Research for Cultural DNA in Design

John S Gero
Computer Science and Architecture, UNCC and Krasnow Institute for Advanced Study, GMU

Abstract. This position paper commences with a brief overview of where the cultural DNA may lie in the enterprise of designing. It puts forward the concept that cultural DNA is not a unitary concept and needs to be treated multi-dimensionally deriving from multiple sources. The paper outlines research that supports cultural DNA research in design.

1 Introduction

The term "Cultural DNA" has come to mean any mechanism that transfers culture from one generation to the next. Culture here is taken in its broadest meaning, ranging from social implicit knowledge to explicit technical knowledge with many shades of knowledge in between. Cultural DNA implies both a means of representing culture and a mechanism that transfers culture from one generation to the next. The notion of generation here does not necessarily imply human generations, rather it is meant to signify that culture is transferable.

Designing, the process of generating proposed changes in our physical, virtual and mental worlds motivated by a set of initial requirements, is one domain where cultural DNA can be studied more formally. Designing involves the value systems of a heterogeneous set of players in its enterprise and it is those values systems that form the basis of a culture.

This position paper commences with a brief overview of where the cultural DNA may lie in the overall enterprise of designing. It proposes seven potential loci. This is followed by a brief overview of what has been studied by researchers in these areas that may point to engaging cultural DNA. The methods used to study design creativity are listed. This is followed by examples of research that captures cultural DNA. The final part outlines a number of future directions for design cultural DNA research and posits a set of research questions for each of the directions.

2 Where Can the Cultural DNA be in Design?

Where can the cultural DNA be in design? Although this is an obvious question is surprisingly difficult to answer. There are seven hypotheses that are candidate answers to this question:

- in the design;
- in the observer/user of the design;
- in the design process that produced the design;
- in the designer;
- in the interaction between the user and the design;
- in the effect the design has on the individuals and the society in which they sit; and
- in the interaction amongst all of the above

Given that are multiple hypotheses about where the design cultural DNA might be implies that cultural DNA in design is not a unitary concept and needs to be treated multi-dimensionally. In the remainder of this paper will use the term “cultural DNA” as a shorthand for “cultural DNA in design”.

2.1 Cultural DNA is in the Design

The design itself would appear to be the most obvious place to locate cultural DNA since it is the design that is most commonly experienced by a user or observer. Designs are consumed and their representations, even when not reified, are transferred and viewed. However, since this requires a consumer or an observer, it may be that it is insufficient to claim that the cultural DNA only resides in the design. However, representations can readily be transmitted from one generation to another.

2.2 Cultural DNA is in the Observer/User of the Design

If the cultural DNA does not simply lie in the design itself it may be that it is an interpretation of a design by the assessor. The assessor may be a consumer of the design or an observer. They generally do not specify the criteria they use in their assessment. This turns cultural DNA from an inherent property of the design to a property of the assessor of the design. The consequence of this is that different assessors would assess the cultural DNA of a design differently.

2.3 Cultural DNA is in the Design Process that Produced the Design

Since designing is a process it can be suggested that the cultural DNA is in the process that produces a design. This has the attraction that processes can be readily studied.

2.4 Cultural DNA is in the Designer

Most designers are recognized as having a regularity and consistency in the designs they produce. It may be that is the unique characteristics of those designers that gives them this consistency. It may be the characteristics of the designer that embody the cultural DNA.

2.5 Cultural DNA is in the Interaction between the User and the Design

It may be that cultural DNA is an affordance (in the Gibsonian sense) between the user and the design and as a consequence is the result of an interaction between the user and the design. This means that the cultural DNA is in neither the design nor the user but is a consequence of the interaction of the user with the design. That interaction could take many forms. It could be a derivation by the user of the behavior of the design. It could be an ascription by the user to the design. It could be a mixture of both of these.

2.6 Cultural DNA is in the Effect the Design has on Consumers and the Society in which Designs Sit

It may be that cultural DNA is an effect that a design has on the individuals and the society in which it sits. This implies that cultural DNA is in the changes in the values of individuals and of society.

2.7 Cultural DNA is in the Interaction of All the Above

It may be that cultural DNA lies in the interactions between users, assessors and the design within a society. The consequence of this is that cultural DNA becomes a situated, constructive act. Situated means that the social interactions of individuals depend on their view of the world at that time and this guides their interactions. Constructive means that any assessment is not simply a recall of past assessments but is generated based on the past and the current situation to meet expectations that come from the situation.

3 What About Cultural DNA in Design Has Been Researched?

All seven of these hypotheses for the location of cultural DNA in design have been examined at various levels of intensity and detail.

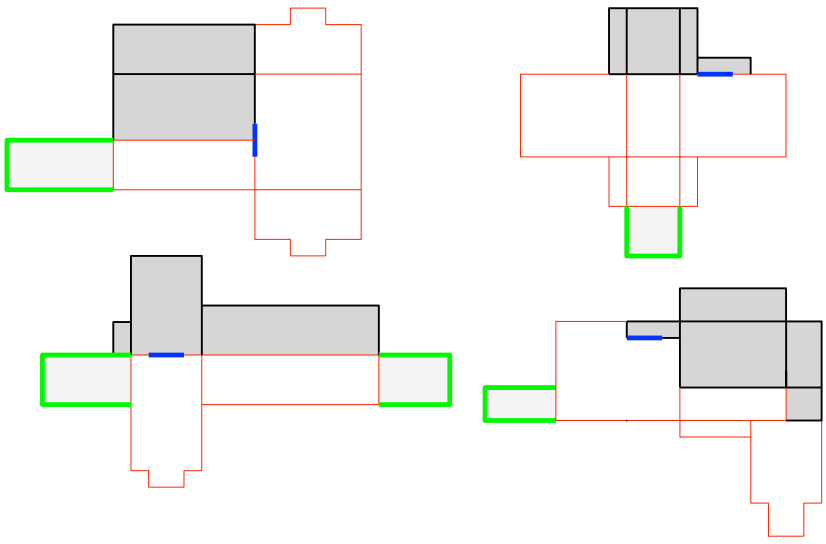
3.1 Studying Cultural DNA in the Designs

The study of cultural DNA in designs assumes that cultural DNA resides in the transferable representations of the designs, ie, the representations embody the cultural DNA. All CAD systems are built on representations of objects. These representations include geometry and topology and increasingly material properties and occasionally behavioral and functional properties, that together make up the cultural DNA Thus, we can observe design style and schools of design from the designs themselves.

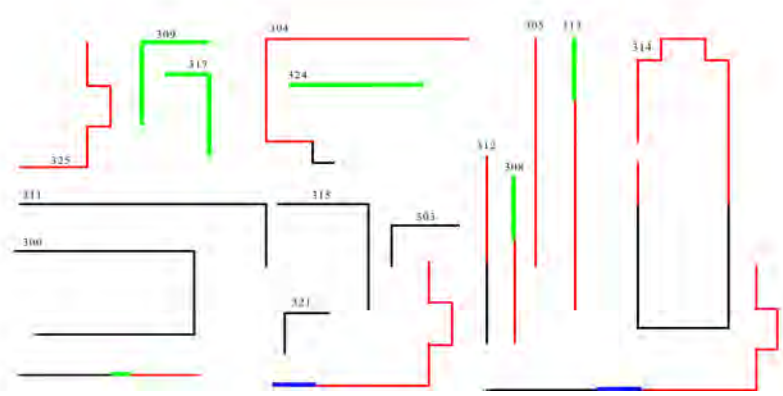
An example of such an approach to the generating the representation of designs can be seen in the genetic engineering of the genes of an object. Genes, in natural evolution, are the building blocks of the representation of an organism. They need to be transformed into the elements of the organism. In design they are building blocks of the representation of a design that need to be transformed into the components of a design.

Genetic engineering applied in design captures gene structures that are causally linked to structures in the design (Gero and Schnier, 1996). An example of this is given in Figure 1 where (a) is a set of four floor plans of Frank Lloyd Wright buildings and (b) shows a set of genes genetic engineered from those plans that capture the cultural DNA of those Frank Lloyd Wright floor plans. Figure 2 is an example of a genetically engineered Frank Lloyd Wright house based on transferring the cultural DNA of such houses to a new instance. Similar ideas are embodied in the induction of shape grammars from examples, where the shape transition rules capture the embodied cultural DNA in the initial representations (Stiny & Mitchell, 1978).

The representations of the genetically engineered genes in Figure 1 become the cultural DNA for these objects. While the “design” in Figure 2 is a demonstration of the use of this cultural DNA in the next generation.



(a)



(b)

Figure 1: (a) Four Frank Lloyd Wright prairie house floor plans, (b) 18 genes that represent the cultural DNA embodied in those floor plans (after Gero and Schnier, 1996).

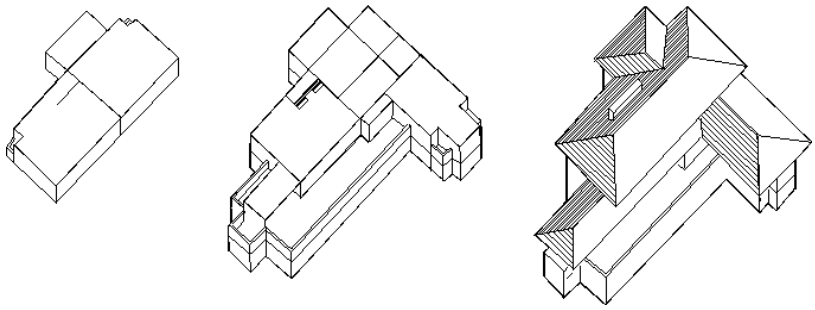


Figure 2: A genetically engineered Frank Lloyd Wright prairie house based on the cultural DNA, in Figure 1(b), of a set of existing Frank Lloyd Wright houses (after Gero and Schnier, 1996).

3.2 Studying Cultural DNA in Observer/User of the Designs

As indicated in Section 2.2 all designs must have an observer/user to bring them into human cognition through perception. This implies that the cultural DNA is an interpretation by an observer of the design. Interpretation is a rich cognitive activity that depends on the past exeperience of the observer and the observer's expectations, which are a function of the observer's current situation (Kelly & Gero, 2014). The past experience covers both Frank Lloyd Wright floor plans and of Andrea Palladio villa plans. If we present the observer with some source data to be interpreted it depends on what the observer is exepcting as to what features they see in the same source data, Figure 3.

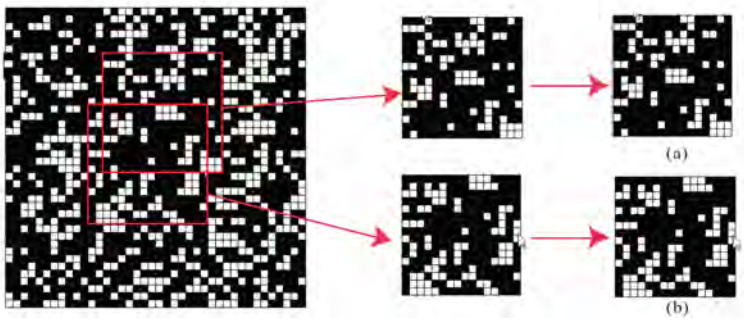


Figure 3: The same source data on the left produces different results for different expectations. (a) Expecting a Frank Lloyd Wright floor plan, and (b) expecting a Palladio floor plan (Kelly, 2011)

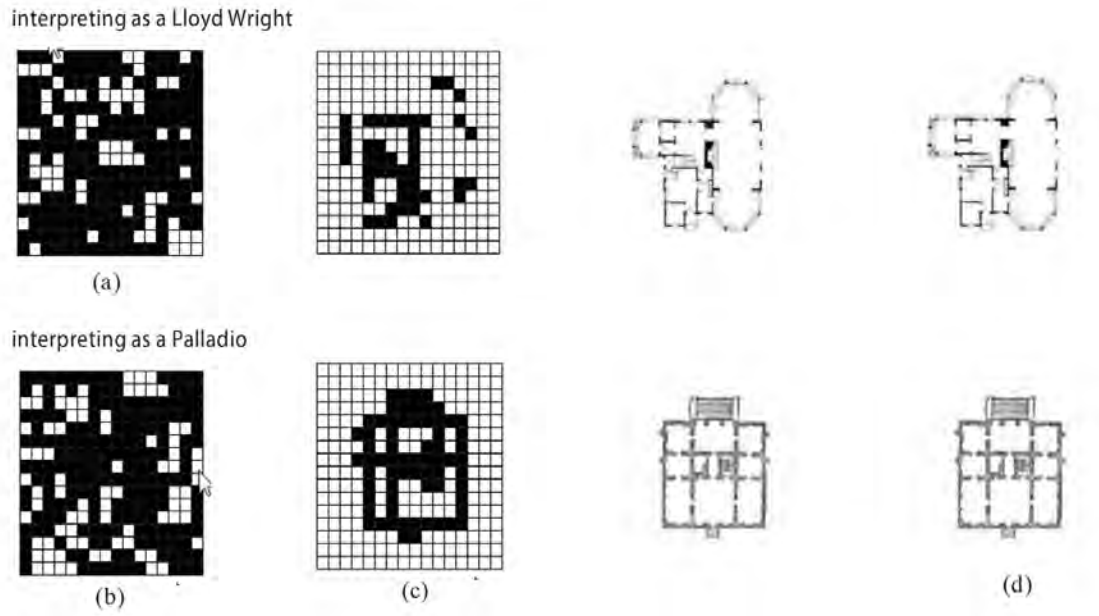


Figure 4: The two interpreted features are compared to the original representations that were part of the training set from: (a) a Frank Lloyd Wright floor plan, and (b) an Andrea Palladio villa plan. The images labeled (c) are representations of the concepts within the system that have been interpreted based on expectations. The images labeled (d) are the original representations used in the training set (Kelly, 2011).

3.3 Studying Cultural DNA in the Design Process that Produced the Designs

All designs are a result of a set of processes. Design processes can be learned and represented so that they can be executed later. Just as genetic engineering applied in design captures gene structures that are causally linked to structures in the design, so it can be applied in design processes to capture regulatory gene structures that are the processes that are causally linked to the structures in designs. This captures the cultural DNA of design processes in the form of the processes that generate a design style.

Take the example of a particular Chinese architectural style exemplified in Figure 5. There are multiple facets of this style that need to be captured such as “eave is above column”, “repeated eaves” and “pyramidal eave is above eave”. Then a process is needed to arrange these style elements into a uniform style.

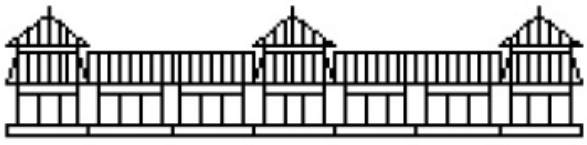


Figure 5: Example of Chinese façade exhibiting a particular style (Ding and Gero, 2001).

We can use the same genetic engineering concepts as earlier to capture the design processes that produce the style. We can commence with the elements of the designs and evolve genes to capture the processes that operate on them to produce the style, Figure 6.

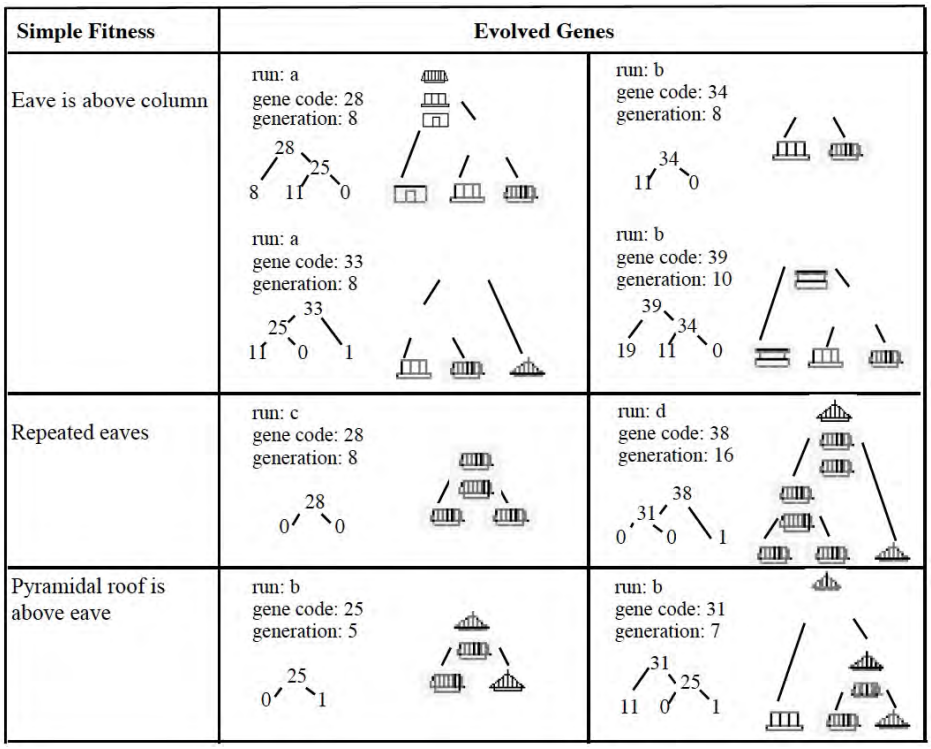


Figure 6: Examples of the evolution of genes that capture style elements (Ding & Gero, 2011).

3.4 Studying Cultural DNA in the Designer

In order to gain access to the designer's cognition we can use protocol analysis and produce models from the results of the analysis. Protocol studies of design cognition involve having designers verbalize as they design and converting their verbalization into semantic symbols. These symbols can then be analyzed in multiple ways to build models of f the designer designing. Exemplary results are patterns of cognitive behavior while designing. A design pattern of a designer is captured in the transitions between different cognitive variables indicated by high probability of moving from one to another. The high probability implies a level of invariance, which can be considered the designer's cultural DNA. A designer's pattern connecting function, structure, expected behavior and behavior from structure, derived empirically, is presented in Figure 7.

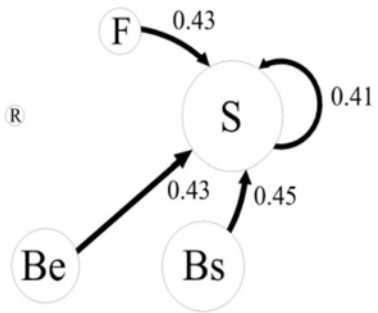


Figure 7: A designer's pattern that contains implicit knowledge (Yu & Gero, 2016).

How implicit knowledge represented by such a pattern can be transferred from one generation to the next is currently unclear.

3.5 Studying Cultural DNA in the Interaction Between the User and the Design

There have been many studies of the affordances the users find in their interactions with designs (e.g., Piper & Hollan, 2009) and there is considerable research on using affordances in design (e.g., Gero & Kannengiesser, 2012; Maier & Fadel, 2009), but there is very little research on learning and representing affordances in a transferable way that is required for it to be cultural DNA. Affordance can be considered as a habituation or grounding of patterns that connect function with structure.

Research on constructive memory (Peng & Gero, 2013) is one direction that has the capacity to learn habituation, which makes it a candidate for learning and representing affordances (Peng & Gero, 2009). An example of a constructive memory system that learns through interactions with its environment is presented in Figure 8. This is a constructive memory system learning concepts that are reinforced through use resulting in habituation of the grounded concepts so that no more learning is needed to apply them.

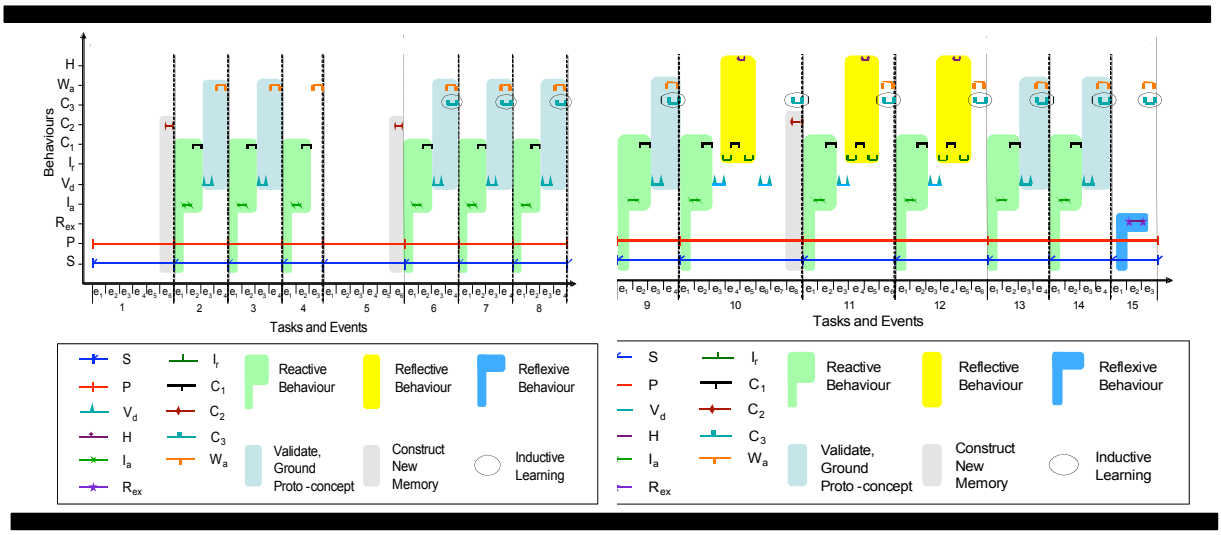


Figure 8: A constructive memory system where an initial interaction results in a proto-concept (shown in grey). That concept is used if possible in future interactions (shown in green). If the use is successful it adds to the grounding of that concept. If no concept can be found that is useful a new concept is constructed (shown in yellow). If a concept is sufficiently grounded it becomes a habituated concept (shown in blue) and becomes a pattern that requires no reasoning only matching for it to be used (from Peng & Gero, ACS2015 presentation).

3.6 Studying Cultural DNA in the effect the design has on consumers and the society in which they sit

From a cognitive perspective any interaction between the design and potentially consumers results in a change in the values consumers use to assess designs. In addition to direct interaction with designs consumers interact indirectly with designs through the social media of the society in which they sit. Agent-based models of interactions including social interactions have the capacity to model and capture this behavior, Figure 9 (Gero & Thomas, 2012; Thomas & Gero, 2015).

The cultural DNA is represented in the value systems of the individuals and is based on their experience. However, it is affected by the social influences of others. In this view cultural DNA is distributed between the designers and consumers and is influenced by their social interactions.

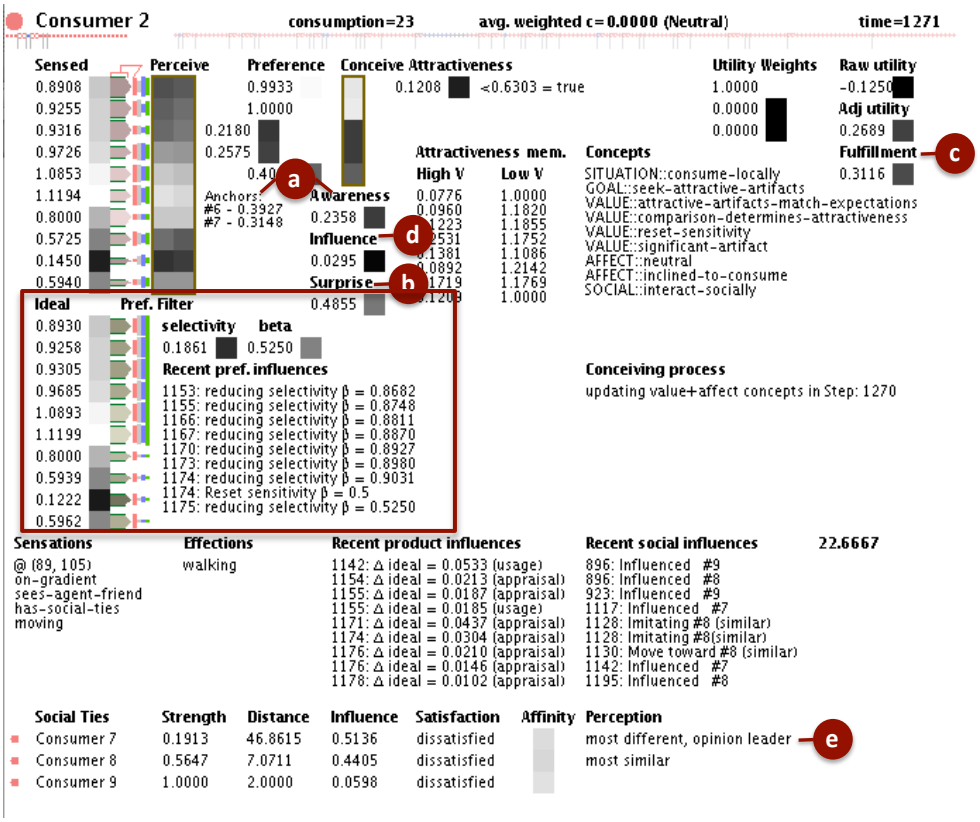


Figure 9: A screen shot of the values inside an agent showing (a) perception connecting with awareness, (b) the surprise metric, (c) the fulfillment metric; (d) the influence metric, and (e) social influence metric, within the sensation-perception-conception-situation cognitive framework. The values that the agent uses for its ideal product, shown inside the red rectangle, change as a consequence of its interactions (Gero & Thomas, 2012).

3.7 Studying Cultural DNA in design in the interaction amongst all of the above

This last notion of cultural DNA subsumes the notions of cultural DNA being in the representation, of the cultural DNA in the process, of cultural DNA being in the assessor, of cultural DNA being in the designer, of cultural DNA being in the interaction between the user and the design and of cultural DNA being in the society within which the design exists. This holistic view has not been researched in any formal way.

6 Conclusions

Cultural DNA may not be a unitary concept: any mechanism that transfers culture from one generation to the next. However, it appears to have many facets. In this paper we have identified seven facets of where the cultural DNA might reside:

- in the design;
- in the observer/user of the design;
- in the design process that produced the design;
- in the designer;
- in the interaction between the user and the design;
- in the effect the design has on the individuals and the society in which they sit; and
- in the interaction amongst all of the above

These and potentially other facets indicate that cultural DNA in design is a rich concept that plays a role in the way in which individuals, groups within a society and societies interact with their artefacts and with each other.

Cultural DNA remains a relatively under-researched area, as a consequence there are numerous research questions to be raised and answered to develop an understanding of it and its role. The results of such research will lead not only to an understanding of cultural DNA in design but will generate the foundations for the development of tools to support cultural DNA in design and to provide society with more formal means to transfer knowledge between its members. In doing so it raises counter-balancing issues: formalization of acquired knowledge facilitates its transfer that increase cultural coherence while at the same time increases the likelihood of it limiting the acquisition of other knowledge that is in opposition to the initial formalization of that knowledge. This is a form of "dynamic conservatism" which is the way that established institutions normally respond in the face of change in order to stay the same (Schon, 1973). For cultural DNA to remain a useful concept it must embody means for its adaptation to changing social values.

Acknowledgements

The research reported in this paper has been supported by grants from the National Science Foundation, Grant Nos. CMMI-1400466, SBE-0915482 and CNS-0745390 and by the National Aeronautics and Space Agency, Grant No. UAH SUB2012-038.

References

Ding, L. & Gero, J. S. (2001). The emergence of the representation of style in design, *Environment and Planning B: Planning and Design*, *28*(5), 707-731.

Gero, J. S. & Kannengiesser, U. (2012). Representational affordances in design, with examples from analogy making and optimization, *Research in Engineering Design 23*: 235-249.

Gero, J. S. & Thomas, R. (2012). Modeling Change in Design Values and Evaluations of Teams as They Interact, *Report to NASA*, Award No. UAH SUB2012-038.

Kelly, N. (2011). *Constructive interpretation in design thinking*. PhD Thesis, The University of Sydney, Sydney.

Kelly, N. & Gero, J. S. (2014). Interpretation in design: Modelling how the situation changes during design activity, *Research in Engineering Design*, *25*(2), 109-124.

Maier, J. R., & Fadel, G. M. (2009). Affordance based design: a relational theory for design. *Research in Engineering Design*, *20*(1), 13-27.

Peng, W. & Gero, J. S. (2009). *A Design Interaction Tool That Adapts,* VDM Verlag.

Peng, W. & Gero, J. S. (2013) Situated concept formation from interactions: An implementable constructive memory model, *Advances in Cognitive System Conference*, Atlanta, Georgia, pp. 1-17.

Piper, A. M. & Hollan, J. D. (2009). Tabletop displays for small group study: affordances of paper and digital materials. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1227-1236). ACM.

Schnier, T. & Gero, J. S. (1996). Learning genetic representations as alternative to hand-coded shape grammars, *in* J. S. Gero and F. Sudweeks (eds), *Artificial Intelligence in Design'96*, Kluwer, Dordrecht, pp. 39-57.

Schon, D. A. (1973). *Beyond the Stable State: Public and Private Learning in a Changing Society*, Norton

Stiny, G., & Mitchell, W. J. (1978). The Palladian grammar. *Environment and Planning B: Planning and Design*, *5*(1), 5-18.

Thomas, R. & Gero, J. S. (2015). Moving targets: How consumers change value systems through interaction with designed products and other consumers, *in* C Weber, S Husung, G Cascini, M Cantamessa, D Marjanovic and M Bordegoni (eds), *DS 80-11 Proceedings of the 20th International Conference on Engineering Design (ICED 15) Vol 11:Human Behaviour in Design*, Design Education, Design Society, pp. 41-50.

Yu, R. & Gero, J. S. (2016). An empirical basis for the use of design patterns by architects in parametric design, *International Journal of Architectural Computing 14*(3): 289-302.

Bibilography

Boyd R, Richerson PJ. (1985) *Culture and the Evolutionary Process*. University of Chicago Press.

Buchen, L (2009) Culture may be encoded in DNA, *Wired* 3 May 2009. (https://www.wired.com/2009/05/songbirdculture/)

Cavalli-Sforza LL, Feldman MW. (1981) *Cultural transmission and evolution: a quantitative approach*. Princeton University Press; Princeton.

Cheverud JM. (2003) Evolution in a genetically heritable social environment. *Proc Natl Acad Sci USA*: 4357–9.

Chiao J, & Blizinsky K (2010) Culture-gene coevolution of individualism-collectivism and the serotonin transporter gene. *Proceedings of the Royal Society B 277*(1681):529-37.

Feher, O., Wang, H., Saar, S., Mitra, P. P., & Tchernichovski, O. (2009). *De novo* establishment of wild-type song culture in the zebra finch. *Nature*, *459*(7246), 564–568.

Henrich, J., & McElreath, R. (2007) Dual-inheritance theory: the evolution of human cultural capacities and cultural evolution. In *Oxford handbook of evolutionary psychology* (pp. 555-570). Oxford Univ. Press.

Lee, J-H. (ed) (2017) *Morphological Analysis of Cultural DNA*, Springer.

Marler P, Tamura M. (1964) Culturally transmitted patterns of vocal behavior in sparrows. *Science* 146:1483–6.

Minkov, M. Blagoev, V and Bond, H (2015) Improving research in the emerging field of cross-cultural sociogenetics, *Journal of Cross-Cultural Psychology 46*(3), 336-354.

Richerson, P. J., & Boyd, R (2005) *Not by genes alone: how culture transformed human evolution*. Chicago: Univ Chicago Press.

Way, B., & Lieberman, M. D. (2010) Is there a genetic contribution to cultural differences? Collectivism, individualism, and genetic markers of social sensitivity. *Social Cognitive and Affective Neuroscience, 5*, 203-211.