ELECTRONIC CHIMERA: VISUAL MEMES AND THE EVOLUTIONARY GENETIC DESIGN PROCESS

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Abstract
Evolutionary approaches to complex quantifiable design problems are becoming common, but the possibilities of using subjective functions in an evolutionary process are just beginning to be explored. Three subjective operations are presented that mimic simple models of biological evolution and genetics, but are based on visual memes as units of transmission: phenotypic blending, memetic meiosis, and meme splicing. The untapped strength of evolutionary design is the ability to unify both objective and subjective criteria in a single method, which will enable it to become the preferred generative process of architecture.

1. Introduction
Chi·me·ra (kī-mîr′, kī-l′): 1: a monster in Greek mythology usually with a lion’s head, a goat’s body and a serpent’s tail 2: an illusion or fabrication of the mind: esp: an unrealizable dream 3: an individual, organ, or part consisting of tissues of diverse genetic constitution (G&C Merriam 1963).
Evolution is here to stay. It has found a home in computers, creating a generative design tool of unprecedented capabilities. New tools make revolutions, changing our artifacts with how they are produced and how they are designed, ultimately changing our culture with how artifacts are used. In design, the use of evolution is currently confined to tool-making programmers, yet many cultural artifacts can benefit from a more intuitive and subjective non-programming application of evolutionary methods.

2. Models and units of cultural evolution
While not new, evolutionary models of cultural change have remained controversial, with disagreement continuing over particulate or discrete versus blended or continuous concepts of inheritance (Chick 2001). A similar debate was resolved in biology nearly a century after Mendel and Darwin, giving rise to the current model of evolutionary genetics as a combinatorial problem of discrete units (Fisher 1929). So if culture evolves, what are the units? Using a discrete model of evolution in design necessitates a discrete unit of cultural transmission analogous to the biological gene: the meme (Dawkins 1976; Laland and Odling-Smee 2000).

3. Evolution as a creative process
Evolutionary models have also been employed to analyze the creative process in both art and science (Simonton 1999). From these, chance, whether called serendipity or mutation, is seen as fundamental to achieving novelty and innovation in any generative system.

3.1. Evolution as a generative design process
Unlike a blank canvas model of creation, generative evolution can be viewed as a search process that is used to examine a preexisting universe of all possible solutions to the design problem, called a solution space (Borges 1964). If the solution space is divided into discrete variables, design becomes a search to discover ‘good’ or ‘best’ combinations, with the obvious brute force search method involving the generation and testing of each possible combination. Traditional optimization strategies engage in variations of this process, but are applicable only to problems with a finite and manageable search spaces (Alexander 2001). Artists intuitive search
methods can work with an infinite search space but are difficult to repeat and often result in entire areas remaining unexplored. Evolution offers a third search option: it can be seen as an optimization search strategy that works with infinite search spaces without having to generate each possible solution (Mitchell, 1996).

Evolutionary computation is the umbrella term now used to encompass the many variations of this process, including genetic algorithms, evolution strategies, and genetic programming. One key feature common to all of these models of ‘blind variation and selective retention’ is the fitness function: the rules or selection criteria allowing an individual to continue to reproduce. Evolutionary approaches have become familiar to complex ‘engineering’ design problems with objective quantifiable fitness functions, having been successfully employed in areas as diverse as investment banking, aircraft engine performance, and automated manufacturing (Coale).

What is just beginning to be investigated are the possibilities of using subjective nonquantifiable fitness functions in an evolutionary design process (Frazer 2002; Ibrahim and House 2004). Given the relationship between subjective selection and computation, it may be difficult to apply the umbrella term evolutionary computation to work that excludes quantification. However, such an approach clearly follows the biology model of the evolutionary genetic process.

3.2. Prologue to tsunami

Early precedents for a genetic design process can be seen in the finite combinations of rule-based composition in classical architecture. George Stiny followed this approach to generate a more complex modern form language with his development of shape grammars (Stiny 1980; Mitchell 1990).

Originating in music and the visual arts of the 1960’s, the concept of serialism is a different label for a combinatorial investigation of a solution space. Sol LeWitt identified the discrete combination of units in his work, saying, “I used the elements of these simple forms - square, cube, line and color to produce logical systems. Most of these systems were finite; that is, they were complete using all possible variations.” (Ostrow 2003). Paying homage to the infinite search space of design, Josef Albers stated, “In visual formation there is no final solution, therefore I work in series” (Fleming 1974).

Splicing operations analogous to genetic engineering also have parallel roots in visual art and music. Israeli painter/sculptor Yaacov Agam produced a series of works where he combined two independent images by cutting and alternately splicing to create a third composition. Martin Denny was among the originators of dissimilar source audio splicing with the use of bird calls to structure his recordings (Hosokawa 1999).

In current popular music, remix trends are raising issues about plagiarism and ‘old world’ copyright law. By marrying tracks from different artists to produce a new composition in a process called ‘mash-up’, the parent recordings are often acknowledged in titles like “Ladytron Vs Johnny Cash” (Miller 2004). Combining original tracks can be seen as a loose genetic process, but it is not yet evolutionary. When mash-ups mash-up mashed-up mash-ups, remix can be seen as evolutionary genetic design.

While not formalized, this process of iteratively recombining disparate elements is rapidly becoming the de facto operating system of our networked culture. Steps by the BBC and Google to allow content sharing, the now ubiquitous blog, open source software, and open access publishing all encourage the continual recombination of discrete packets of information with mutation to evolve something new (Knight).

Meme’s the word.

4. Evolutionary genetic design with visual memes

In 1994 I started a series of experiments in architecture and printmaking to investigate repeatable design methodologies of iterative operations. These methods mimic simple models of biological evolution and genetics, but are based on units of coherent visual structure, or visual memes, as the units of transmission. They can be executed without programming skills and
are based on combinatorial decisions, fitness functions, and mutations of subjective choice and random numbers (Haahr). All were accomplished with off-the-shelf digital imaging software Microsoft Windows Paint and Adobe Photoshop v.3 – v.7. Three basic operations were developed and have been tested individually as well as in combination: phenotypic blending, memetic meiosis, and meme splicing.

4.1. Phenotypic blending

By treating a visual image as analogous to an individual physical biological organism, or phenotype, it is possible to combine whole images to produce progeny without overt knowledge of the underlying memetic structure. Color blending of discrete pixels is accomplished by the Photoshop image/apply image operation, which maps one image onto another while effectively introducing a mutation by the choice of a specific blending operator. To start the process, a single parent image is copied and mutated one or more times via Photoshop image/adjustments or filter operations to generate diversity in the initial breeding population. The iterative recombination of image pairs develops a family tree, with the designer selectively retaining and rejecting image attributes much as plants and animals have been domesticated in the past.

All the usual cautions regarding inbreeding apply.

4.2. Memetic meiosis

By treating a visual image as analogous to the biologically coded instructions for organism reproduction, or genotype, genetic models can be employed to produce new visual structures. Following the genetic process of meiosis, two images are partitioned by visual inspection into an identical number of discrete meme slices, with these slices recombined to generate progeny of various meme combinations (Thompson et al. 1991). A random number of offspring are then selected from the set of possible combinations of the two parents, with a specific meme combination identified for each. Recombination of the memes is accomplished via a matching rule that determines the connecting point of adjacent memes. Frequency and location of crossover operations are determined by random number. After meme recombination, the type and degree of mutation as well as the number of offspring to receive mutations are selected by random function. Photoshop filter operations are used as the library of possible mutation operations.

4.3. Meme splicing

Following the genotype analogy for image structure, recombinant splicing operations from genetics can also be applied to image manipulation (Passarge 2001). Two variations of the meme splicing technique have been investigated, self recombination and dissimilar
recombination, both resulting in a visual continuity of gradual pattern transformation. In self recombination, or duplication of memes from within the original image, the image is first partitioned into meme slices as previously described for memetic meiosis. Discrete slices are then repeated and re-inserted into their original location in the visual structure, expanding the structure by the number of repetitions. By pairing mirror and translation symmetry operations to repeat a slice, the exposed edge of one meme slice is joined by a mirror slice to achieve visual continuity across the splice.

Dissimilar recombination, or the introduction of different source memes, has been investigated using the principle of substitution, both in the interweaving of slices in a manner similar to the self recombination process, but also as discrete unit insertion within a dissimilar meme structure. Comparable to the substitution process of materials science, memetic substitution is based on unit connection alignment and geometric fit, remaining independent of the function or meaning originally associated with a dissimilar meme (Phillips 2001).

5. Discussion

Work to date with architectural form language has been accomplished in plan and section, using post-evolution traditional processes to transform results into the third dimension. Subsequent investigations are intended directly in a 3-D modeling environment. Perhaps the most noticeable difference between evolutionary and traditional design methods is in working with populations of design solutions instead of the concentration on a single solution. Even when a design problem requires a single definitive solution such as a building, the evolutionary strategy is to adapt an entire population of possible solutions before an individual is selected. It is the population approach that yields a wider exploration of the search space than traditional design methods.

5.1. Behavior of design populations with subjective fitness functions

Observations of a qualitative evolutionary design process reveals similar population dynamics as those found in their quantitative counterparts. Slight variations in initial conditions or minor differences of any iteration can lead to significant differences in outcome. The process may be repeatable step-for-step, but the output is reproducible only if every single subjective decision or random selection remains identical. This allows a structured repetitive rule-based design process to achieve a high degree of solution diversity and innovation.

Evolutionary design can be viewed as a continuation of serialism in that it may generate a series of interesting results but not necessarily the definitive masterpiece: the subjective equivalent of producing many near-optimal solutions but not one true absolute.

Figure 2: Original image is divided into meme slices, with selective slices repeated and reinserted via mirror and translation operations. Dissimilar discrete memes are then substituted into the expanded origin meme structure.
Populations can converge on strikingly similar individual characteristics, with periods of continued reproduction resulting in little noticeable change. These repeated periods of population stasis followed by rapid change would indicate a punctuated equilibrium model of evolution (Eldridge 1989). Stasis plateaus may evoke familiar feelings of becoming ‘stuck’ in design, but evolution offers a built-in method of becoming ‘unstuck’: reintroduction of mutated or previously rejected individuals back into the active population will move designs off the plateau. Initial generations after reintroduction will appear sub-optimal before proceeding in a different direction toward improved solutions.

5.2. Pattern recognition as an objective fitness function

Several trials of meme meiosis have been run using objective fitness criteria with pattern recognition as the fitness determinant. Based on site climate analysis, thermally desirable patterns of solar penetration through a building envelope were translated into three simple visual selection criteria. Using these as the fitness function, the evolution process was completed for 15 to 20 generations, with the most promising results graphically analyzed for solar performance. These early experiments indicate that visual pattern recognition has considerable potential as the objective fitness function in a single criteria optimization, but may not be capable of successfully resolving the conflicting criteria of real-world design. Rigorous examination of the correlation of pattern recognition and quantitative feedback in design remains to be done.

6. Conclusions

The evolutionary genetic design process has passed the first test of design: it can be used to make beautiful and interesting things. It has successfully demonstrated the ability to produce novel solutions of high quality that would not have been considered using traditional tools. Not to be mistaken as a question of human versus computer design, the use of subjective fitness functions in a computer based evolution methodology allows the human generation of artifacts. As every new medium for art has produced an incredible diversity of individual expression, emergence of individual style will follow.

The real but untapped strength of this tool is the ability to reconcile both objective and subjective design criteria in a unified repeatable methodology. The key is allowing both the computer and human to interact, doing what each does best. This unique attribute will propel it to become the preferred generative methodology for architecture and other design disciplines that often struggle with ‘Jekyll and Hyde’ choices in balancing issues such as proportion and performance.

Memes can be used to view the current state of design practice and the vagaries of design fashion: the spread of popular fonts and colors, the pieces of form language that come and go. Precedent-based approaches to design and teaching can also be viewed in terms of meme transmission. But these existing practices remain dependent on individual cognitive categorizing and often rather idiosyncratic cognitive maps, which lack a comprehensive theory or common formal structure. Just as evolution and genetics have provided design with the digital tool, the structured blueprint for its use can be found in the bioinformatic unification of biology. A division of design search space into discrete units of a commonly accepted and domain specific ontology will be necessary to complete the revolution.

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References


Knight, W. *NewScientist.com*, http://www.newscientist.com/channel/info-tech/dn7724 (08-04-05)


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*Areas of interest: artificial life, real life, morphology, crystallography, grain elevators, plants, wire, bugs, battleships*