The derivation and use of an optimising parameter for incorporating information into the decision making process

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1 Introduction

Transferring information across the interface between the underlying science (the mathematical descriptions of Nature) and human use of the science in our technologies is shown to be aided by the derivation of an optimising parameter that has its roots in the underlying science. Optimising parameters are a single parameter that captures the full complexity in its value; each computed value capturing only a small part of the full complexity.

Optimisation of our technologies then reduces to the manner of human interaction with the optimising parameter that best meets social purposes. This social purpose can, in the first instance, be accommodated by a correlation between a socially important characteristic (such as odour) and the value of the optimising parameter.

A range of interactions with an optimising parameter are shown to be possible to support different social purposes. Of particular interest is the interaction between the values of a technology's optimising parameter and the cost of manufacturing the resulting technology. This interaction is argued to generate technological niches that are particularly useful for commerce.

The paper finishes by considering the notion of efficiency and how to widen its base to include human sustainability on our planet. For this application, one needs to consider two layers of efficiency. As each technology type can be optimised using the optimising parameter, there remains the question of how to choose between different types of technology. Choosing the best type of technology needs to attach to the pre-technology boundary as this location retains the underlying mathematics but excludes any technology-specific equations. It therefore begins without bias.

As this particular derivation is based around composting human faecal waste, we can ask, and get an answer to, the question: "what is the optimum method for dealing with our waste streams?"

2 Background

The case for the development of an information processing architecture composed in part of *Information Processing Structures* (Structures) is argued in Chapman (2013). These Structures are information-rich mathematical formulations built using bottom-up modelling from the chemistry conjunction (Chapman, 2010).

Given that any technology has multiple social roles to satisfy such as:

- Purpose for its development (treating our waste streams in the case of sewage).

- Performance characteristics.
- Manufacturing cost.
- Necessary social functions (pathogen control, odour free, social perceptions etc);

Then the issue needing to be solved is a boundary condition between Nature and human use of Nature; necessitating taking information from many sources, some of which are not mathematical.

A successful technology will satisfy all of its multiple human roles while using Nature's services at least cost.

As Nature is neutral in terms of human use of Nature in our technologies, and has been mathematised, then there is a need to consider the social mechanisms by which we can use these mathematical Structures to develop better technologies. In this space between Nature and human use of Nature, Nature can be captured using the Structure detailed in Chapman (2013), leaving the task needed for development of our technologies in the manner of our interaction with this Structure.

One such approach to a Structure is the existence of the Beacon. The Beacon is a theoretical technology that is sustainability perfection (Chapman, 2015). Such a technology is unable to be manufactured, but can be used in an aspirational role by commerce and councils.

However, commerce's role in society necessitates a degree of pragmatism as a 'perfect' technology that is prohibitively expensive will not be a commercial success.

The question for this paper is how using a Structure can assist commerce to move towards more sustainable technologies. To this end, the mathematical Structure can be extended to the technology's container by using the purpose to determine a suite of technology-specific equations (Figure 1).

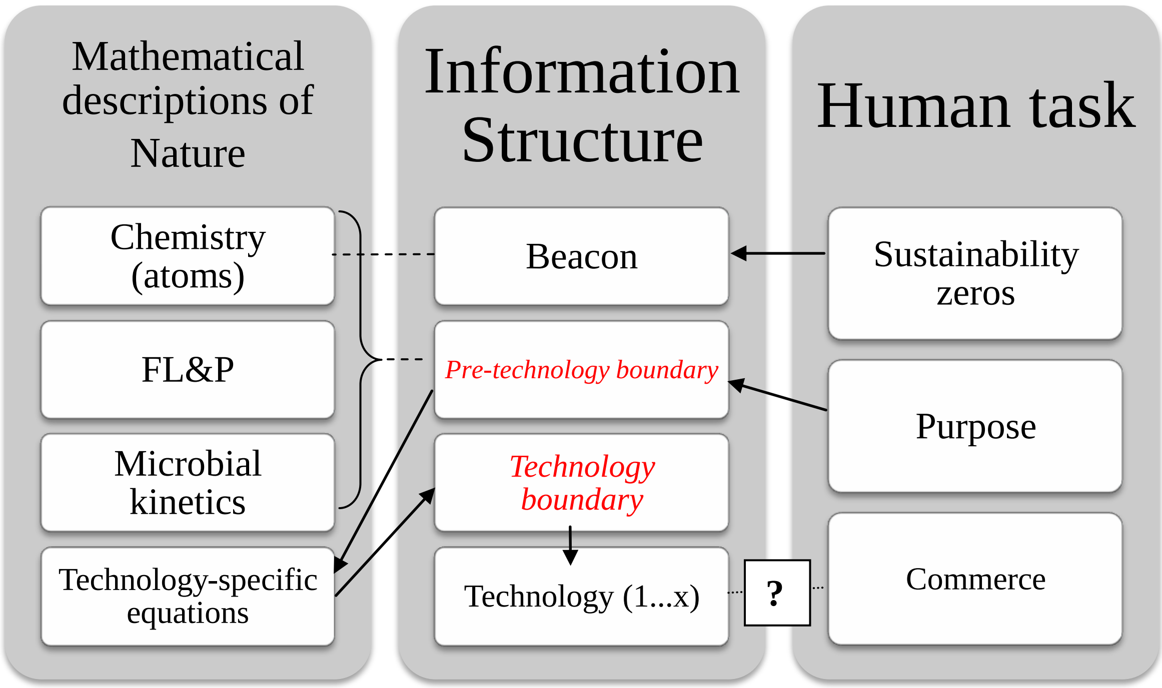

Figure 1 – Using purpose for selecting a suite of technology-specific-equations that enables the boundary of the *information processing structure* to capture the behavioural characteristics of the technology. The question for commerce in developing technologies that utilise Nature is accessing the technology-specific sets of equations within the mathematical Structure.

In effect, this is making the mathematical boundary the same as the physical boundary of the technology – we form a 'virtual' technology. The mathematics however, insists on **all** parameters having a value so using this 'virtual' technology necessitates identifying all those effects that cross this boundary. These parameters have real-world equivalents such as: temperature, oxygen, substrate, container size, level of use etc) so this boundary also coincides with where many of the measurements would be taken to determine the success of the technology, and consequently where commerce needs to make decisions before proceeding to designing a technology.

As the equations can exist without the necessity for a value to be set for any parameter, this conveniently separates the biosphere from human use of this biosphere. For example, Chapman's (2008) assemblage for the 3-phase system called composting could apply to any combination of different sizes and types of particles, in any sized container for which any aeration regime could be used (the model only requires a value for oxygen concentration at the particle surface – how this value is set is a detail of the technology design and how the technology is used in its particular location).

The optimising parameter sits between this suite of equations and commerce's use of these equations. The ideal optimising parameter has roots in the mathematics of the information Structure enabling it to respond to any element of design, operation or use of the technology, but also has strong linkages to the social domain.

This social domain linkage can be in the form of a correlation.

3 Optimising Parameter for compost toilets

The primary social impact needing to be minimised is odour production. The microbial world produces the most obnoxious odours when there is no oxygen available to access the energy needed for growth. If oxygen occurs in the *aerobic* parts of the pile then these odours originate primarily in the non-aerobic (1-aerobic) parts. Aerobic proportion of the pile (Φ_pile) therefore is negatively correlated to the odour production potential. Φ_pile is a single parameter based entirely in the underlying mathematics and consequently influenced by the full range of variables that impact on a technology which uses composting. As it is computed, Φ_pile is infinitely variable between 0 and 1.

If we roughly divide the aspects involved in technology choice surrounding a compost pile into engineering aspects and biological/management aspects, then the engineering aspects include things such as:

- Container design.
- Aeration regimes.
- Temperature modification.
- Particle size etc.

And biological/management aspects such as:

- Loading rates.
- Mixtures of different particles.
- Moisture content.
- Management regimes etc.

There are emergent properties from the interaction of these aspects. For example, a chain of events that could arise from adding a non-degradable bulking material is:

- Free Air Space modification; and/or
- change in energy density at the pile scale; and consequently an effect on
- diffusion into the pile; and consequently
- oxygen distribution in the pile; and consequently
- aerobic proportion of the pile (Φ_pile).

Repeat above for other chains of events, either engineering or biological/management and aerobic proportion also changes. No change in design, change in management or usage pattern, or different climate would generate the same value in Φ_pile (it is possible, but extremely unlikely as the calculation can go to as many decimal places as necessary). We would always be able to say whether the change was beneficial or not. We would also be able to track the effect of the change over time, by calculating a moving average Φ_pile. For example, a high level of use over the weekend followed by a 5 day rest period may result in an acceptable Φ_pile for the whole week.

Aerobic proportion is an information-rich parameter with considerable potential to guide technologies to achieve social goals.

It is eminently suited for use in the engineering profession, for example:

- Consider the notion of an engineered maximum. If there were no limits to the technology design then one could aim for a maximum Φ_pile and this would have optimum performance. It would be a good engineering solution. This exercise would identify the optimum *combination* of macro and micro-scale parameters; diffusion into the particle would be balanced with diffusion through the pores. This may extend to insights regarding optimising operating conditions (temperature, aeration regimes, bulking material etc.).
- Compare different design strategies to find the best one based on maximum Φ_pile.
- Use a Φ_pile range to aid technology choice and implement desirable ones:
    - Identify major design strategies that achieved close to maximum Φ_pile. These could be encouraged – useful at the industry/institutional level.
    - Identify design strategies that are fundamentally flawed (those with a low Φ_pile). These could be actively discouraged.
- Determine a design's overload point by calculating a level of use that would result in some predetermined Φ_pile. That is, use a threshold based on the lower limit of acceptable Φ_pile. This is a better way of determining the overload point than Chapman's (1993) proposal, as it includes all aeration sources. These are more than the pile surface as it also includes: side walls, changes in pile composition, moisture content changes etc.

Φ_pile therefore is a useful parameter for entering the social sphere via the engineering discipline. However, the level of precision of Φ_pile in the modelling context vastly exceeds the variability in the input material. In particular, the calculations require a particle diameter, as particle size has a significant effect on the composting time course (Chapman, 2008). It is unlikely, in other than a laboratory setting, that the actual particle size would conform to this level of precision.

This variability in the substrate input may swamp any attempts to design for optimum. With variable inputs, a conservative approach to design is required and this would not need the precision advocated here. However, other technologies can be attached to the main technology to reduce this variability with detectable impacts on Φ_pile. Mechanisms whose task is to 'prepare' a substrate for composting can exist between the raw material and the composting pile. The main task being to make even sized and well mixed particles. The reduced variability in input material would have downstream benefits in terms of predictability of performance.

With the large quantity of information embedded in the optimising parameter, social processes can use this parameter to move towards the notion of an *optimum* social and environmental technology – a tension can be generated between where we are and where we could be. This is significantly different from a technology meeting some minimum standard, and potentially much more useful.

3.1 Other elements of a technology's social interface

The optimising parameter contains one element of the social interface – albeit an important element such as odour production in the case of composting. However, having a physical boundary to a technology enables other elements of the interaction with social systems to be quantified. This potential arises from locating the virtual technology boundary at the technology boundary. The technology (and its virtual equivalent) can be treated as a contained system meaning **all** inputs and outputs can be quantified and this measure used in the social context.

For example, with a faecal waste system under the sustainability banner one could:

- Constrain the engineering design to minimise the inputs, such as:
  - Energy consumption.
  - Water requirement.
  - Bulking material.
- And/or minimise the outputs:
  - BOD_5
  - Odour.
  - Pathogen count in material exiting the chamber (useful for disease risk assessment).
- Or use emergent properties from these inputs/outputs for other assessments for example:
  - Nutrients, carbon and their recycle potential, by considering transport costs.
  - Disease mitigation by including vector risk with pathogen count.
  - Disaster effect mitigation by combining pathogen outputs with dependence on the integrity of other utilities e.g. water, electricity and sewerage systems.

Other socially desirable benefits arise such as:

- Prioritise the constraints for the local environment. A system adjacent to sensitive receiving waters would clearly put nutrient recovery as a priority and this priority would differ from the community with a shortage of water.
- Manufacturer's performance claims can be scrutinised and challenged if they don't measure up. The linkages to fundamental science provide a useful counter measure to industry PR.

3.2 The commercial element of the social interface

Consider the ecological notion of a niche for any particular design. In the ecological context a niche is the set of environmental conditions to which a species is adapted to. In the case of a *technology*, the niche is the set of social/environmental conditions a technology is designed for. In this case the 'technology' is the 3-phase system with a surface, known as composting, and used in a compost toilet technology.

For each set of social conditions there will exist:

- Usage patterns (seasonal, weekly, steady, high/low).

- A performance threshold specific to the social location (a tramping hut will have a different threshold to a family home). This threshold is likely to differ due primarily to cultural expectations and building design – toilets are typically outside the hut in the case of the tramping hut.

And environmental conditions such as:

- Certain site characteristics which include:
    - Climate (temperature, solar radiation).
    - Location (particularly whether the site is exposed to, or insulated from, the climate).

For any social setting there will exist a minimum Φ_pile that will perform acceptably; it will serve the requirements of the social threshold.

This particular social setting will occur in a certain location, for which the climate is a dominating influence on composting; as temperature plays such a significant part in composting. Consequently, for each *combination* of social and environmental conditions, there will exist a design that will perform to this minimum Φ_pile. Change the combination of social or environmental conditions or the minimum Φ_pile and a different design may be needed. The term 'may be needed' reflects the fact that while a science based design may indicate a different design, in reality there would only be a limited number of different manufactured designs and each design would service a range of social and environmental conditions.

It follows, that when we can determine a design's performance with high precision, then we can respond to different social and environmental conditions with different designs. For example a holiday home with intermittent high use may accept a drop in performance (lower Φ_pile) during these high use periods knowing that recovery can occur in the intervening periods.

Manufacturing a technology will have a cost. This manufacturing cost will then be assessed in the wider social context i.e. is it affordable. We have two important elements in a technology's interface with social systems:

- The technology, its cost and performance. As engineering complexity is likely to be highly correlated to Φ_pile, then performance has a similar correlation to its engineering complexity and consequently cost. Cost therefore has links to the fundamentals, and the social and environmental conditions, albeit not necessarily as strong a link as a strictly scientific perspective would prefer.
- Affordability in the social context.

Producing a range of designs, with attendant range of costs that can then match affordability with meeting performance expectations would seem to be a highly desirable outcome of being able to predict performance accurately. This would enable a minimum cost design to be used that would meet the performance expectations.

Cost is an important component of the social use of any technology; it is therefore potentially useful as a means of linking the fundamentals to social function. But this will only occur if there is a minimum performance expectation set by the fundamentals (via Φ_pile in this case), which is then incorporated into the design. The engineering solution occurs within the limits set by the minimised Φ_pile and any other social constraints (e.g. energy and water consumption), while the cost of this solution determines its commercial success. This balance can guide the technology towards serving its social function. Indeed the wealth of the society in which the technology is used can enter deliberations as the cost is related to Φ_pile, so a social choice can be made as to where on the cost/performance continuum a particular society wishes to place itself.

There is a down-side to having flexibility in determining an acceptable Φ_pile. Any industry would lobby to set this parameter at the maximum profit point. Venting odours (arising from a low Φ_pile) is likely to be cheaper than improving the design and hence the technology produced by an unconstrained industry (even using the scientific linkages detailed here) could differ from that which society may deem suitable. Divergence of the two optimums is possible as a vented odour is likely to detrimentally impact on one's neighbours who have not played a part in the commercial decision; making these impacts external to the commercial process. Mechanisms to keep these two aligned are required.

Fortunately, a vehicle is available by which the social optimum may be advocated. Considering the close negative relationship between Φ_pile and odour production, in conjunction with odour being the most likely social impact of significance, then excess odour can be simply controlled by raising the minimum Φ_pile. The power imbalance may not be such a problem, although 'acceptable odour' may not be easily quantifiable.

Cost and reliability issues also arise in the social adoption of any technology (cheap and nasty). It is possible for a design to 'appear' to include all the necessary elements, but if those elements do not perform their task reliably then the design will fail. Reliability can have two separate elements:

- Conceptual reliability. For example forced air would *appear* to eliminate the effect of diffusion in the pores and hence free-air oxygen levels could be used as the boundary conditions for the particle. However, this assumes plug flow through the pile and if this assumption is not valid then the whole concept would need scrutiny. It is likely to be some combination of plug flow through macro-pores and diffusion in micro-pores.
- Technical reliability. The concept remains unchallenged with poor technical reliability; find a better engineer or manufacturer.

3.3 Incorporating other elements

There are elements of a pile's performance which are implicit in Φ_pile, but may need to be explicitly accounted for in technology design.

- Moisture content is easily measured; there can be too much or too little, so it appears to be a significant parameter. However its impact is expressed through other fundamental elements such as particle size and pore size filled with water. Consequently, moisture content affects Φ_pile only indirectly. It does not appear as a computationally visible component, yet it constitutes an important element of design.
- Lack of adequate management by the user of a poorly performing compost toilet has been used by manufacturers to avoid scrutiny of their design. The approach advocated here enables scrutiny of the *actual* effect of management actions; their proportionate contribution to the success (or otherwise) of composting can be made explicit. A poor design needs to be seen as a poor design for commerce to act most effectively.

4 Efficiency

The notion of efficiency is widely used in modern society, but the base on which the use of the term rests is often less than obvious. Efficiency is outputs divided by inputs with no allegiance to any particular set of parameters, discipline or context.

If we were to widen the notion of efficiency to include human sustainability (or ecological footprint) on this planet then the most *efficient* technology is likely to fill all of the following:

- Least resource consumption
    - Water
    - Energy etc.
- Least environmental impact
    - Nutrient recycle potential
    - Carbon (particularly methane) considerations
    - Pathogens etc.
- Satisfy all of its social tasks.

Due to the quantification that is possible when using the underlying science (Section 3.1) then a mechanism exists where the notion of efficiency can have a *very wide base* firmly rooted in the social context, yet retain linkages to the fundamental laws and processes. All of the above can be included in the assessment.

Embracing this level of complexity necessitates mechanisms other than an optimising parameter as one cannot assume any technology-specific sets of equations. In effect optimisation at this level needs to use the pre-technology boundary of Figure 1. The result of this 'first question' then determines the *purpose* which can in turn be used to determine the suite of technology-specific equations. The *type* of technology that best serves this purpose (which includes human sustainability on this planet) can be identified.

One could view this as two layers of efficiency:

- Using the pre-technology boundary and the purpose (assumed to be human sustainability on this planet) determines the *type* of technology that achieves the purpose. This in turn enables the technology-specific suite of equations to be assembled; in effect extending the FL&P to the technology boundary. When this first question is resolved for the best type of technology then:
- For each *type* of technology there would be a design that would achieve the minimum requirements for the particular social/environmental context – an optimum (most efficient) design. Using the optimising parameter facilitates locating this optimum within this type of technology.

This is a wider notion of efficiency than that commonly met in the economic, business and engineering spheres, as it includes all of the disciplines and a wee bit more.

In the wastewater industry for example, there are two types of technologies: those that use water as a transfer mechanism (the flush toilet) and those that require no flush water. The flush toilet is the incumbent technology and consequently has both economies of scale, and a cultural dynamic that resists scrutiny of its adequacy. Yet in a world experiencing a shortage of water, having difficulty finding energy sources that do not have long term environmental consequences and the need to produce food for an increasing population when phosphate availability is emerging as a future issue; surely needs to scrutinise the adequacy of the flush toilet.

The flush toilet fails on most of the sustainability criteria (water use, nutrient recycle, and energy) so the focus needs to be on other types of technologies.

Using the logic based analysis discussed above the most *efficient* type of technology for human sustainability can be identified independently of sewerage's lengthy cultural and commercial history. The most 'efficient' can then be given due weightings in the political/institutional structures. For human faecal waste disposal, we surely have thoroughly explored the consequences of moving towards the least cost (for which dumping raw sewage into a river is by far the cheapest method of disposal – especially if you can avoid having to pay for the health costs of people living down river). The history of sewerage is littered with many unsavoury examples of this and the reluctance of the institutions to change their stance even in the face of overwhelming evidence (Benidickson, 2007). In this history, the absence of these institutions asking the basic question as to whether a water-based system is necessarily the optimum starting point is surely evidence of the need for an assessment basis that is largely free from these institutional biases.

Readers interested in further debate around this higher level question may like to read a different approach to this question in Chapman (2015).

5 Conclusion

Substantial information can be incorporated into an optimising parameter. When such a parameter is used in decision making, then this information is incorporated into the decision and the 'quality' of the decision is enhanced because of this information.

As the value of an optimising parameter captures all of the information relevant to the system performance, then any technology that uses its contributing parameters (composting in the case discussed here) will be somewhere on the optimising parameter's continuum. The optimising parameter in effect 'carves' a path through the system complexity on the back of the fundamental laws and processes.

Choosing an optimising parameter that is significant to the technology's performance (such as the inverse relationship between odour and aerobic proportion in the case of composting) generates an output that both: occurs on a continuum and is useful for assessing the technology's performance in the social context.

Social (and commercial) processes are not excluded by this formulation, rather they determine where on the continuum the calculated value of the optimising parameter will be. This attribute increases the optimising parameter's versatility as it becomes possible to choose the manner of the interaction to best serve the needs. The output resulting from this interaction can be used to satisfy social goals, such as:

- A minimum (or maximum) value represents the theoretical optimum; where the technology's performance is limited only by the fundamental laws and processes.
- A relative difference can be used to compare two competing technologies – better performing designs can be compared to poorly performing designs.

- Minimum performance standards equate to a fixed value on the continuum. However, minimum performance standards are only one point on the continuum, albeit a socially informed point.

The direction in which the technology can be improved becomes visible as by using two calculations that cover the effects of any proposed improvement it can be determined if the change would be closer to or further away from the theoretical optimum. The limits arising from engineering, technology or economic constraints can be scrutinized as to whether they can be easily transcended.

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