Evolutionary Cooperative Design Methodology: The Genetic Sculpture Park

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The productive engine of human creativity is one of the most celebrated of cognitive processes. The engineered form, shape and function of each newly created object is first born as a flash of insight in the imagination of an engineer. Given advances in our understanding of elements of creative cognition, it is clearly feasible to envision a specially tailored computer interface that can augment and support the cognitive processes of engineers. Such an interface could amplify the breadth, novelty and efficiency of key phases in the processes of visualization and decision that drive human creativity. Even a small improvement in the creativity of engineers can have dramatic impact on economic productivity.

While many software tools, such as word-processing and CAD programs, support the crafting and manipulation of symbolic systems associated with creativity, few tools directly support the real engine of human creativity, the creative thinking process itself.

To be efficient and valuable, engineering creativity must satisfy special constraints. Engineering creativity is defined by how well an object, function or form serves the needs of a specific community of users. From the space of all possible objects or forms, the designer seeks a form that will work within (1) physical or functional constraints, (2) product semantic constraints (the form’s perceived style and the meanings that form evokes in the user) and (3) aesthetic constraints. From the theoretical design space of all possible shapes, there are many acceptable and a few ideal solutions to the design problem within all three constraints.

Evolution of Form

In our previous studies [1], we allowed groups of subjects to selectively evolve shampoo bottle designs based on simple aesthetic criteria, such as “like”/“don’t like” (our preliminary work had shown success with these broad definitions [2]). In this case, the subjects were simply asked to indicate either that they liked the design or that they did not. We specified shampoo bottles using an artificial genetic code that allowed shape and color to be evolved by selective combination. Each design was printed on a separate card and the stack of 90 cards was given to the subject to sort into one of two piles (the “I like this design” pile and the “I do not like this design” pile). This sorting was re-

Fig. 1. The upper pair of images shows different views of one specific subject’s favorite head model from the initial population. The subject’s preferences were used to drive the evolution of facial appearance; the lower pair of images shows this same subject’s favorite head model after six generations. Subjects consistently preferred the more evolved faces. (© M.I.N.D. Lab)
peated for 40 subjects (newly selected for each generation), and a fitness was calculated for each design by counting how many times it was placed in the “I like this design” pile. Color Plate B No. 1 shows the visual effect of this selective evolution on the population. Further studies investigated the success of the evolution by comparing the highest-rated bottle from each population. Statistical analysis reveals that the more evolved a bottle was, the more highly it was rated.

We then extended the shampoo bottle studies, which were based on simple aesthetic preference, to evolve consumer products based on marketing concepts [3]. These studies successfully showed how groups of consumers could selec-
tively evolve designs such that the perception of the design conveyed certain desired marketing concepts. For example, starting from the same population, one evolution of bottles was bred to convey “Pampers your hair for that special occasion,” while another evolution tried to optimize the “Leaves the hair shiny and healthy looking” consumer concept.

In further studies, subjects successfully evolved three-dimensional head models to their own particular preference [4]. We obtained 3D depth models of a sample population of human heads (see Fig. 1) and then performed a statistical analysis to discover and order the main ways in which the heads varied. This knowledge was used to create a design space of possible head models. Gene values were then defined to specify a location within the space (in effect, mapping gene code to head model design). A specific head model could then be specified by a set of gene values.

There is a significant methodological difference between the shampoo-bottle study and the head model study worth considering. During the consumer study, 40 subjects controlled the evolution of the populations. During the head model study, each subject evolved his or her own set of faces, giving each of the 36 heads a rating of 1 to 7 on attractiveness. To assess whether evolution was occurring (and if so, if it were in a direction away from average, as previous studies on facial attractiveness had indicated), we made average 3D head models from the initial and final populations and asked the subjects to select the most attractive average. Subjects consistently reported finding the more evolved faces more attractive, and analysis showed that the evolution occurring was in a direction away from average, which is consistent with the face-attractiveness literature from human psychology [5].

THE GENETIC SCULPTURE PARK

Our previous investigations into the evolution of form have concentrated on perceptually meaningful objects (i.e. shampoo bottles and faces). Interaction with these objects and the evolution itself is altered by previous exposure of the viewer to other objects from the same class. For example, it is possible that the products evolved toward existing marketplace designs. The Genetic Sculpture Park allows for the abstract generation of forms [6], thus freeing studies of aesthetics from this historical bias. The park also encapsulates the evolutionary experience in an entertaining web-based interaction.

Methodology

Visitors to the park are initially presented with eight empty pillars and a spinning double helix (see Fig. 2). Clicking on this double helix generates eight random gene strings, which are used to create eight correspondingly random sculptures to top each pillar. If a visitor “walks” close enough to a pillar, the column rotates to allow the form to be viewed in its entirety. Should a guest dislike the object, clicking on it (or on the pillar) removes that sculpture from the population. Once the visitor has only two or three sculptures remaining, he or she again clicks on the rotating double helix. The computer then randomly selects breeding pairs from the remaining sculptures and generates progeny genetic strings (and corresponding sculptures) to top the now empty pillars (Fig. 3). This process can be repeated any number of times to allow visitors to evolve sculptures that they find most aesthetically pleasing, or indeed to any discernible criteria. The evolution could possibly stagnate due to a limited gene pool (if, for instance, the two parent sculptures were nearly identical, then all their descendants would be practically the same). In such an instance, the user is instructed to leave either one or none of the sculptures remaining. Since a pair could not be selected for parenting, the computer then generates “random” sculptures to fill the empty positions.

Sculpture Graph Structure

A sculpture is described by a recursive tree structure with the nodes containing the genetic information. Thirteen individual nodes are combined in a sculpture graph to produce the final gene string for a sculpture (although normally, not all the nodes will be drawn, since they have the potential to have their effect turned off).
The current on-line version of the park has a recursion depth of two, with each node having three branches. We have selected these values to provide a varied range of sculptures while at the same time putting an upper limit on the amount of geometry each sculpture requires. Therefore, the sculptures that are generated are visually interesting and varied (there are $2^{1,625}$ potential sculptures), but can still be rendered in real time (for examples, see Fig. 3).

CONCLUSION
The goal of the Genetic Sculpture Park was to create an engaging experience where novice users could control the generation of novel 3D sculptures in a dynamically changing world. We achieved this by having the environment change to conform to visitors’ sense of aesthetics. In terms of computer-aided design, purely aesthetic constraints could be combined with physical ones to evolve both beautiful and useful designs. In addition, the very ability to generate “random” forms from within the constrained space of all possible forms often sparks new ideas and directions for the designer to explore. This interactive style of design allows the computer to assist human creativity in two ways: first, it is empowering, providing the user with a simple interface with which to create pleasing and complex 3D structures, and second, it is an aid to creativity in that it forces the designer to examine areas in the solution space that might otherwise be ignored.

The sculpture park can be viewed as one implementation of a broader cooperative design methodology. The human-computer collaboration extends what would be possible by either party alone, with the human providing the insight and design direction and the computer providing creative fuel and visualization. Our current work is expanding the technology to enable multi-user design collaborations over the Internet, whereby several designers, separated by time and space, can work together to effectively create optimal solutions.

References
3. Rowland [1].
4. Rowland [1].

Bibliography

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