

From products to produces: Design In the Making

ABSTRACT

A growing number of design and engineering fields has become focused on creating dynamically pliant artifacts inspired by complex and biological systems. Not only novel artifacts will emerge eventually from this emerging dynamic approach; the activity of designing itself will undergo radical conceptual and practical changes. In short, to pursue dynamic artifacts, design processes must themselves become dynamic. This paper discusses a range of issues related to a dynamic design paradigm; from modularization in production to issues relating to the branding of dynamic artifacts. The paper deploys contemporary biologically inspired trends in IT design as both paradigm example of dynamic design and point of departure for the investigation of future design processes. IT design is pioneering dynamic approaches at present, but the paper broadens the perspective to prospect designing in general. Various examples of possible design processes are provided to illustrate the tenet of dynamic design, and we discuss different conceptual and practical relating to the design of dynamic artifacts.

1. DYNAMIC DESIGN: ARTIFACTS FOR LIFE

Ever since the emergence of synthetic materials, natural materials like wood and leather have been praised for their superior construction and wearing abilities. Wood and leather are paradigmatic because they seem to get better, more beautiful and precious with time. They are moderately self-repairing by ‘swallowing’ scratches and stains and passively adaptive by ‘breaking in’, expanding, and contracting when needed. In contrast most artifacts starts ‘degrading’ virtually from the minute they leave the assembly line. The more technological the artifact the faster the degradation as reflected in the sky-diving market value of used computers. Both because of the inferior materials high tech artifacts are normally made from, the linear nature of present day technology deprived of any kind of self-repair and reconfiguration capacities and the pace of development, which renders high tech devices surpassed or even obsolete within months.

However, nothing but the actual state and - perhaps more important – conception of technology seems to make it so; not any deep ‘law of artifacts’. As consumer goods, characterized by the relative short life span of commercial items, high tech artifacts are close to perfect. But users are not only consumers. They are also historical beings enjoying the long-term relationship with their favorite chair or old jeans. So why not explore emerging dynamic materials in an effort to break the spell of techno-consumerism and confer some of the qualitative elements of human relations to technology and artifacts in general? Let us take a look at the prospects for dynamic design principles to make artifacts more valuable and meaningful life companions.

1.1 Toward dynamic artifacts

However uncertain the future might inherently be, there is little doubt that our engagement with artifacts will become increasingly dynamic when materials and technologies allow for it. By ‘dynamic’ I mean artifacts coping with, or preferably intrinsically dependent on, prolonged temporal extension for their proper function. Much cognitive research has characterized interactive dynamics as our primary competence as embodied cognitive beings [9, 11, 18, 32, 36, 38] and how we prefer to organize our everyday [19, 20, 29, 30]. Consequently, as dynamic technology and materials become generally available, new produces designed to enter the dynamic

life world of human beings will emerge. A number of publications has pointed to the increased merging between use and designing and thus further radicalize present trends in user-centered and ‘customer made’ designs [21, 27, 35, 43]. Customers will no longer merely buy finished products. Rather, they will increasingly buy *into* produces, i.e. adaptive services comprising developmental constraints, and a relevant level of sensitivity for the history of use. Accordingly, designing is likely to become interactive processes unfolding between design initiators and governors (today’s designers), the relevant users, and the functional ‘ecology’ of the artifact.

In accordance with the general dissolution of entities, institutions and mental and social phenomena hitherto considered stable and substantial into decentralized and distributed processes as described by modern natural science, post-modernism, models of complexity, dynamic systems, and networks [1, 3, 8, 13, 14, 23, 38, 41] and as manifested by everyday life, design will become distributed, ubiquitous, and increasingly processual. We may very well be witnessing the notion of the designer creating finished products slowly fading away. At least in relation to artifacts where focus change from thing (substance) to adaptive assistance (process). At the same time design will start encompassing much broader analytical tasks than merely providing things according to functional and aesthetic preferences. Designing will start incorporating a much wider theoretical and disciplinary spectrum. An example of the new assignments for designers could be facilitating smooth transitions of organizational change for companies, organizations or institutions by guiding an open ended process of adjustments and change toward a defined goal or continued adaptation [15].

That artifacts undergo reiterated improvements is no news. What is new is that the cyclic improvement processes become intrinsic to the artifact in use and not merely something that separates subsequent generations of the product. To refer to organic metaphors, if design has traditionally been construed as ‘conception’ and ‘birth’ it will transform into ‘raising’ and ‘educating’. Instead of a top-down controlled creation of products, designing will become a multi-authored and highly interactive process of cultivating *produces*.

1.2 Dynamic design of IT: Biomimetics

‘Living’ is probably the most apt metaphor for such produces, as the guiding inspiration for dynamic design discussed in this paper comes from living organism. An approach I shall refer to as ‘biomimetics’ [2, 6, 7, 35]. Especially in relation to IT, biologically inspired ways of designing will be among the most important weapons in our efforts to meet the challenges from ever growing and pervasive systems likely to exceed traditional ‘static’ ways of designing soon [16, 35]. But the art of design in general will most likely change from focusing on minutely planned products to open ended processes dynamically incorporating contextual factors. Instead of creating products as finished, static entities, a lot of design will come to guide dynamic *produces* evolving with use and changed functional contexts. However, the principles are universal for dynamic design. The computer is simply more plastic than most artifacts as it allows for radical changes in functionality by mere reorganization of control (software). Hence the original characterization of the computer as ‘the universal machine’. The history of IT is in fact a story about half a century’s quest for dynamic technology; a pliant technology adjusting to user needs and capabilities [37]. Biomimetics, the youngest branch on the IT family tree,

represents an inherently dynamic understanding of design processes by systematically deploying developmental and evolutionary principles found in complex adaptive systems research and biology.

Even if biomimetics, resting on a process understanding of complex phenomena, implicitly opposes the strong bias towards substantialist and dualist understandings of reality dominant in the western world [13], biomimetics is not endorsing software-chauvinism. On the contrary, materials will become increasingly important for biomimetics as smart materials and theories provide for better hardware-software integration. The ultimate objective is to create highly dynamic devices that respond to changing requirements in an integrated way. Just as most forms of natural adaptation cannot meaningfully be divided into material and control adaptation (the brain for instance is both), artifacts should develop in an integrated way rendering the software-hardware distinction merely an expression of inadequate understanding. According to Simon Levy and Jordan Pollack:

treating the building blocks and compositional rules of a system as two separate components may be an inherently limiting approach...[]...we may well need to turn away from the traditional dichotomy between building block and rule, and seek out substrates in which such distinctions emerge as artifacts of human observation, rather than being stipulated design principle. [25]

At present only software allow for dynamic adaptive processes, as evolvable and reconfigurable materials are still in their infancy. ‘First wave’ biomimetic IT design will thus primarily focus on facilitating adaptive software. But by applying modular techniques in designing, we can remedy the lack of subtle dynamics of living materials and gain some of the adaptive qualities also at the structural and material level.

2. DYNAMIC DESIGN: MODULARIZATION

All ways of designing complex artifacts, are dependent on a range of modularizations to facilitate commercial production. The challenge is identifying the relevant and opportune modularizations to counter any functional disintegration resulting from such compartmentalization. On the other hand modularity is not only a remedy for the lack of intrinsic dynamics in artifacts, forcing us to devise a certain level of universality and uniformity in the name of (mass) production. The complex biological systems modeled in biomimetics, exploits reuse, ‘standards’ and various kinds of module-like organizations themselves to constrain and guide adaptive dynamics. Sex, species, DNA, cells, organisms and life cycles are all module-like constraints guiding variations and economically reusing general solutions. Modularization thus understood serves multiple purposes most of which can be characterized as providing for variability and flexibility while retaining structure and control giving you the three cardinal principles of evolution: variation with functional consequences (individuation), selection and inheritance.

In dynamical terms, an important kind of modularization for dynamic design is sequentiality. Without materials fully capable of self-assembly or reconfiguration we have to model development by parsing the creation process of artifacts into sequences. Biological growth, development and evolution are not to be understood as homogenic fluxes themselves as natural adaptive dynamics are heavily dependent on phase transitions and bifurcations for individuating purposes [13, 14, 22]. The difference being that such continuous transitions are intrinsic to biological systems while extrinsic to present artifacts.

Besides practical production concerns sequentiality is also motivated by a necessity to constrain the dynamics of

semi autonomous processes in dynamic devices. Without global tradeoffs and horizontal alignment some parts might obtain local adaptivity in conflict with the global adaptivity of the device [40]. For instance ‘over-adaptation’ of energy management of a device might result constant in constant ‘sleep’ and thus very low overall adaptivity. Let us begin by considering temporal modulation in the form of phases of development and design. As designers we need to be concerned – everything else being equal – with the overall performance of devices.

2.1 TEMPORAL MODULARIZATION: PRE HOC, AD HOC AND POST HOC DESIGN PHASES

Given our incomplete knowledge about natural adaptive dynamics and present lack of truly dynamic materials we should strike a balance between adaptivity and control by parsing adaptive artifacts into modules and phases. Modules and phases serve to facilitate better guidance of dynamics and to replace natural growth by discontinuous structural reconfigurations. The following sections investigate a proposal for dynamic design of dynamic IT devices that comprises three phases of artificial development. The model proposed serves mostly as an analytical tool to highlight salient dynamic properties of dynamic artifacts and only derivatively as a specific method for design.

The three phases of the analytical model are delineated by dynamic characteristics and relevant implementation focus, i.e. phases have different strengths for different kinds of artifacts and most artifacts will not go through all three phases (c.f. figure 1). The phases bare only limited resemblances to nature’s three grand principles of phylogeny (evolution of the species), ontogeny (pre-natal development of the individual organism) and epigenesis (growth and learning of the organism). In a sense this sequentiality serves both to guide artificial adaptation and remedy our lack of ontogenetically growing and epigenetically learning artifacts to achieve similar adaptive qualities with feasible means. This division of labor between human control and autonomous self-organizing does not only delineate the design phases but exemplify a productive synthesis of intentional design and autonomous self-organization, which biomimetics seeks to capitalize on.

Design phase	Strengths	Examples	Keywords
Pre hoc	Structurally biased artifacts	Furniture, buildings, mechanics: wheel-chairs, bi-cycles	Personalization, specialization
Ad hoc	Dynamic artifacts: cognitive devices	IT: virtual assistants applications, complex control systems	Learning, ongoing adjustment
Post hoc	Short lived, simple and general devices	Web bots, virtual antibodies in artificial immune systems	Evolutionary improvement

Figure 1: Design phase matrix: design phases coupled with typical target artifacts

The three phases are termed ‘pre hoc’, ‘ad hoc’ and ‘post hoc’ (referring to the proper deployment phase ‘hoc’) and refer to pre-launch development, post-launch adaptation in use and post-use breeding respectively. With time and in certain circumstances the linear sequence of the phases as presented here might mould into a more truly evolutionary cyclic dynamic rendering the pre hoc and post hoc phases

merely different aspects of the same phase – namely when the artifact is taken ‘off line’ for improvements that cannot take place on the go.

2.1.1 The pre hoc phase: Breeding

In analogy to conventional R&D based production new types of dynamic devices go through a pre hoc design phase before commercial launch. The focus of the pre hoc phase is to generate what we can term ‘design DNA’. The ‘DNA’ of an artifact maps basic capacities in the form of general developmental potentialities and, if relevant, a matching infrastructure facilitating such dynamics. DNA refer to codes for core functions of a device, like a simple operating system for Pocket PC’s or the structural description for hybrid artifacts such as smart furniture. Even though the artificial DNA is more syntactical elaborate (but immensely less complex!) than the DNA of biological organisms, the device still needs development to deliver specific user-adapted services such as special applications and features and adjusted user interface. Some of these additional features will be modules pre-fitted to a type of DNA, others need to be included in the evolutionary processes of the pre hoc phase, to obtain the proper functional coupling and others again will be added in the ad hoc phase.

For practical reasons and because fully dynamic materials are presently unavailable, hardware will initially be both more universal and statically modular than the software, and primarily provide the infrastructure for the adaptive software to develop within. The aim of the pre hoc phase regarding hardware is to obtain maximum functional coupling with software and to strike the right balance between too many and to few structural constraints in order to guide but not prevent subsequent ‘soft’ adaptation. However dynamic hardware is also on its way [34, 42].

Due, among other things, to the lack of fully dynamic materials and an incomplete theoretical understanding of learning and epigenesis, evolutionary principles are presently less difficult to model than developmental dynamics. Especially Evolutionary Computing (EC) has had enormous success in solving complex tasks by automatic evolutionary means. EC basically amounts to recursively generating candidate solutions (coding) for a given task, testing them (assign a fitness value to the solution) and selecting the superior. Such ‘brute force’ iterative processes take advantage of the calculation speed of computers. Much of the biomimetic work during the pre hoc phase will thus be accomplished by EC methods creating candidates ‘in vitro’, i.e. generating and evaluating numerous candidates in simulated or mock up environments. Various biologically inspired techniques – such as simulated development of software as in ALife, co-development of software and hardware by EC and neural nets techniques as known from e.g. modern robotics [10], hardware design [31] and evolutionary design by computer [4] – will be important tools to develop devices until an appropriate level of functional complexity and reliability is reached.

Appropriateness is determined by requested functionality; autopilots and controllers for automated factories require a higher level of perfection than creative assistants for children, designed for serendipity and inspiring disorder. Simulating the functional context of hardware devices is much more difficult than operating on purely virtual parameters (e.g. the ‘environment’ of web bots without real world dynamics or users). But with recent advances in behavior based or embodied robotics specifically addressing these issues and not least powerful industries such as car manufacturing, aircraft design, and space research spending lots of money on research on real world simulation, dynamic design is likely to benefit from the efforts.

The pre hoc phase is likely to decrease with the realization of biomimetic design for many standard artifacts. Just as selection in natural evolution operates on mature individuals

chosen because of their relative phenotypic superiority (that their genome and epigenesis gave rise to), pre hoc development should gradually merge with post hoc selection in a circular evolutionary dynamic picking out successful devices to breed on. As we build up a critical mass of useful biomimetic devices and become capable of devising creative automatic processes for generating interesting variants, the thorough pre hoc developmental of many artifacts phase will be replaced by minor (one generation) variations and tests of their functionality. But for specialized or otherwise idiosyncratic artifacts a pre hoc evolution from scratch might still be necessary.

It should be stressed that because autonomous technology must respect our norms for functionality (and our plain psychological need for being in ultimate control) and since natural ‘blind’ dynamics probably benefit from human deliberation facilitating aimed searches in design space, we will interfere with the variation and selection processes to guide biomimetic evolution or at least decide when the outcome of the artificial evolution is satisfactory. Yet, it remains an very important empirical question how much deliberate intervention is needed and opportune and to what extend automated ‘blind’ adaptive dynamics are capable of honoring our functional norms.

2.1.2 The ad hoc phase: Interactive adaptation

During the ad hoc phase of design, devices continuously adapts to user habits and changing contexts. Developmental variations do not change the genome of the device, they merely make small mutations of non-genome software (typically in applications). Devices beyond a certain complexity could be constructed as a swarm of devices, each with unique genome developed to perform a given function in the ‘niche’ of the swarm. Ad hoc variation in such ‘superdevices’ might thus include evolutionary upgrades of some of the devices.

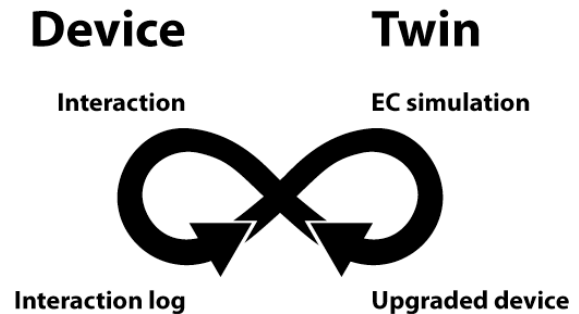


Figure 2. The upgrade loop illustrating how certain devices might have a ‘clone’ undergoing updating’ while the device is in use.

For hardware-dependent devices, where a necessary change of hardware will impact functionality (e.g. changing the functionality as compared with merely adding more ram in a computer), an evolutionary upgrade of hardware might be necessary. A hardware upgrade is when the software is transferred to new hardware configured offline in a simulator to match on the basis of information gathered from the specific device and similar devices during their use. To lessen inconvenience devices can have twins simultaneously undergoing offline developmental upgrades by simulation fed with data from the device ‘in the field’ implementing the latest evolutionary upgrade (c.f. figure 2).

The functional coupling between user and artifact emerging from adaptive development during the ad hoc phase are likely to become the most important aspect of biomimetics. By letting some functional configuration of devices happen by epigenetic ‘learning’, i.e. letting data from actual use take part of EC simulation updates, use become part of designing - a design symbiosis. But learning and development are also the hardest parts to get right being still poorly under-

stood and seemingly very complex. The proper way to proceed despite incomplete knowledge is through conservatism, i.e. to rely mostly on offline upgrades that allow us to test variations before implementation, and let true epigenesis slowly take over more and more functional reconfigurations as we get better in modeling learning. Eventually simple learning models will be available for implementation as a result of the massive interest from cognitive science, AI and robotics, but until then we have to manage without.

2.1.3 *The post hoc phase: Selection and reproduction*

Successful devices will get selected for reproduction, i.e. devices that have reached a certain fitness level will either reproduce immediately or when a customer buys a device. The 'genome' of the successful device forms the evolutionary basis (as 'generation 0') of the pre hoc phase of new devices with similar functionalities. If the hardware of parent and offspring is similar, the functional and organizational coupling between the genome and hardware of the offspring device has been done by the development of the parent device. Otherwise simulated co-development might be necessary. Additional software such as applications will be added to the EC simulation when hardware and genome has been coupled.

Whilst reproduction should have high replication fidelity in general to facilitate incremental evolutionary adaptation, all adaptation rests on variation. Whether reconfigurable, sexual or both reproduction should provide some variation to allow for adaptive dynamics. It will be a matter of empirical investigation to determine how much reproductive variation and in which functional contexts 'genomes' of still functionally relevant devices should undergo and to which extend mere replication (cloning) is best.

Reproductive variation resembles developmental variation in certain respects but differ in others. First of all, reproductive variation offers more radical changes via reconfiguration and crossover of genomes. Due to a 'one-to-many' mapping between genotype to phenotype changes at the genome level often have consequences for a range of traits expressed. As technology becomes more complex and non-linear a similar one-to-many mapping of code and behavior is likely to emerge in artifacts as well. Besides non-linear mapping, variations are inheritable and provide accumulative adaptation of generally useful capacities. On the level of 'species', i.e. types of devices, this phase provides retentive or post hoc adaptation.

2.2 Structural modularization

Dynamic design will also rely on structural modules and in this aspect dynamic design is not that different from present practice. The main difference will be the greater number of different modules that dynamic design can handle via extensive simulation of various combinations and consequently the unique ways these modules can be configured to personalize a given artifact. Under a certain threshold of granularity modular artifacts comes to resemble truly dynamic systems enough to offer interesting adaptive capacities.

Now let us take a look at two different examples of the dynamic design principles sketched above. The examples are chosen to highlight different phases of development and different constraints of design. In the first example, the evolved sofa, the pre hoc phase is most important; in the second example, the adaptive car, ad hoc development is most salient. In a way the examples also points to the order of concrete implementation as the pre hoc phase resembles present day praxis within high tech production, which has already adopted some artificial evolution principles (e.g. EC aided design of circuits and chips, airfoils and car suspension). Ad hoc adaptivity on the other hand will be novel to design.

3. DESIGN EXAMPLE 1: THE EVOLVABLE SOFA

As a cognitive prosthetic for visualizing dynamic design principles let us consider a sofa. Furniture provides good examples because of their rather simple functionality expedient for clarifying the concept of dynamic artifacts. Besides, quality furniture carries the marks of time beautifully, and furniture illustrates the value of historicity of artifacts whereas present day IT devices hardly ever age with grace – quite the opposite. The intention with dynamic design on the other hand, is to make artifacts express their history of use actively through adaptation as a story about habits, trends and aging. Again, until the arrival of truly dynamic materials, furniture will probably benefit most from the principles of the pre hoc phase due to their 'structure-biased' nature. The pre hoc phase provides for the design of functionally adequate and highly personalized artifacts. The ad hoc phase will become relevant for furniture only when interesting smart materials becomes available to allow for ongoing reconfigurations. It is hard to say whether it will be opportune to gather genomes from furniture in the post hoc phase. It is probably still worth collecting general data of value for the hidden parameters (general design constraints) for subsequent pre hoc developments. In the furniture example all three phases are demonstrated for didactic purposes even if their practical value is quite different.

You enter a website or a showroom of a given brand and select from groups sofas composed from dimensions such as size, shape, feature, materials and style. How fine grained this modularization is will depend on the brand. Traditional strong brands might have got more customer goodwill and hence more autonomous power in the design. Other brands might be famous for its fine-grained options and the sensitive adaptivity it provides.

After a session aiming to extract information identifying your preferences from your choices along various type, style, materials, size and color dimensions (via data mining calculating your likely preferences from the choices of other users and neural network techniques to identify patterns in your preferences), the computer compiles your choices into numeric values for constraining parameters. An evolutionary computation starts working on algorithms containing the chosen values plus hidden parameters. Hidden parameters are universal parameters such as constructional laws and material characteristics as used in engineering to exclude unstable constructions beforehand; It is the kind of modules the brand operate with and design characteristics of (quantifiable constraints capturing the essence of the brand).

Different candidates present themselves visually on the screen or holographically. Texture and color of the candidates can be changed using for instance VR software to give a more adequate display. You evaluate the candidates on different levels of specificity and on relevant variables, i.e. not if the sofa has got a seating surface, legs or other fundamental requirements. Such prerequisites are filtered by the system. Connoisseurs can specify precisely which aspects they like and dislike. Other customers can use less articulate evaluation, and the preference detection software will be able to identify your preferences along different dimensions.

Your feedback assigns fitness value to the different candidates (and perhaps even specification on which candidates you want to 'breed' on) and form basis for the next generation of candidates. After multiple runs the best candidate can be printed out using a 3D printer and placed in the targeted setting if requested. When you decide on a sofa it is built from various modules, partly automatically by CAD and robotic techniques and partly handcrafted, according to the blueprint generated by the program on the basis of parameter values. The creation of your first sofa marks the end of the pre hoc phase.

To rehearse the conceptual idea of ad hoc development

let us imagine that you decide to let your sofa have developmental capacities and subscribe to a developmental service. According to your preferences for subsequent development, an optional number and types of sensors are built into the sofa to deliver feedback for future updates. In addition you might choose among different ‘life cycles’ determining the frequency of evolutionary upgrades, i.e. when the firm will inquire whether you are interested in an evolutionary upgrade. The sofa can be upgraded with regular intervals according to taste, how often you change residence, and economy. You can always change the frequency and skip suggested developmental upgrades if you are low on money or ask for an upgrade if moving or buying a dog. You also set the weight of the developmental parameters. Some customers prefer more momentum of original design and less interactive feedback, greater sensitivity for your habits over trends or vice versa, design-alignment with the room or other furniture in the living room etc.

In use the sofa wirelessly transmits sensor readings to a server identifying zones of extra pressure, wear, damage or changes in context such as other furniture, new lightning conditions, or a new placement. The data will be used as values for the next developmental upgrade of the sofa reflecting use, changing habits or circumstances and fashion. Upgrades happen when (and if) you approve implementing changes suggested by the evolutionary simulator, which has been generating candidates on the basis of data from the previous period and your explicit requirements. If for instance the sofa is placed in a dark room (detected by ambience sensors) the color will lighten or the fabric get more reflective, if children often jump in it its suspension will be fortified, or if users often wet the fabric it will be replaced with a more moist repellent. And if the sofa has been moved to another room you can require to make the sofa a three person instead of two or vice versa, if moved occasionally wheels might be suggested etc.

The ad hoc phase of design comprises developments takes place from the sofa enters your house till it is disposed of. The data of especially successful designs (measured by age and explicit user feedback) will be fed back into the computing method of the pre hoc phase of new sofas. It probably makes little sense to reproduce the actual ‘DNA’ that gave rise to the ‘parent’ sofa, as most changes in such an artifact will be developmental. Besides, customers might prefer developing their own personal furniture (from a set of preconfigured parameters), and not adopt sofas with determinant ‘DNA’ from earlier furniture. Rather reproduction will mostly feed back knowledge for the engineering parameters of future designs i.e. types of fabric, construction etc. and not strictly aesthetic parameters. Nevertheless, the idea of reproducing the actual DNA will remain a theoretical option.

In opposition to devices with a shorter lifespan dynamic quality furniture lasts for decades as worn or broken parts are continuously replaced and the style kept up to date. At the same time the furniture grows and adapts to your preferences, so there will be little reason to throw it away because it has become obsolete. On the contrary, a responsive sofa might become a dear life companion for you in a sense not possible for static artifacts because you have developed together with it and invested resources in it. To make a dynamic approach fully satisfying the modifications must be conducted in a resource sensitive and recursive way that minimizes waste and ideally produce up-cycling, i.e. letting used materials enter the production loop again as nourishment for new products of the same complexity and beyond [26]. Just as natural systems reuse design and components all the time (tinkering) and conserves energy within growth-and-decay cycles. One of the style options could be a high level of reuse (branded as the ‘organic’ model) probably appealing to generations grown up with remixed music, vintage clothes fashion and

‘junk design’.

4. EVOLUTIONARY DESIGN EXAMPLE: THE ADAPTIVE CAR

To exemplify dynamic design of high-tech artifacts highlighting the ad hoc phase consider a car. Cars serve as good examples as far as they are everyday assistive artifacts heavily loaded with hidden technology. People interact with their cars in multiple ways and cars offer ample room for adaptation. Even if we presently do not have the technical skills to allow for extensive dynamic processes on cars while maintaining a high level of safety and comfort this may change very soon.



Figure 3 The GM AUTOnomy concept car consists of an undercarriage containing the hydrogen fuel cell. The basic shape and layout of today's car is heavily influenced by its source of power. Including the mode of propulsion in a minimal undercarriage provides new levels of freedom in design.

For instance, with the introduction of hydrogen cars, like the concept car AUTOnomy that General Motors presented in 2002, where the driving technology has been harnessed in a very modest frame, leaving ample room for personalization and adaptation.

Adaptation in cars takes two different forms. The first kind of adaptation concerns interface and handling related adaptation such as positioning and forming of seats, appearance and placement of displays, habit determined styles of power shift and suspension, variant levels of information of context or specific traffic information related to user experience. In addition, cars will be endowed with autonomic capacities to make them perform better and minimize the need for repair (along the lines of [34, 24]). This happens only indirectly from the user and because of this indirect adaptation, let us focus on the first kind of dynamics to highlight interactive issues.

The pre hoc phase of a dynamic car is less customer controlled than other artifacts as cars need to meet a lot of safety, handling and comfort criteria which have to be handled by professional product development before the customer enters the picture. The pre hoc phase of a car amounts to development and thorough testing of the hidden parameters mentioned above. Hidden parameters will be developed by the company through intensive simulations of co-development of subsystems within modules and between modules. Extensive pre hoc experimentation is simply too risky for cars and for the customer the pre hoc phase merely amounts to synthesizing thoroughly tested standard modules. Nevertheless, most customers will not notice the constraints, as the combinatory number of choices left is still vast.

Even though too coarse structural modularization is counterproductive to full functional coupling due to decreased mutual cooperation and complementarily functions, modularization is a ‘nature approved’ avenue to obtain adaptive systems. Besides modularity has a lot of design- and some functional advantages. First of all modularity decreases the complexity of design significantly [33]. Second, together with evolutionary conservatism, modules facilitate greater perfection of details. Third, modules might be deployed as

important means against cascading effects common in dynamic systems as they operate with greater autonomy. This is precisely what bestows robustness on networks of autonomous nodes [3, 47]. Furthermore, modularity often implies some functional redundancy crucial for reliability and robustness. With the use of shared engines, transmissions, interiors etc. across models modularity has been common practice in the automobile industry for years, and this established production procedure will ease the acceptance of new dynamic design principles.

To enter the pre hoc development of your new car you enter the website or showroom of a chosen brand and select between modules along e.g. sport, family, mini, off-road themes with a few platforms, more propulsion modes (e.g. combustion with manual or automatic transmissions or fuel cells), and numerous interiors and instruments etc. After a further specification of preferences among themes such as energy economy, safety, spaciousness and sport performance an evolutionary computation starts working. Different solutions present themselves visually at the screen or holographically. Color and additional equipment are changed directly on the candidates using VR software. You evaluate the candidates on preferred levels of specificity, iterate the process, and finally choose one.

An optional number and types of sensors are built into the car for subsequent evolutionary updates. In use, the car will transmit sensor readings of driving environments, wear, damage, and failures to a server gathering information from cars of the same make or with similarities in specific details (e.g. tyres). These readings are used for developmental upgrades of the car reflecting wear, changing habits, and fashion. In addition, the shared database of e.g. readings typically preceding malfunctions (a generalized variant of the black box in aircrafts) serves to provide the cars with the ability to detect relevant warning signals. Such anticipatory capacities will be very important. Enemy number one of dynamic artifacts will be dynamic failures such as cascades and destructive lock-in effects starting with minor and perhaps even unnoticeable irregularities still harboring the potential to grow devastating [3, 47].

The car goes into 'pit' periodically to get upgraded on the basis of data from the car's sensors, from the server collecting general data, and explicit feedback from the owner. On the basis of a more or less fine-grained range of choices the car will get adjusted to the typical use in the passed period. For example, the transmission might be changed if you move from the countryside into the city or vice versa, the trunk will be enlarged because of your new dogs or growing children, the box for skis and other holiday gear may be replaced with a transparent roof because you are going south this time. Materials taken from the car will get recycled or perhaps even up-cycled as nutrients for successive modules or devices [26].

4.1 Focus: Interior

The car is created with the equipment specified by you besides mandatory or default features such as seatbelts, airbags and a spare tire. Most modifications will be a matter of fine-tuning or context specific changes. Most monitoring of driver habits and preferences takes place by an eye-tracking device mounted in the dashboard (determining e.g. the drivers level of attention), by sensors in the seat (detecting e.g. stress) and the steering wheel (monitoring the drivers condition through e.g. transpiration) and by general monitoring of the car's driving technologies (propulsion, transmission, suspension etc.).

To facilitate instrumental plasticity most displays will be pixilated to allow for smooth and real time adaptation. Individual display assistants specialized in providing context specific information will replace traditional dashboard in-

struments. Assistants will only manifest themselves when the driver looks in a given direction or if the situation predicts the need for a specific service. Just like cars with automatic transmission select the proper gear (normally in a preset mode such as 'sport', 'economy' or 'mountains') an adaptive car chooses which explicit information to convey and how. Modes for instrument information can be highway, city, way-finding or cruising. Such contextual modes helps narrowing the range of relevant services, i.e. when going to an appointment and looking for way you are not interested in sight seeing, when you are in the city you should focus solely on the traffic, if you enter reverse you want to know how much space is left behind your car, and if cruising you do not want to be disturbed by information on your speed.

As examples of how to convey information in different degrees of relevance and from periphery to center of focus, speed can be displayed as a discrete change of color of the windshield (e.g. in the normal green - yellow - red spectrum), by an ambient sound, or gentle vibration in the seat and only if prompted by the 'context-cruise-control' or as friction in the speed pedal. The context-cruise control renders speed not absolute (e.g. as a digit) but relative to the road quality, an upcoming turn (informed by the navigation system), or the drivers state of alertness, excitement (determined by eye tracking, infrared measurement of face temperature and transpiration from the hands) etc. Likewise, the level of fuel is only relevant if the source is running low in relation to the present radius of the car and the next station (determined by the cars position system).

To make the instrumentation more ambient and calm ways of displaying is determined by learning mechanisms monitoring the behavior of the driver on the basis of certain preset modes. Gaze tracking, seat sensors, and cameras coupled with databases logging subsequent behavior after announcement of information will be prime mechanisms for feedback determining what information the driver finds relevant and useful. All data are stored and submitted to statistical analysis to facilitate proactive behavior from the assistants in subsequent similar situations.

Since cars are highly dependent on safety and general functional smoothness, upgrades will mainly happen through simulation, and they will only be implemented with the replaced configuration as back up. Through a swift version of the regression tester of [24] critical functions will switch to the former mode within fractions of a second if the new upgrade fails. Minor alterations that take place on the fly are for instance the reorganization of displays and timing for primers and warnings.

5. DYNAMIC DESIGN: CUSTOMIZATION VS. ADAPTIVITY

The relation between the development of an organism and its environment is a complicated and controversial issue within biology. As noted earlier, more and more biologist tend to conceive the interactions between organisms and their environment as mutually constitutive. Hence many biologists reject the hitherto dominant picture of genes as a discrete causal source of development [28]. Cognitively, the organism constructs its environment as a 'world' of features relevant for self-maintenance, and the environment constrains which constructions are possible [9, 17, 44, 45, 46]. Physically, organisms change and construct their environment by building dams and nests, killing pray, eating vegetation, fertilizing etc. in the process of adaptation [12, 40]. The history of human civilization is an overwhelming demonstration of this fact and our interactions with the surrounding has led to fundamental changes of nature given niches.

Adaptation is thus not to be understood as the accommodation of an organism into a specific niche but the reciprocal forming and co-development of these two aspects of an

ecology. Talk within the fields of Human Computer Interaction (HCI) and Usability of 'natural interaction' (e.g. 'natural handling', 'natural use', 'human interface') often rest on a slight misconception of development and adaptivity, as there is no essential and fixed 'nature' of an adaptive being other than in a broad sense. 'Naturalness' is nothing but the present state of adaptation, and adaptation rest on variations rewarded or punished for their consequences.

Technologically speaking devices co-determine their use as well as the 'natural' habits of the users and this interaction is what makes development of artifacts truly dynamic and complex. For dynamic methodologies it means that the design for adaptivity in artifacts have to be carefully considered. Firstly, because dynamics without constraints are uninteresting we must learn to implement constructive channeling of dynamics. Secondly, because interactive coupling amounts to adaptivity and not a customized fit that fixes the user into a specific user pattern adjustment should be dynamic and preferably open ended. The fitting of a skilled tailor is good customization, the breaking in of the clothes is adjustment and the continuous reconfiguration of a smart fabric is adaptivity. The distinction between customization and adaptivity is a small but important motivation for dynamic artifacts.

5.1 Examples: The adaptive news service and computer game

Take an on-line news service providing customization of content and form by allowing the customer to determine dimensions of interests (themes, regions, countries etc.), extension (length/inclusiveness), layout preferences etc. If the news service never breaks the initial and explicit parameters by spontaneous variation it will become dysfunctional over time. The news service cannot be said to deliver news in the proper sense, and the reader will not be widely enlightened but withheld within the exact same realm of knowledge. Besides, if the reader, perhaps even unknowingly, changes interests the news service cannot follow because it will not get corrective feedback as it has not provided variations to choose among. Similar to the standard procedure of successful websites such as Google and Amazon, parts of the news service have to be subjected to occasional variation of content, format etc. to obtain adaptive dynamics. Consider for example the case where the category of 'foreign policy' is not within the preferred dimensions of interest to the reader. If a major terror attack strikes abroad then the reader will not read about it. But this 'breaking news' may in fact also be of interest to the reader normally only interested in domestic affairs.

If the news service has not got a dynamic 'backdoor' open to let in critical news from outside the normal dimensions of interests it can only be said to be one-way adaptive; a customized filter. An adaptive news service will throw in something unexpected from time to time. The level of variation is determined by learning mechanisms optimizing positive feedback from the reader. Feedback that is provided by for example eye-tracking, determining where, in what manner, and for how long readers look at specific sections, and by explicit evaluation by the reader.

Take a computer-game adapting to the players performance, sensor feedback on stress, alertness, affectivity etc. A game adjusting to keep suspense at a constant maximum or to obtain another equilibrium would quickly become boring. That is, if the game AI predicts most of the likely actions of the player it simply becomes too strong and if predicting none it becomes boring. Suspense is dependent on relaxation, and good game-play is dependent on changing amplitude of intensity. The game must throw in something genuinely unexpected from time to time to be of interest. That is the reason why game developers strive to give AI characters human characteristics such as temperament, irrational decisions, and general unpredictability in order to render them engaging. In

fact mere randomized relevant actions are reportedly considered 'smart' by players [38].

These are trivial examples but thus more apt to contrast adaptivity with customization. Customization is not adaptability but rather a tailor-made fit and therefore not adequate for a lot of artifacts when the user is a dynamic system. Or more correctly, artifacts meant to interact with the variant aspects of (adult) human-technology interaction, e.g. cognitive capacities broadly considered (as opposed to in variants such as our physiology) should be adaptive and not customized. This is why the evolved sofa is still functionally interesting without frequent adaptive updates. The only dynamics a dynamic design of furniture must take into account is changing fashions and occasional changes of placement and this is covered by eventual upgrades. In contrast to customization, adaptivity rests on variation and sometimes ruptures to obtain the possibility of informational feedback. Even variations that proved unsuccessful before are (within certain limits) legitimate for dynamic artifacts as the selection context may be changed. Besides, selection happens post hoc so unpredictability is an inherent ingredient in adaptive dynamics.

6. DISCUSSION

To a reader less enthusiastic than the author, it might seem like as if dynamic artifacts has been unduly presented the deepest dream of everybody with its adaptive functionality, strong emotional bonding from shared history, and a high level of personalization. The story is of course not that simple, neither technically nor socially. All technologies have downsides, and many different questions on dynamic artifacts have been left untouched so far. Besides a number of technical and practical issues there is also the basic question whether ordinary people really want dynamic artifacts if it means spending time nurturing the artifact. For instance, will the concept of dynamic artifacts and distributed authorship of design get into conflict with consumers wish for strong brands?

I shall be the first to admit the conceptual nature of the arguments and the examples brought forward. Dealing with the future and novel technologies admittedly gets a little awkward as we cannot yet take into account most practical problems and obvious possibilities. The future most often turns out differently than imaginative minds depict, and for the conservative it might simply seem a waist of time to make any effort to 'catch up' on the coming. However, let us briefly sum up the merits of the analysis undertaken in this paper.

The main point in investigating dynamic design is to become familiar with the circular nature of prospect dynamic artifacts. The linear consumerism is so powerful that opposing this logic and introducing the idea of artifacts as something worth cultivating seems close to perverse. It has become bad business to produce artifacts that last and naïve of customers to believe they will do - if they want them to last at all. The interesting anthropological question is of course whether customers really want artifacts to last.

We might soon have the adequate theoretical and technological means to create adaptive artifacts that reflects the unique habits and tastes of their users and bears the mark of the way a given brand guides the adaptation. But it is still to be seen how consumers react to a new combination of these dominant design factors. Even if we live in an increasingly high-tech and allegedly more technologically pliant world, it is now more than ever the added value, the narrative cloaking and identity yielding capacities of products - the branding in short - that convey a special feeling or identity to the customer and thus the decisive attractiveness to commodities. Most brands build on an extensive narrative, and branding always implies aggressive conservation of certain core ideas

defining the brand. For dynamic artifacts, brand value is an important caveat as new types of artifacts simply do not survive if too much in dissonance with important psychological and sociological constraints. Dynamic design primarily gains its strength from functional coupling whether as brands build on social coupling. Dynamic artifacts might not stand a chance as design paradigm, if the dynamics is in fundamental conflict with the conservative nature of branding; functionally superior or not.

The structural fibers of social processes are to a large extent symbolic, and in all processes the right balance between structure and dynamics is crucial. You cannot have artifacts too dynamic to conserve the semiotic value of it, as all symbolic systems rely on identity or at least compatibility through processes. If artifacts get too personal and idiosyncratic, they do not allow for immediate categorization of your fellow social agents. Even though e.g. a Nokia cell phone was functionally superior to a Panasonic, it is unlikely that a Japanese schoolgirl would choose the Scandinavian one if it was totally unknown or associated with the wrong segment (e.g. business) in Japan. That is the reason why advertising takes up the majority of expenses for very brand dependent products and companies.

Put in more general terms, users will not necessarily embrace dynamic artifacts for their functional superiority alone. As an analogy, despite its name, functionalism in furniture design and architecture is just as much adored for its visual characteristics as its actual functional deeds. So with the probable exception of deep infrastructural elements, dynamic artifacts might need additional layers of normativity and semantics in order to gain commercial leverage. The crucial question for dynamic design then becomes: Is it possible to design and convey added values for artifacts continuously adapting to the user? Is it necessary at all? Does the need for added value stem from a fundamentally useless nature of many artifacts and the resulting semantic vacuum? Could adaptability be a strong branding feature? Can dynamics be trendy?

Being a layman in questions regarding brand psychology and sociology, I can only guess how dynamic artifacts will manage in a brand-crazy world. My guess is, that the nature of branding will change with dynamic artifacts, without diminishing the importance of what branding offers socially and psychologically. So given that importance of branding is not only a passing post-industrial phenomenon related to mass production but actually rest on deeper social, psychological and even existential traits of human living, let me sketch the positive version.

As an extension to present mechanisms, branding would start comprising services extended in a historical unfolding of developing produces, not just a synchronic and passive semiotic badge for social identification. Produces and thus brands would literarily gain a new dimension. Evolutionary produces would be highly personal and historical, a genuine reflection of their users. A branded produce would still indicate choices of aesthetics and functionality as in static products but on the basis of evolutionary algorithms providing ongoing adaptation and change.

This scenario seems like a win-win solution as customers get both the brand value, which is so important socially, and a highly personal produce. Customers will feel an attachment toward produces that has grown with them for years and they can decide how much 'brand' the process reflects (by tuning the dominance of original DNA, c.f. section 2.1.1). As for the personal bias of dynamic devices confronted with inherently social branding semiotics, I should emphasize that adaptivity is 'blind' and excels in proven worth. If any social process benefits from a service, this service will per evolutionary principle be available sooner or later.

Ultimately, a new dynamic design trend might be a win-win solution. The problem of pollution related to consumerism would be seriously diminished if we started to implement long term dynamical principles such as making old produces provide nourishment for new produces in ecological cycles. McDonough and Braungart argue at length that consumerism in the pejorative sense is tied to a linear and myopic view on artifacts created by the mass production invented during the industrial revolution [26]. In nature on the other hand variance and abundance are valuable and necessary principles as all living organisms provide the basis of subsequent life in cyclic processes of growth and decay, nutrition consumption and nutrition production. By expanding the scope when designing to allow for the productive and 'life-giving death' of artifacts, consuming would become meaningful. Such ideas admittedly seem quite idealistic and unrealistic today. But the way design of technology has been conducted for centuries might just as well seem strange and archaic in a couple of decades if dynamic design principles catches on. It is not exaggerated to talk about a genuine commercial and social revolution if we follow through such dynamic considerations when designing artifacts.

Even if granted that dynamic artifacts are culturally resonant there are other more intrinsic problems in making artifacts evolve critiques could argue. Evolutionary processes are inherently historical and 'path dependent' but we often rather get rid of our user history. For instance, when we change habits, style or context we need to be able to do so without major problems. There is no point in inventing dynamic artifacts if they do not allow for the sudden shifts of human life. History serves to prevent techno-alienation and to promote tight functional coupling. But not all of our personal technology should follow us for long periods of time.

It is true that certain features of natural adaptive dynamics are not at all attractive for technology. Adaptation by evolution is a general method and quite elegant and robust as such. But in a range of specific technological contexts evolution is insufficient or even destructive. Especially some of the long-term dynamic aspects such as lock-in and tinkering could get counter productive if imported into dynamic design.

Nonetheless biologically inspired dynamic design is all about identifying and exploiting the beneficiary principles of natural adaptive processes and to avoid the rest. Counterproductive path dependency might be somewhat remedied by logging evolutionary dynamics so that getting back to an earlier genome for a device is always possible [24]. Yet, such a conservative measure will pile up immense amounts of information and need some kind of filtering to be feasible. Lock-in syndromes are worse by allowing for the dominance of inferior solutions due to structural and historical characteristics. Such syndromes are almost impossible to 'reverse' and change because of their universality. Lock-in is widely known in technological 'evolution', as for instance the QWERTY keyboard I am writing on right now. Other classic examples are the VHS video format and Microsoft Windows operating systems. Because these artifacts got the dominant market share at an early point they enjoy practical monopoly today.

Besides monitoring and guiding the evolutionary and self-organizational processes of biomimetics in an effort to promote the, to our best judgment, superior solutions and standards I cannot provide any cure for such historical phenomena. Certain problematic dynamic phenomena might simply be the price we pay for adaptively dynamic artifacts.

7. RESUME OF PAPER

We have examined and discussed a range of issues relating to a prospect dynamic approach to design. The paper departed from biomimetic IT design, as dynamic design will probably

first and foremost manifest itself in IT. Biomimetic IT design is primarily a design methodology for complex IT systems, but it bares just as much witness to a general change in design and conception of artifacts. If technology today is conceived of as products allowing for minor surface changes to meet the user's habits and preferences, there is no natural law (only historical circumstances) preventing artifacts from becoming much more adaptive and personal.

Through conceptual analysis and different examples this paper has investigated how dynamic artifacts might come to be designed in the future. Dynamic artifacts are characterized by their responsiveness to use and their parameters are chosen for their developmental capacities rather than as an idea of ideal use contrived by the designer. I have introduced the term 'produces' to capture the open ended process character of dynamic artifacts as contrasted with finished high tech products leaving the assembly line only to degrade. Similar to present production, and to a certain extend natural systems, dynamic design will rely on modularization. I have introduced a distinction between structural and temporal modularization. Structural modularization serves to remedy the lack of autonomous reconfigurable materials capable of responding adaptively to changed functional circumstances.

Structural modules are widely used in present production and the only difference for the modularity of dynamic design will be greater variability and personalization made possible by extensive EC simulation of functional coupling between a number of different modules. Temporal modularization means dividing the functional adaptive process into phases to guide adaptivity and benefit mostly from the hybrid of human design and evolution. I have proposed three different adaptive phases, named pre hoc, ad hoc and post hoc, capturing different qualities and powers of dynamic design. To illustrate different qualities of dynamic phases two examples was presented and analyzed. The evolved sofa represents artifacts that will benefit mostly from careful pre hoc design and only to a minor extend from ad hoc adaptivity. The adaptive car is an example of how high tech devices are likely to gain a lot of reconfigurable possibilities from ad hoc interactive adaptivity.

Finally, I have discussed expected critique of dynamic design and dynamic artifacts more generally. Not surprisingly the issues relating to dynamic artifacts are matters of this very dynamics. The dynamics of artifacts might simply be in conflict with certain basic social and consuming phenomena such as brand value and identity generation. In addition dynamic artifacts might either come to suffer from a range of inopportune dynamic traits such as lock-in or simply get too historically 'heavy' (conservative) to allow for fast changes characterizing modern life.

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