On Metabolic Complex Networks for Entropic Robust Autonomy

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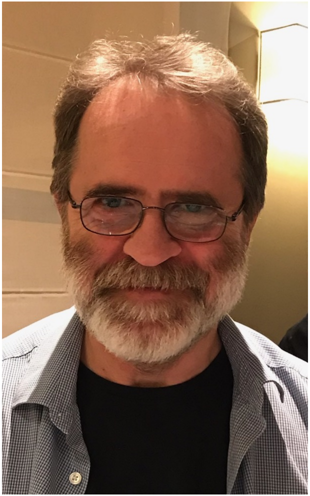

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1. Introduction

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- can function without external support

1b. Metabolic Systems (MS)
- can handle perturbations

1c. AS = MS
- can function without ext. support—despite perturbations
- can handle perturbations—and function w/o ext. support

1a. Autonomous Systems

an *autonomous system* is a system that can keep working without external support while maintaining (and possibly modifying) its structure, functions, capabilities and behaviours in order to reach its goals

1b. Metabolic Systems

metabolism is understood as a set of life-sustaining activities (including all chemical reactions) in biological organisms

in a more abstract (non-biological) settings, it can be understood as a set of activities that allow the system to continue functioning (cf. city's metabolism)

a metabolic system is capable of detecting and handling perturbations, and maintaining its homeostasis (the state of dynamic equilibrium)

it can be claimed that the essential property of an autonomous system is its ability to handle perturbations

1c. Autonomous Systems = Metabolic Systems

- autonomous systems:
  can function without ext. support—despite perturbations
- metabolic systems:
  can handle perturbations—and function w/o ext. support
- autonomous systems must be able to handle perturbations, and are therefore metabolic; hence, AS $\subseteq$ MS
- metabolic systems are autonomous w.r.t. the goal of continuous functioning; depending on how they function, they can be autonomous w.r.t. producing and consuming energy, or w.r.t. fuctioning correctly as a socio-technical system in real world settings (possibly processing intentions, influences and ethical norms);
  hence, MS $\subseteq$ AS
- hence, MS $\equiv$ AS

2. Metabolic Systems

2a. Complex Networks (CN)

- complex systems (systems with complex behaviour)
- complex networks are models of complex systems
- complex behaviours in complex environment
  complex env.: dynamic, partially observable, uncertain
- complex env. $\rightsquigarrow$ perturbations

2b. Metabolic Complex Networks (MCN)

- complex networks that can handle perturbations
- a metabolic complex network follows the path:
  - perturbation
  - detection of “out of dynamic equilibrium” state
  - catalysts
  - homeostatic (or allostatic) control mechanisms
  - move to the old (or a new) “dynamic equilibrium” state

2a. Complex Networks (CN)

- complex networks are models of complex systems
- complex networks are neither random nor regular, complex networks exhibit non-trivial behaviours
- examples:
  - the internet
  - protein interaction networks
  - transport networks
  - foodwebs
  - social networks

2b. Metabolic Complex Networks (MCN)

- complex networks that can handle perturbations
- an example of a metabolic supply network
  - an unusual flow *perturbs* the supply network
  - the network's node can *detect* that it can't be *effective* w.r.t. the flow
  - the flows are matched to the network's capabilities; the matching process is the *catalyst* that facilitates effectiveness/efficiency
  - *homeostatic/allostatic control mechanisms* modify the flows, modify nodes/links' capabilities, modify the topology
  - the network functions in an *equilibrium* state of maximised effectiveness/efficiency

3. Ontologies / Conceptualisations

1. metaphysical level (of processes and spacetime regions)
2. Dennett: physical level
3. Dennett: design (or functional) level
4. Dennett: intentional (or attitude) level
5. metabolic level (of systems handling perturbations)

3a. Dennett's Intentional Stance

- Dennett: physical level
- Dennett: design (or functional) level
- Dennett: intentional (or attitude) level

The *intentional stance* suggests that we should analyse systems at different levels of abstraction: at the *physical level* (using the language of physics, and physical properties/relations), at the (more abstract) *design level* (using the language of biology and engineering, and analysing the system's design), and at the (more abstract still) *intentional level* (using the language of attitudes, ascribing beliefs and intentions to the system).

3b. Intentional Stance Extended

- metaphysical level (of processes and spacetime regions)
  - *process philosophy*
  - Allen's *temporal algebra*
  - Region Connection Calculus (qual. space), qual. orient.,. . .
- Dennett's Intentional Stance / physical level
- Dennett's Intentional Stance / design level
- Dennett's Intentional Stance / intentional level
- metabolic level (of systems handling perturbations)
  - perturbations
  - detections and measures (perturbations detected)
  - catalysts
  - homeostatic & allostatic control mechanisms
  - dynamic equilibrium states (equilibrium maintained)

3b. Intentional Stance Extended

A brief history of the work on conceptualisation:

P D I	Dennett's conceptualisation
M P D I S	adding *metaphysical* and *social*
M E F I S	renaming: *environmental* and *functional*
M E F I S 2	the Mephisto conceptualisation
M E F C S	renaming: *cognitive*
M P D I S	back to Dennet's *physical* and *design*
M P D A	collapsing *intent.* & *social* into *attitudes*
M P F A	back to *functional*
M P F I	using *intent.* for (social) agents' attitudes
M P F I M	adding *metabolic*
M P D I M	if *design* is used instead of *functional*
M P F I M	preferred (*funct./design* & *intent./attitude*)

4. Measuring Functioning Systems' Performance

- curvature: communities have *positive curvatures*
- topology: better connected networks are better
  topology: better connected networks are worse
- dynamic topology: the network topology changes
- network properties: capabilities of nodes and links
  (nodes/links' capab. influence the system's capability)
- system variables: maximising effectiveness/efficiency
  (desire to be *effective/efficient* determines the behaviour)
- dynamic network: topology & nodes/links' capab. change

4. Measuring Functioning Systems' Performance

How to *measure* how well is the system *functioning?*

- community formation: the network's curvature increases (see Section III (and Section I))
- flow maximisation: adding links makes the network better (see Figure 5 and Section IV-A (first half))
- network optimisation: arbitrary attributes can be selected, then networks are ordered w.r.t. that set of FCA attributes (see Figure 6, Section IV-A (second half) and Appendix A) (note that g_4 of Fig. 6 is *not* the top element of Fig. 5)
- network optimisation: select an appropr. set of measures, for instance: select *effectiveness* and *efficiency* (see Figure 7 and Table IV and Section V)
- network, with subnetworks, optimisation: interdependence; optimise subnetworks—and optimise interaction of interdependent subnetworks (see Figure 9 and Section VI)

5. Homeostatic / Allostatic Control Mechanisms

- homeostatic control mechanisms:
  - maintenance of body's temperature
  - maintenance of blood glucose levels
  - maintenance of supply chain networks
  - energy supply and maintenance
  - water regulation
- allostatic control mechanisms:
  - achieving homeostasis
    through behavioural changes

6. Applicability of the MCN framework

- physical systems:
  a *watershed system* (the land drained by a river and its tributaries) can handle perturbations
- functional systems:
  a *water dam system* can handle perturbations, according to its design (intentions are not explicitly represented)
- intentional systems:
  a *goal-oriented ethical agent* would process beliefs/intentions and ethical constraints (for instance, by using modal logics of beliefs and obligations, respectively)
- metabolic systems:
  a disaster relief centre would try to return the affected system back to its normal state; but the centre itself can be further perturbed when it encounters multiple disasters (earthquake, tsunami, flood, fire & biol./chem. contam.)