DESIGN CYBERNETICS AND CAAD RESEARCH

Aspects of our shared interests

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Abstract. In this paper, we offer an overview of several aspects of cybernetics that are relevant to CAAD research. We present key cybernetic ideas, the development of the field and its relationship to design research, followed by a brief mapping of eight intersections between cybernetics and CAAD, covering design cognition, design computing, design process, design management, design production, design outcomes, design research and design values.

Keywords. Design cybernetics; systems; interdisciplinarity; CAAD research; metaphor.

1. Introduction

Half a century ago this year, Gordon Pask proclaimed “the architectural relevance of cybernetics” (Pask 1969). Cybernetics as a discipline had emerged a few decades earlier during and after World War II. Propelling – and propelled by – technological advances of “scientific” warfare for example in cryptography and missile guidance, cybernetics became known as the science of “communication and control” (Wiener 1948). By the mid-twentieth century, its focus on technology and rational determinism rendered cybernetics a prototypical, dominant paradigm for various areas of science, engineering, social science and governance. Cybernetic thinking in these fields was technical and, in one way or another, based on the idea of the closed technical control loop between a sensor and an actuator. Cybernetics also became closely associated with computing, especially of the digital kind. This is, amongst other reasons, because the universal machine computer lends itself as a tool for symbolic modelling and control systems, and because key originators of digital computing, including Alan Turing and John von Neumann, were also key figures in cybernetics. Many founders of the discipline, including Norbert Wiener, Margaret Mead, Gregory Bateson, Heinz von Foerster, Warren McCulloch and Ross Ashby, however, were more concerned with the intricacies of living and social systems than with technology per se. They tended to consider and to build technical and computational systems as metaphors to illustrate or model behaviours of higher organisms.

Design research, likewise, emerged from the application of “scientific” methods to the pressing problems of World War II, alongside operational research.
methods and management decision making techniques (Cross 2006, p. 1). Like cybernetics, design research would develop the status of an academic discipline in the decades that followed. Design research and cybernetics began to engage with one another when Ashby’s (1957, p. 121ff) notions of variety and constraint were first used to describe the design process. Ashby had introduced variety as a quantitative measure of the number of states systems may assume, whereas constraints are limitations on variety. These concepts and their application to the design process are discussed further in section 4 below. Independently, these cybernetic “sparks” jumped from cybernetics to design research twice: once in the work of Gordon Pask (1961) and once in the work of Horst Rittel (Protzen and Harris 2010). Various lines of design cybernetic thought have developed since then, to coalesce in recent years under the umbrella of Design Cybernetics (Glanville 2007, Fischer and Herr 2019).

In the 1970s, cybernetics underwent an extension from its early focus on technical systems (“observed systems”) to a broadened attention to “observing systems” (Varela 1984, p. xviii). Having embraced circular causality already with its early interest in technical control loops, cybernetics now also acknowledges the notions of observer-dependence and non-determinability, thereby departing yet further from conventional natural science (Dent and Umpleby 1998). Within the field, this expansion from so-called first-order cybernetics to the less orthodox second-order cybernetics is understood as an unfinished revolution (Müller and Müller 2007). Meanwhile, design research focused on design methods in the mid-twentieth century, but soon abandoned this focus for being too simplistic and mechanistic (Alexander 1984, pp. 312–313). It underwent a transition from “first generation” to “second generation” design methods, which recognise that design problems are observer-dependent with problems and concepts of their solution are circularly interdependent (Rittel 1984, p. 321).

From the design cybernetic viewpoint, cybernetics and design research share a key commonality: a concern for process and performativity in time. This sets both cybernetics and design research apart from natural science and its basis, formal predicate logic, whose arguments conclude in atemporal terms of truth and falsity (Bateson 1979, p. 117). As will be detailed below, the temporal, performativistic perspective of design cybernetics manifests itself in various aspects of CAAD. These various lines of design cybernetic thought are, however, not yet uniformly recognised in the CAAD discourse. CAAD literature presently tends to focus on two aspects of design cybernetics, which descend along two lineages of thought from Pask’s and Rittel’s aforementioned early adoptions of variety and constraint: In the Rittel-tradition, this is an interest in design as open-ended and “wicked” as opposed to “tame” (Rittel and Webber 1973, pp. 160ff) and in the design process as an alteration between variety amplification and variety reduction (Protzen and Harris 2010, p. 107). In the Paskian tradition, this is an interest in cybernetically (computationally) enhanced design outcomes such as the homestatically or non-deterministically adaptive architectural designs of Cedric Price, to which both Gordon Pask as well as Julia Frazer and John Frazer have been consultants (Frazer 1995).

To offer CAAD researchers a more comprehensive introduction to the overlaps
and shared interests between cybernetics and CAAD research, and to facilitate cybernetically informed CAAD research, we offer in the following an overview of the relevance of cybernetics from several CAAD perspectives.

2. Cybernetics and design cognition

Cybernetics has grown beyond its early focus on simple feedback loops that exercise technical control to loops that include the observer, who, as a self engages others in “conversational” loops of acting and understanding (Glanville 2014). This extension of cybernetics is retrospectively described as the transition from first-order cybernetics to second-order cybernetics. An important milestone in this transition was the Conversation Theory by Pask (1976), which Glanville and others developed into today’s design cybernetics (Glanville 2007, Fischer and Herr 2019). As in everyday conversation, “conversants” engage in circularly-causal back-and-forth to soon arrive at subjects and points that moments ago were unanticipated. Conversation is a prototypical notion of epistemic practice through which we arrive at the previously unknown, and which unifies the processes that are of central concern to CAAD: learning, researching and designing.

Radical constructivism, a close relative of second-order cybernetics, assumes that we construct subjective realities. This view does not rule out the possibility of sharing a found reality as such (in other words: this view is not solipsistic). It simply avoids epistemological claims that cannot be rigorously justified from within systems whose experiences are entirely mediated along neural pathways, with any attempt at testing the faithfulness of neural mediation, in turn, being dependent on neural mediation. This avoidance of difficult-to-justify epistemological claims is of particular value in developing and defending academic theses in the view of adversarial rigour. In the second-order cybernetic and radical-constructivist view, cognition is the process of “computing a reality” (von Foerster 2003, p. 215). Here, the term computing is not used in the narrow sense of symbolic processing by machine, but in the sense of concerted (lat. com) contemplation (lat. putare). Realities, in this view, are subjective descriptions, whereas “description” is understood in the sense of embodied performance, not in the sense of symbolic representation (Segal 1986, p. 83–109).

From within a subjective reality, engaging with anyone or anything else, it is virtually impossible to match their reality exactly, to have the same number of possible states, i.e. in cybernetic parlance, to achieve requisite variety. Requisite variety, the same number of states on both sides of a feedback loop, however, has been identified as a necessary condition for effective control (Ashby 1957, pp. 206ff). Hence, our every-day engagements with others (including imagined others, technology, pen and sketching paper etc.) are, in the absence of requisite variety, by definition out-of-control (Glanville, unpublished). This is why conversation can take us to the as-yet unknown, the new – be it the new at the individual or at the social level (Boden 2004, p. 43). Differences between self and other, and noise on the channels between them are therefore, from this perspective, not nuisances to be minimised and avoided but potentials to be pursued and valued. Self finds herself in out-of-control engagements with others, challenged to expand her own variety to accommodate (construct concepts of) the encountered as-yet-unknown.
Her reality is thus in a state of constant expansion (Glanville 2009, p. 122).

3. Cybernetics and design computing

Cybernetics is commonly associated with computing, as is evident in the general association of the prefix “cyber” with all things digital and online. Indeed, cybernetics and computing grew up together, with each depending on the other, and the development of both analogue and digital computing machinery owes much to cyberneticians such as John von Neumann, Norbert Wiener, and Alan Turing. Different basic blueprints for computing machinery are referred to as “computer architectures”, whereas CAAD investigates the application of computing machinery in the processes of designing and operating built environments, i.e. “architectural computing”. In *cyberspace* (Spiller 2002), interest in computer architecture intersects with interest in architectural computing.

According to the linear, syllogistical thought patterns engrained in modern culture and formal science, the computer is often thought of as a linear system that takes input and processes it into some output. In the cybernetic view, however, with its particular interest in the relationship between man and machine, computing is considered a circularly-causal activity that involves an observer, as Bateson (1972, p. 317) points out: “The computer is only an arc of a larger circuit which always includes a man and an environment [...]”. Winograd and Flores (1986), accordingly, present a view of computing that is based on the notion of *structural coupling*, focusing on the relation between systems and their environments. Design computing investigates both human-machine design interaction that harnesses the variety-generation capabilities of the computer (Chan et al. 2001) as well as use interaction with digitally enabled adaptive built environments. These areas of shared interest are further described in Sections 4 and 7 below.

4. Cybernetics and the design process

Concerned with processes of navigation towards (as well as with the negotiation of) goals, cybernetics has much to offer to the study of design processes. As widely agreed in current design research discourse, designing can be characterised as a circular process generated by recurrent feedback loops. This circularity allows for ongoing reflection and adjustment throughout the design process, and results in unpredictable dynamics: the outcomes of such processes are not determinable from the outset and are often considered surprising and innovative. Conversation Theory (Pask 1976) describes circular exchanges along paths of alternating amplification and reduction of variety as a way of enquiring, developing shared understanding and reaching the new. Characterising the circularity of sketching as reflective conversation with a situation, Schön (1985) developed a theory of architectural practice and education that employed concepts from both cybernetics and constructivist theory. The “reflective practice” model offers an alternative to the rationalist focus on linear problem solving that Schön saw as inadequate to describe design practice. Building on Pask’s work, Glanville (2007) describes the design process as a cybernetic activity, where
cybernetics is understood as the theory of design, and design is understood as the practice of cybernetics. Glanville’s cybernetic account of designing shows how conversational exchanges can create novelty from differences in understanding among conversation participants. Design conversations with others can take place between human conversants, but may also involve exchanges with objects and imagined or virtual others.

In the cybernetic view, novelty-generating processes are of a circular, open-ended, conversational nature, and grounded in differences in interpretation among conversation participants, such that newly arising interpretations can offer insight, surprise and delight. These characteristics distinguish design processes from the kinds of processes which limit feedback loops to the enactment of narrow sets of predetermined choices and options. While ‘error’ and misunderstanding are regarded as problems to be avoided in other areas, they are recognised as endemic and fostered as stepping stones towards the previously unknown in design conversation (Glanville 2007, p. 1181). The surprising, variety-amplifying quality of design conversation is referred to, in cybernetic parlance, as interactive. Interactive technologies in this sense are referred to as media and distinguished from pushbutton-responsive, predictable tools: “A medium is a tool that kicks back” (Glanville 1997, p. 48). This distinction is of broad relevance to the field of CAAD research, where digital design support during the early, novelty generating stages of design remains an important area of interest. Key strategies by which digital technology engages in variety-amplifying conversation are by generating options for designers to choose from (based typically on the re-combination or geometric transformation of design elements) or by being creatively re-appropriated (Glanville 1992, Fischer and Herr 2007).

5. Cybernetics and design management

The cybernetic perspective on management extends the scope of management strategies beyond linear problem-solving approaches. Management cybernetics recognises that organisations are typically involved in two kinds of feedback processes, pursuing the parallel goals of maintaining stability and at the same time adapting to changing contexts. Management cybernetics fosters this balance by examining and organising circular feedback loops to encourage processes of self-organisation. To this end, Beer (1972) proposed the Viable System Model as a conceptual tool that allows the assessment and structuring of recursive processes within an organisation with a view to the longevity of the system, and without resorting to centralised control. Beer emphasised the necessity of understanding an organisation’s status quo as a starting point for any intervention rather than focusing on expectations or presumptions: the purpose of a system is what it does. This approach is familiar to designers who recognise the necessity to adapt to and work with the dynamics of found contexts in order to achieve viable and sustainable results.

CAAD research addresses various aspects of professional architectural practice that are related to management cybernetics, such as collaborative processes mediated by digital tools. A cybernetic perspective introduces a concern for the autonomy of self-organising circular processes and offers models to work
with them. Cybernetic approaches seek to balance the dynamics of autonomous systems with purposeful intentions of steering these systems in circular and interconnected feedback loops. Following on from the Viable System Model, Beer (1994) developed syntegrity, a non-hierarchical process designed to create synergetic processes of shared learning among teams. In CAAD research, similar attention to circular processes can often be found in descriptive studies examining sketching during the early design stages, but less in work focusing on the design of systems for collaborative exchange. While cross-disciplinary collaboration and data sharing workflows facilitated by BIM technology have come a long way to approach the syntegrative management vision, Beer’s proposals for creating viable and sustainable conversational systems remain under-explored in CAAD research.

6. Cybernetics and design production

With advanced digital tools increasingly becoming commonplace in architectural design practice, much recent CAAD research has focused on tools and workflows for design production, ranging from geometry rationalisation to digital fabrication. Cybernetics relates to a broad range of aspects of design production, from deterministic control systems found in artificial intelligence to human- and user-centered participatory systems. Cybernetic approaches typically inform the procedural aspect of design production by offering models and terminology supporting efficiency in realisation on the one hand, and viability in organising processes involving many actors on the other hand. A cybernetic approach to design production was presented by Scheurer (2007), showing how artificial intelligence methods can be employed to organise parametric digital models. In addition, materialisation processes benefit from cybernetic feedback cycles at various stages of the production chain as these processes are not of a linearly-deterministic nature and adjustments are routinely required to deal with constraints as they arise. The cybernetic concept of variety can be employed to describe both linear processes of narrowing down options as well as conversational (design) processes that can both increase and decrease variety. In geometry rationalisation, for example, the process of reducing a large number of options to a smaller number according to given constraints can be framed cybernetically as a reduction of variety. In a broader perspective on geometry rationalisation, Fischer (2012) however also describes such processes as embedded in circular processes of reflection, demonstrating the role of designers and researchers in steering such processes.

Thinking through the framework of variety control makes it possible to determine the nature and dynamics of production processes. Linear deterministic control processes maintain or reduce variety, as for example in digitally controlled robotic fabrication where robotic tools are typically not expected to influence the production in open-ended ways. When circularity is introduced in the form of dialogical exchanges, such processes can potentially generate novelty and surprise. Processes that increase variety are however rare in control-focused digital production and more common in processes that involve human interaction. Design production can be structured to encompass both, as the cybernetics-informed work of Pratschke (2007) and dos Santos Cabral Filho (2013) shows: both
discuss cybernetics-informed processes of architectural production that involve user participation and collaboration.

7. Cybernetics and design outcomes

Throughout their life cycles, buildings, and the products and services they are comprised of, become hosts to various regulatory processes addressing ongoing needs and requirements of both buildings and users. These include, among others, building services and maintenance systems as well as automated capabilities to adapt to changing internal and external conditions. Extending the scale of the classic example for homeostatic cybernetic control processes of the thermostat that keeps room temperature constant, these performative “soft” services, added to “hard” architectural structures, are increasingly important in architectural design and research. While the operation of self-adaptive systems in our built environment has long relied on predetermined thresholds and processes of operation, “smart” buildings are introducing increasingly sophisticated technology to create more efficient and more comfortable environments for their inhabitants. Similarly, façade systems are increasingly conceived as adaptive façade systems that can change their configuration in response to changing environments. Cybernetic frameworks provide a basis for designing the operation of building services and façades as feedback loops in terms of positive (reinforcing) and negative (decreasing) feedback. From a cybernetic perspective, such systems could be designed for increasing levels of independence and autonomy in the future, as envisaged by early cybernetics-inspired architects such as Price (Matthews 2005).

CAAD research proposes a range of technologies for virtual, augmented and networked spaces. These technologies are inherently cybernetic as they involve exchanges between humans and digital tools. From a cybernetic perspective, the performative and procedural aspect could be employed to achieve qualities beyond predetermined interactions, as Haque argues (2007). One example is contemporary media façades, which increasingly populate large areas of urban vertical spaces, but are mostly employed as trivial large display screens (Herr 2011). Suggesting the possibility of expressive interaction between buildings and populations at the urban scale, media façades promise new opportunities for novelty, surprise and delight once opportunities for circular feedback with urban inhabitants are introduced.

8. Cybernetics and design research

As mentioned above, cybernetics departs from some basic assumptions underlying natural science. This allows cybernetics an alternative perspective for enquiry that, rather than proceeding through the natural scientific paradigm, can critically evaluate the natural scientific paradigm. From this perspective, Glanville (1999, p. 88; 2007, p. 1179) rejects the general notion that design is a subset of scientific research. Instead, he argues that science is a particularly constrained form of the more general human activity of designing.

The cybernetic perspective furthermore allows a relative positioning of the
observer, the observed and its description (Fischer 2011, p. 629), which in turn permits the relative positioning of key science-philosophical traditions (pragmatism, idealism and empiricism) and thus of key research agendas (usefulness, meaningfulness and predictability) to offer a theory of enquiry as a methodological guide for CAAD research.

9. Cybernetics and design values

As digital coding determines the performance of computing machinery, so do design processes determine design outcomes. In this relationship between composition and performance, designers make choices on behalf of others. These choices may be restricting or enabling, both in physical as well as in cyberspace. However, designers are typically removed from the situations they shape. This gives rise to a dilemma between competences of users who are situationally aware on the one hand and competences of designers who are professionally trained on the other hand. The fault lines that separate them are the systemic boundaries (Fischer and Richards 2017, p. 37) of design and application contexts. In recognition of these boundaries, cybernetics is deeply committed to the autonomy of others (von Foerster 2003, p. 298) and, therefore, to designing with, as, and “through the eyes of” those designed for. This applies to CAAD research where design tools are developed for others, and to general design practice where built environments are developed for others. Ethical considerations apply at both levels accordingly.

The commitment to the autonomy of others results in a reliance on (and trust in) internal guidance where ethical questions are addressed (Sweeting 2016). This reliance recognises the uniqueness of design contexts, the non-repeatability of design and the absence of clear success criteria (Rittel and Webber 1973). The cybernetic conception of ethics is thus grounded in the subjective responsibility of the self, as defined by his/her systemic boundaries, ascertaining a fundamental individual freedom of choice. Von Foerster (2003, pp. 287–304) argues that this freedom engenders responsibility for one’s choices, such that ethics is primarily addressed to oneself (“I shall...”, “I shall not...”). He distinguishes ethics from morals, which involves instructing others what to think and what to do (“thou shalt...”, “thou shalt not...”). Ethics, therefore, is manifested primarily through action. To help propagate the requisite freedom, von Foerster proposes his Constructivist Ethical Imperative: “I shall act always so as to increase the total number of choices.” (2003, p. 295). Aiming to increase the total number of choices, both CAAD research and cybernetics encourage ways of addressing design challenges that involve open source, collaborative and participatory design approaches. While these may require greater efforts to produce results, these results promise greater viability and sustainability in the long term.

10. Conclusion

In this paper, we have offered CAAD researchers a concise and up-to-date introduction to cybernetics, with a view to its relevance to CAAD research. Previous literature in the CAAD field tends to focus on two particular interactions
of cybernetic and CAAD thought, namely a view on the design process as an alternation between variety amplification and variety reduction, and a view on design outcomes as cybernetically (i.e., computationally) enhanced adaptive spaces. We have shown that there is further shared interest between cybernetics and CAAD in the areas of design cognition, computing, management, production, research, and values. These areas are already frequently discussed or implied in CAAD discourse, but as yet often without consideration of those aspects that tie cybernetics to design while setting both apart from natural science: observer-dependency, circular causality and non-determinability.

References
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