One solution could be skill transference centres, e.g. the Make Liverpool (2019) project with courses in traditional crafts, and the UK Men's Sheds Association which encourages practical skills. (Men's Sheds, 2019)

Conclusion

Empirical observation led to the idea of investigating dementia prevention based on social categories which appeared to avoid the disease, e.g. railway modellers, to look for relevant characteristics. This idea was rejected by the dementia research establishment when proposed in 2015. However, it has continued as an individual research project. This included collecting data at the 2015 National Model Railway Exhibition in Birmingham which confirmed that the pastime of railway modelling appeared to give a significant level of dementia prevention.

The analysis incorporated systems theory to identify the following common factors:

- Railway modelling involves a wide variety of complex handicraft techniques.
- The various skills and tools involved are only used intermittently.
- Model railway club membership brings social interaction.
- Enjoyment and enthusiasm are associated with the pastime.

The combination of a range of complex handicraft techniques coupled with sporadic involvement is the most significant. Being intermittent, the need for concentration for the fine motor control of a wide range of hand, finger and thumb positions continues to exercise the neocortex. This in turn helps to prevent atrophy of the neocortex, Alzheimer's disease. This is reinforced by social interaction from club membership and enjoyment in the hobby, both of which further encourage neocortex activity.

The combination of concentration and dexterity introduced the term cognitive dexterity. Furthermore, the findings challenge the assumption that dementia, at least in the form of Alzheimer's disease, is primarily an age-related inevitability. This research indicates that a significant reduction in cognitive dexterity and the associated neocortex inactivity could result in atrophy of the neocortex leading to Alzheimer's disease. Furthermore, the link between complex handicrafts, such as railway modelling, and preventing dementia could explain how the current increase in dementia cases is an unintended consequence of the decline in handicraft skills following the rapid transition to a computer dominated throw-away society.

This research and analysis highlight a weakness in current medical records. They do not record pastimes. If the UK is to reverse the forecast increases in dementia to 2 million by 2051, this information is needed to identify and promote dementia preventing life styles and help target individuals at risk. Collating the additional information could help answer questions including involvement timelines and the relative significance of group interaction. Meanwhile, ophthalmic patient records, which do include lifestyle, hobbies and health summaries, could provide an interim route to identify, develop and promote appropriate pastime and lifestyle strategies which incorporate cognitive dexterity and thereby help prevent dementias such as Alzheimer's disease. However, to make significant progress in dementia prevention, further research may have to come from outside the current dementia research establishment boundaries, e.g. from areas such as the political, social and economic disciplines.

Furthermore, given their potential to help prevent dementia, one of the biggest challenges the nation faces, it is suggested that the time has now come to ask for the crafts to be given the status, recognition, resourcing and, in particular, funding, as already enjoyed by the arts?

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U.S.

'We the People: Supporting Food SMEs Towards a Food Circular Economy'

Toni Burrowes-Cromwell, Prof. Alberto Paucar-Caceres and Prof. Susan Baines
Manchester Metropolitan University Business School
T.Burrowes-Cromwell@mmu.ac.uk

This project examines collaborative support for food SME participation in food waste reduction. It locates hospitality and food services (HaFS) within a dense food waste system, where multi-stakeholder alliances are essential for business change. The literature discourse is mostly about defining food waste; measurement, and technological processes along the food supply chain, in which concepts such as: *food citizenship, feedback loops* and *open innovation* emerge as important aspects of collaboration.

This study aims not only to support HaFS in tackling waste but to enable their movement towards the regenerative focus of a Food Circular Economy (fCE). Overall, the scenario reveals classic systemicity, impacted by human inputs/ outputs and inter-relationships. In terms of philosophy and meta-theory, these ideas resonate with holism and systems thinking, that could inform organizing against the messy food waste problem.

Critical Realism also contributes to this discourse around change. It highlights the relational complexity and power dynamics of HaFs struggling to flourish within their communities. This single case study employs multiple methods (interviews, focus group, workshops) in examining how the collaborative nature of the London TRiFOCAL project (to promote food waste reduction, healthy eating and food waste value) is enabling HaFS transition to circular practice.

Keywords: critical realism, complexity, feedback loops, food circular economy, food waste, holism, hospitality and food services, systems thinking, open innovation, SME and TRiFOCAL.

Circularity and the conceptualisation of a hub of practice for cancer support services as guided by a virtual paradigm methodology

Gary Evans, Layne Hamerston, Lynn Sherrett and Dr Debbie Sadd
gevans@bournemouth.ac.uk

The purpose of this paper is to set-out how Systems Thinking, Systems Practice (Stowell et al. 2012) assisted in conceptualising what a hub of practice needed to do, to more effectively lead and deliver cancer support services to those living with cancer in the southwest of England.

The catalyst for this inquiry was the change in healthcare policy, such as *A Five Year Forward View* (NHS, 2016) and *Cancer Healthcare for the Future* (NHS, 2015) that intended to provide more services in the community and for patients to take more ownership of their health and wellbeing. However, the transition from a centralised healthcare system to community-based provision seemed fraught with complexity and lacking any real direction or approach. The stark reality of the situation was that only 1:12 patients (Evans et al. 2018) were likely to receive a referral to physical activity, health and wellbeing interventions, to support them on their journey to normalisation.

In an attempt to tackle this opportunity situation for those living with cancer, a cohort of health professionals, patients and physical activity specialists were purposively selected to inform the inquiry to conceptualise a hub of practice for physical activity, health and wellbeing interventions for those living with cancer in the conurbation of interest. A virtual paradigm methodology (Castle, 1998b) was the preference to guide the inquiry after careful analysis of the opportunity context as called for by Flood and Jackson (1991), preliminary discussions with participants and what type of dataset was necessary to advance the inquiry. Commentators such as Midgley (2000) might contest a virtual paradigm methodology is controversial; however, so is a referral rate of 1:12 cancer patients. Work to operationalise the hub of practice continues.

Lastly, the hub of practice is an example of how circular economy thinking might result in a reconfiguration of organisational delivery systems to improve effectiveness, efficiency and economy, which Jackson (2000) contests are the imperatives of any systems approach.

Keywords: cancer support services, health system, hub of practice, multi-paradigm methodology, physical activity and systems thinking, systems practice.

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