Cybernetic Design Cycles

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Abstract: One fundamental question for 'digital landscape architecture' is: “What are the roles (and pros and cons) of digital approaches in design?” In this paper I describe a simple six-part cyclical framework which may help to locate instrumental digital aspects of design processes in a slightly larger conceptual and cybernetic view.

The cycle is represented on a simple circle, with six nodes: (1) *inhabitation*; (2) *perception/measurement*; (3) *analysis/needs*; (4) *design*; (5) *representation/communication;* and (6) *implementation/construction*. The cycle starts with inhabitation, which leads to perception, needs analysis and design, which is communicated and then built, which changes the world and we continue to inhabit, perceive, analyze, design, represent, and build a new … It is the circular causal relationship that makes this view ‘cybernetic’: having to do with feedback loops in which some action causes some change which causes some action, and so on.

Each of the steps in this cycle, from inhabitation to construction, is colored by and increasingly dependent upon digital technologies, including computation, simulation, visualization, fabrication and algorithmic processes. In the body of this paper I examine each step and its technological needs and opportunities in more detail.

Keywords: Design, cybernetics, cycles

1 Introduction

“Digital landscape architecture” may arguably claim to be over a half-century old this year, as very early roots of it can be traced to 1965 in the Laboratory for Computer Graphics and Spatial Analysis at the Harvard University Graduate School of Design, where researchers and designers seized upon the power of computing to amplify the tasks of gathering and interpreting information about the built and natural environment, collaborating, communicating, and coordinating in design teams and, of course, making representations: mostly maps, charts, graphs, and crude drawings. The power of the tools, and the complexity and sophistication of those maps and drawings, have increased steadily, in some cases exponentially, since those early days, developing into the technology we call ‘GIS’, and have coalesced into the undertaking we now call ‘Geodesign’ – a clear example of “digital landscape architecture”.

For many landscape architects however, the last several decades of digital transformation have primarily been about mechanizing the production of graphics: construction drawings, renderings, and increasingly, videos and multimedia web content. CAD, image processing, and desktop publishing software have today become the standard work tools of the discipline. Ever since “computer aided design” software became available on affordable microcomputers (e. g. AutoCAD on the IBM PC in the early 1980s) there has been a largely unexamined acceptance of the term without much critical examination of the question “How exactly do/might computers aid design?” (Some formerly skirted this issue by referring instead to computer-aided ‘drawing’ or ‘drafting’.) The abilities of digital tools and techniques to mechanize, enhance, and even occasionally automate drawings and graphic representations

Journal of Digital Landscape Architecture, 1-2016. © Herbert Wichmann Verlag, VDE VERLAG GMBH, Berlin/Offenbach. ISBN 978-3-87907-612-3, ISSN 2367-4253, doi:10.14627/537612001.

have indeed been impressive, even if some complaints and concerns may be justified. But my purpose here is to broaden the scope of the question, to “What are the roles (and pros and cons) of digital technologies in design?” In this vein I will first describe a simple six-part framework which may help to locate instrumental digital aspects of design processes in a slightly larger conceptual and cybernetic view.

2 Cybernetic Design Cycles

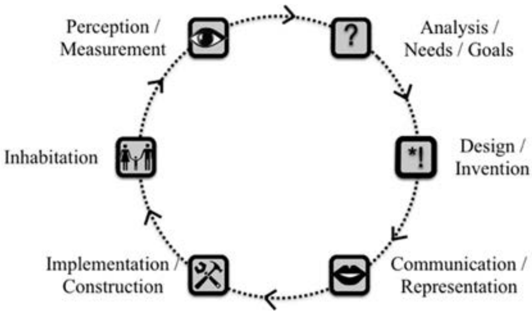

Fig. 1:
6 Nodes on the Design Cycle

The cycle starts on a simple circle, (Fig. 1) a recognition of the essential cyclic nature of so much of human life and effort on this planet. From diurnal to weekly and seasonal, to annual and even longer-term cycles, the world around us and our activities are often regular, recurring, and predictable, even if punctuated by irregular, episodic, exotic, and delightful variations that give life its texture. Design – the complex, and mysterious, but extremely valuable activity by which human beings “take courses of action designed to improve their living situation”, to paraphrase the immortal words of Herbert Simon (SIMON 1969) – defies attempts to characterize its course with simple geometries, regular recurrences, or formulas and predictions; its hallmark is often exactly the unexpected. Nonetheless the broad features of a recurring design cycle, with six major phases, or nodes, is outlined below.

1. We start with the simple fact of living in the world – as individuals, as families, and as societies living in a wide range of circumstances across the natural-to-built, and urban-to-rural spectra. We ***inhabit***: build shelter and use tools, communicate and express, and change, despoil, repair, create and co-evolve with our whole environment – air, water, fire, bricks, glass, politics, music, ideas… The ultimate goal of landscape architecture is to make the world more inhabitable, and hospitable, for all species and generations.

2. As human beings we depend upon our five senses and intelligence to survive and flourish. Our ***perceptions*** guide and color our lives and thoughts. For many designers, visual perceptions dominate, though the tactile and auditory are not far behind. Just as we make tools to add leverage to our physical strength, we devise ways to extend our perceptions: microscopes, telescopes, microphones and loudspeakers… And in so doing, we often engage in ***measurement*** and systems of measurement and description: surveying, geometry, trigonometry, geodesy, are among the many tools for surviving and flourishing.

3. As thinking beings though, we do not just passively perceive, measure, and describe. We necessarily reflect and analyze in order to make sense of our environments, our perceptions, our measurements. This process of ***analysis*** is involuntary in many ways, but often leads to

calculated chains of reasoning, the apprehension of patterns, sometimes of cause-and-effect, and inquiries into questions of “Why?” and “How?”

We analyze perceptions and measurements across time spans and across senses and disciplines, consciously or unconsciously, looking for patterns and trends, from which we learn; and compare what we have experienced with what we want, or need, looking for improvements. We use the tools of measurement to refine our analyses, in a recurring cycle of measuring, analyzing, refining tools, re-measuring, and re-analyzing.

These processes of reasoning, analyzing, and seeking to perceive and to measure are often driven by fundamental ***needs***: we need shelter, warmth, food that is safe to meet and delicious, and so on. As Maslow (MASLOW 1943) described, some of these needs are basic, primitive and physiologic, others may be more like dreams and aspirations, the higher levels of human needs and abilities. In any event this awareness of needs, arising from living in the world, augmented by our abilities, senses, measurements, and analyses often gives rise to a perceived need for some change. Often, our analyses lead to conclusions about some opportunity that might be seized, or some resource of value; often the beginning analysis of simply “What is happening?” leads to the question: “What is needed, or what might be improved?”

4. And so we have ***design***! Design is often motivated by some analysis indicating some opportunity for improvement, some better way, some need for change.

Herbert Simon famously wrote “Everyone designs who devises courses of action aimed at changing existing situations into preferred ones.” (SIMON 1969). Some amount of predilection, training and experience, and community recognition combine to identify some individuals as ‘designers’, but design is often necessarily a collaborative exercise, engaging specialists and ordinary citizens, as well, especially when confronting the grand challenges of geodesign in the 21st century (STEINITZ 2012). Simon also proposed an early model of design, that he called the ‘generate-and-test’ cycle; a deceptively simple, robust, and deep model of design. A familiar ‘analysis-synthesis’ cycle is often used to describe design processes; Vijay Kumar’s 4-part ‘Research-Analysis-Synthesis-Delivery’ model (KUMAR 2003) puts that in a slightly enlarged framework, much in the spirit of the 6-node cycle described here.

Design is not the same as “problem solving” – though some problems may be solved by design – for one essence of design activities is that they are not linear, not always ‘rational’ or ‘logical’; rather they are characterized by innovation, ‘out-of-the-box’ thinking, transformations as much as combinations, often preferring invention over convention (KALAY 1986). There are often apparently conflicting requirements, options, and ideas, and one art of design is to resolve apparent contradictions by some new way of seeing or doing. There are no formulas, no guaranteed approaches or right answers, and no algorithms for design; but there are ‘heuristics’, trial-and-error approaches, and occasionally what some would call ‘magic’ (because it is inexplicable). And there are also cycles (HALPRIN 1970).

5. Designers who have a design only in their imagination may have a hard time convincing others of its value, or of seeing it built (unless they simply build it themselves.) In most cases, some representations – models, drawings, abstractions – are made along the way, to help designers explore alternatives, to share with colleagues and clients, regulatory agencies and financiers. ***Communication*** by ***representation*** is often largely visual, though rarely only so.

Designers sketch and make diagrams in notebooks, for their own reference, as part of many design processes. 3-D physical models, 2-D rendered views and animated ‘walk-throughs’

(4D?) are prepared for community and client meetings, and construction documents are prepared for contractors and fabricators. Each of these kinds of representation has its own conventions, limitations and powers, and uses and misuses, across differing levels of abstraction and scales of consideration.

6. Finally, when a designer has worked with an idea, a need, a problem, or a possibility for some time, there is usually some communication, some documentation, that constitutes a proposal and a recipe for some ***implementation***, or action, often ***construction*** or fabrication. In this phase, material realities and physical (or socio-political) laws are confronted head on by builders. If the designer has been experienced and thoughtful, these are not obstacles. In other cases, the builder must also be a designer of sorts, inventing solutions to 'real-world' practical and logistical problems overlooked by the original designer. (When this is based on application of well-known formulas, principles and details, we may call it 'engineering'.)

And then finally when a design has become a reality, that new change becomes part of the existing world, that is (re-) inhabited, and perceived, and analyzed, and that prompts new designs, and constructions … and so on in an ever recurring cycle. One specific form of analysis may be called 'post-occupancy evaluation', when new conditions, needs and opportunities are compared to pre-existing ones, to help designers and others to learn from the experience.

This is not to say that life, or design activities, occur always in regular cycles with pre-determined steps. Both are prone to skipping, and recycling, and alternating, and spiraling, sometimes pursuing dead-ends, and sometimes leaping with flashes of insight over whole steps (Fig. 2) This is one reason no simple algorithm or mechanization of design may be possible. But in general the progression from an existing lived-in situation, leading to a new design idea that is built and becomes the new reality, is a ubiquitous recurring cyclical process.

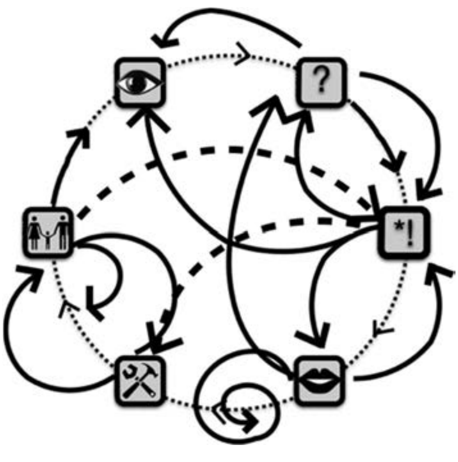

Fig. 2:
Non-Linear, Complex Design Paths

3 Digital Technologies in the Design Cycle

Technology in the 21st century often implies digital, since so many of our sciences and tools are not just enabled by, but fully dependent upon digital technology: bits and electricity, fiber optics and copper wires, switches and routers, computers, their Boolean logic and algorithms, visual displays and other input and output devices, their attached memory and detachable storage, and increasingly, digitally connected sensors and robotic activators and tools that perform the role of connecting the digital and virtual worlds to the non-digital, 'real' world. Of course there are other exciting non-digital technologies for landscape architects: materials science, biological and chemical technologies, environmental methods at many scales, and others. But these, too, are increasingly enabled and augmented by digital computation. The following sections briefly outline some of these many technologies and their uses and values in landscape architecture.

3.1 Inhabitation

There's no denying that we live and a hyper-digital world. Digital signals, processes, and artifacts are all around us everywhere: from cell phones and music players to bank machines and restaurant menus. Digital watches, digital glasses, digital hearing aids and all manner of 'wearable computers' are appearing daily. The Internet is the ether in which we exist and communicate (even though it may be inequitably, unreliably, and unevenly distributed over the planet just now.) We have digitally enabled and controlled airplanes, subways, even passenger cars. We have digital health monitors, thermostats, and household control systems. We are increasingly developing so-called 'smart cities' (PICON 2015) with digitally connected transportation, energy, waste management, and other municipal systems and services, as so well articulated in William Mitchell's '*E-topia*' (MITCHELL 2000). The digital technologies that promise increased efficiency, reduced carbon footprints, improved accessibility, quicker response times, and more readily optimized mixtures and interactions are today the realities of life, and increasingly crowd the canvas upon which, and the palette with which, landscape architects need to work (CANTRELL & HOLZMAN 2015).

3.2 Perception/Measurement

How and what we see, hear, and measure has been transformed also. From electron microscopes to Earth-observation satellite platforms, our range of sight has been expanded to include enormous areas, light and energy in otherwise invisible parts of the spectrum, and dynamic ecological and urban processes at scales imperceptible to the human eye. Surveying for 2D site plans is performed by lasers and computers and GPS signals now; and 3-D digitizing of objects and LIDAR scanning of landscapes and cityscapes are now commonplace. Landscape architects regularly manipulate point clouds gathered by digital sensors on remote controlled unmanned aerial vehicles (UAVs, or drones).

Augmented- and virtual-reality displays literally take over our optic system; Google Glass and Oculus Rift are all new ways of seeing/perceiving/experiencing the world. Digital audio is everywhere. Touch has already been supplanted by 'haptic feedback' devices. Our senses of taste and smell are so far relatively untouched by digital enhancements, but that seems only a matter of time …

3.3 Analysis

Digital analysis of data today reinforces and extends not just designers' eyes, but their brains too. Ground sensing radar enables perception of hidden spaces and geologic structures; GIS modeling enables sophisticated analyses of all manner of geospatial phenomena across multiple scales. Computing sizes, areas and volumes from remotely sensed data is commonplace; modeling environmental degradation, and simulating dynamic processes from surface water flow to multi-modal traffic patterns, are necessary components of modern site analysis. Methods of Computational Fluid Dynamics (CFD) software enable better understanding of air flow and water currents; and many other dynamic models are increasingly essential to evaluating impacts of landscape, architectural and urban design proposals.

3.4 Design

The essence of design, a mental cognitive activity, may like our senses of taste and smell, seem relatively immune, so far, from digital encroachment. But certainly the supporting matrix within which our designers' minds must work is increasingly entirely digital. Sketching, remembering, seeking and re-appropriating precedents, re-combining, graphically transforming, associating and mutating ideas – all time-honored design activities and techniques – are all aided by modern software, the internet, web browsers, digital cameras and sketchpads, etc. Surely great design can still be done with only a pencil and notebook; but increasingly, the complexity of design challenges outstrips the human eye-mind-body's capacity to absorb sufficient information or effectuate sufficient change. We increasingly do need computer-aids, cybernetic tools, and robotic assistants.

In that regard, a vivid illustration is the emergence of the practice of 'geodesign' in the past decade. Referring broadly to systems-oriented planning and design for large complex projects, by interdisciplinary teams using computers and other digital devices and representations, and algorithmic techniques including simulation and impact assessment, geodesign was initially conceived in the context of Geographic Information Systems (GIS). Those systems were initially not thought of as design-aids, but as tools for measurement, analysis, and representation (i. e. map-making). As they became a staple part of landscape architects' toolboxes, as interoperability between GIS and CAD increased, and as the complexity and scale of environmental design problems exploded in recent decades, the need arose for a whole new term to describe an emergent practice of synthetic, machine-aided, responsive design (STEINITZ 2012, ERVIN 2012).

3.5 Communication/Representation

Designers find a need to convey design ideas to others, either colleagues for comment, community or clients for approval, or contractors for subsequent construction. In all these cases, communication by representation is essential. CAD and GIS software was developed initially to augment pencils, paper and hand-drawings, but have come to largely supplant them (except in the case of 'conceptual sketches' and 'abstract diagrams', which are still more easily done non-digitally, for most experienced designers.)

Video is now produced by the smallest hand-held cameras and cellphones and distributed world-wide over the web with the click of a button. Videoconferencing makes face-to-face-meetings possible across time-zones and geographic divides. Collaborative markup software and version-control/revision systems make tracking changes manageable. The core needs to communicate and collaborate in design are perhaps unchanged, but just as with design itself, the supporting matrix is almost entirely digital today.

3.6 Construction/Implementation

Traditional construction methods included razor knives and straightedges in the studio, and shovels, rakes, and wagons in the field. Today, laser cutters for producing 2D cutouts (such as topographic contour models), and 3D printers, CNC routers, and other ‘rapid prototyping’ fabrication technologies have taken over the traditional model-building shop. New materials may have digital connectivity, LEDs, and sensors embedded directly in them. Garden furniture may be embedded with sensors and activators, and viewpoints or specimen plants augmented with WiFi stations and associated web-pages. Digitally created grading plans that use not contours, but point-clouds and triangulated irregular networks (TINs) can now be implemented by plugging a small USB data stick into the dashboard of a digitally enabled robotic bulldozer, equipped with GPS sensors that enable it to control position, elevation and slope to within centimeters. Computer controlled drones can be used not just to carry cameras and sensors, but also to deliver materials and documents on-site. Digitally aided robotic construction enables new levels of precision in the field for landscape architects. Digital construction methods are the logical extension of digital measurement and representation tools.

Digital construction highlights the difference between, and the seamless integration of the concrete/analog real world (dirt, stone, water, plants) and the abstract/digital (words, drawings, coordinates, ideas). In this vein, note that the ‘left-hand side’ of the design cycle contains the three most concrete/analog phases (Construction, Inhabitation, and Perception) that are most fully dependent upon our bodies and the physical world (digital fabrication and measurement technologies notwithstanding); while the ‘right-half’ contains the most abstract/digital activities (Analysis, Design and Communication) that depend most heavily upon our brains, and abstract ideas and constructs (information, diagrams, algorithms) (Fig. 3.) On further examination, we may conclude that ‘Perception/Measurement’ and ‘Representation/Communication’ are in fact in themselves hybrids of both digital and analog; perception and measurement depend on our sense organs and physical instruments, to be sure, but also upon our brains, logical systems, and abstract ideas; while representation and communication, arising mostly from abstract/digital content, must necessarily bridge to the physical world of sounds, graphic marks, physical models… and finally, concrete implementation.

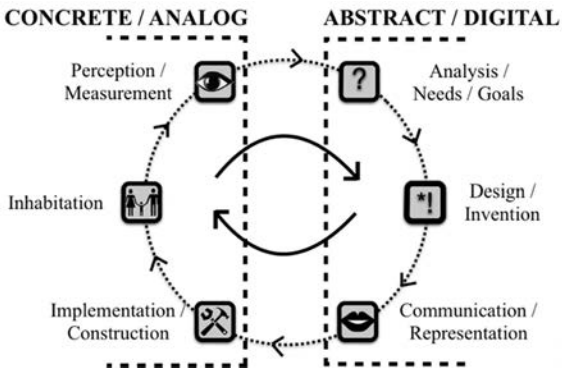

Fig. 3:
Concrete/Analog and Abstract/Digital Phase of Cybemetic Design Cycle

Here then, in these two domains, are perhaps the most fruitful areas to look for 'bionic' solutions, in which humans and their mechanized assistants are hybridized together for evermore-effective synchronized and symbiotic action; from speech-recognition and multi-function digital assistants to bodily sense-, action-, and perhaps even thought- amplifiers.

4 Conclusion

The term 'computer-aided design' naturally begs the question: "How can computers ('digital technology') aid design?" The long and growing list of examples as outlined above provides some answers to this question, while of course raising others in turn.

Augmented-reality goggles and 3D-printed houses, no longer science fiction, may not, in themselves, create 'better designs', by any metric (testing outcomes remains a rich and rewarding research area), but they are certainly indicators of the ways in which technology can aid and abet design and designer. Landscape architects' toolboxes have expanded considerably since the design and construction of New York's Central Park, but our challenge remains the same as it was then: to envision and create built landscapes that respond to real human needs while respecting environmental constraints and conditions, contribute to human delight and satisfaction, and provide a medium of expression for imagination, and ecological and cultural values. In this way, using technology to these ends, we may better answer the deeper question: "How can technology make us more human?"

I have no doubt that as technology increases in its capabilities across all six of the nodes on the design cycle described above, and landscape architects deploy these technological advances, digital landscape architecture will remain truly people-oriented at the centre, and increasingly computer(technology)-aided around all its many fractally-complex edges.

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