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GENERALIZING EKPHRASTIC EXPRESSION

A Foundation for a Computational Method to Aid Creative Design

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Abstract. This paper presents the results from exploring the concept of ekphrastic expression as the foundation for a computation method to aid creative design. Ekphrasis or ekphrastic expression is the expression of a concept that is represented in one medium in another separate medium. The paper describes the concepts of ekphrastic expression and presents two implemented examples that demonstrate the method and produce new results. The first example involves the creation of new shapes through representing the shape designs in the evolutionary domain and introducing new operators within that domain beyond the standard evolutionary operators of crossover and mutation. The second example involves the creation of new genes to represent aspects of Frank Lloyd Wright's Prairie House style. This generates a space of genomes beyond those that were there at the commencement of the process. New designs that could not be directly produced in the original domain are generated.

Keywords. Creative design; ekphrastic expression; design method.

1. Introduction

Ekphrasis or ekphrastic expression, originally described by Plato in the *Republic -Book X*, is the expression of a concept that is represented in one medium in another medium. He used the example of a bed, which has three expressions: the physical object, the representation of the bed as an image, and the bed represented in another art form. It has been used extensively in the arts and literature such as when a scene from a poem is the basis of a painting or when a sculpture describes a dramatic event previously described in prose. This paper takes the idea of ekphrastic expression and applies it to design through its elaboration as a computational method to aid creative design.

In the arts ekphrastic expression involves the transformation of concepts represented in one domain into isomorphic concepts represented in another domain (Fowler, 1991; Goldhill, 2007; Leader, 2014). Take as an example the mythical story of St George killing the dragon, sourced to around the 11th century AD. The precise nature of the story and what it exemplifies is not of interest here. What is of interest is that the story is depicted in multiple other forms. It is expressed as a sculpture in Figure 1 (left). The same story is expressed as a painting in Figure 1 (right). This is an example of ekphrastic expression, where the nature of the domain of expression allows for different expressions. The story and its expressions are used as the basis of many characters and plotlines in video games.

Figure 1. The story of St George and the Dragon expressed as: a stone sculpture (left) and as a painting (right).

Ranjan, Gabora, & O'Connor (2013a; 2013b) showed that the cross-domain interpretation of artistic ideas, i.e., ekphrastic expression, can be tested empirically and that such a cross-domain interpretation of artistic ideas can be the basis of some form of creativity.

The remainder of this paper introduces the concepts of ekphrastic expression more formally before presenting examples of implemented systems that produce designs that are novel or both novel and surprising through ekphrastic expression.

2. Ekphrastic Expression is Not Re-Interpretation in Design

2.1. RE-INTERPRETATION IN DESIGN

In design we are familiar with the notion of representing ideas in different media and particularly so when we use computation since all computation is symbolic, i.e., we have transformed the design idea into symbols and those symbols are acted on not the design idea. Representation and re-representation have a well-established role in design and in computational models of design. Schon's reflective model of design is based on this representation and re-representation approach (Schon, 1983). Many design models and methods have been constructed from this foundation (Damski & Gero, 1994; Davies, Goel & Nersessian, 2003; Gero, 1999; Jupp & Gero, 2004; Karmiloff-Smith, 1995; Kurtz, 2005; Oxman, 1997; Sperber, 2000).

2.2. EKPHRASTIC EXPRESSION IN DESIGN

However, there are two significant differences between the use of ekphrastic expression as practiced in the arts and in design. First, we have a double ekphrastic expression in design. After we transform from the initial domain, d_1, into a second domain, d_2, we need to transform the results of the activity in domain d_2 back into the representation of domain d_1, which is the domain of the design. Second, we carry out processes in domain d_2 that do not necessarily have a counterpart in domain d_1. The processes in d_2 are contingent on d_2 and are a consequence of the paradigm of that domain. The representations in domain d_2 offer affordances that are not available in the representations in the initial domain. The activity in domain d_2 may be capable of producing new and surprising concepts in domain d_1 and as a consequence can be considered the basis of a creativity method. Further, we can produce new processes in d_2 that generate completely new results compared to previous results in d_2 that are then transformed back into d_1. Thus, ekphrastic expression differs from re-representation as used in design.

The rest of this paper outlines the concepts of ekphrastic expression and presents two examples including an implementation that demonstrates the method and that produces new or new and surprising results. The first example involves the creation of new shapes through representing the shape designs in the evolutionary domain and introducing new operators within the evolutionary domain beyond the standard evolutionary operators of crossover and mutation. This generates a space of genomes beyond those that existed at the commencement of the process. The new genotypes are viewed as shapes in the original domain, shapes that could not be directly produced in the original domain. The second examples also commences with re-representation into the evolutionary domain but introduces the new evolutionary operator of genetic engineering.

Ekphrastic expression can be treated as both a design method and a framework for a class of design methods within which a number of existing methods can fit. As a framework it provides structure to determine commonalities amongst apparently different methods. As a method it provides an approach to the production of designs that may be creative (Miller & Mair, 2006; Milligan, Connor & Ross, 2007). Any representation offers affordances and any change in representation offers new affordances that can be acted on to produce new behaviours and hence may potentially produce creative results (Gero & Kannengiesser, 2012).

3. Formalizing Ekphrastic Expression

3.1. REPRESENTATION AND RE-REPRESENTATION

We can describe all computation, C, as being composed of representation, R, and processes that operate on those representations, P. This can be written as:

$$C = \{R, P\} \tag{1}$$

Designing computationally involves design processes, P^d, operating on design representations, R^d, producing designs, D. This can be written as:

$$D = \left(R^d x P^d\right) \tag{2}$$

Where all design representations are composed of elements, E, and relationships, H:

$$R^d = [E, H] \tag{3}$$

Re-representation involves a transformation process, T, applied to the original representation, R^{do} resulting in R^{dn}:

$$R^{dn} = T\left(R^{do}\right) \tag{4}$$

Hence, designs are produced by applying the processes associated with the original representation, P^{do}, to the new representation, resulting in new designs, D^n:

$$D^n = \left(R^{dn} x P^{do}\right) \tag{5}$$

3.2. EKPHRASTIC EXPRESSION IN DESIGN

However, in ekphrastic expression in design we have two phases, the first is the expression in a new domain and the second is the transformation back into the original domain. We can describe ekphrastic expression using the same symbols as we used to describe representation and re-representation.

Computation, designing computationally, representation and re-representation remain the same, except that the re-representation is in a new domain, N, resulting in R^{dN} and associated with this new domain are processes that substitute for the processes in the original domain:

$$R^{dN} = T\left(R^{do}\right) \tag{6}$$

In the first phase we have the added activity of substituting the processes that apply in the new domain, P^{dN}, where SP is a process substitution process:

$$P^{dN} = SP\left(P^d\right) \tag{7}$$

Designing in the new domain becomes:

$$D^{dN} = \left(R^{dN} x P^{dN}\right) \tag{8}$$

In the second phase we need to transform designs back into the initial domain using an inverse transformation operator, T^{-R}, to produce designs from ekphrastic expression, D^E:

$$D^E = T^{-R}\left(D^{dN}\right) \tag{9}$$

with the expectation that the designs produced through ekphrastic expression may not necessarily be the same as those produced without it. In this paper this concept is demonstrated:

$$D^E \neq D^n \tag{10}$$

Figure 2 illustrates these transformations and substitution graphically.

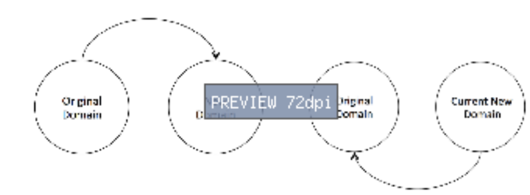

Figure 2. Left: Ekphrastic expression moves from an original domain to a new domain through transforming the representation in the original domain to those in the new domain and substituting processes from the new domain for those in the original domain; Right: a second ekphrastic expression occurs after designing in the new domain that moves the design back to the original domain through transforming the representation in the current new domain to those in the original domain.

4. Ekphrastic Expression Using Interpolation in Genetic Representation of Mondrian Paintings

4.1. HOW EKPHRASTIC EXPRESSION IS FORMULATED

Here we present an example where the original domain is Mondrian-like images represented graphically, Figure 3. The representation consists of rectangles, their colours and their topology.

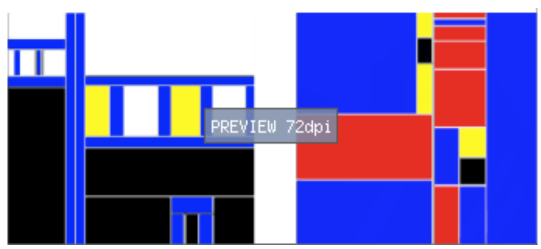

Figure 3. Two Mondrian-like images used as designs

These elements and their relationships are the sets of variables that make up the representation of a design, R^{do}.

R^{do} = *[{rectangle, colour}, {topological relations}]*

Any design in this domain is the result of a rectilinear division process coupled with a colour selection, P^{do}, operating on R^{do}:

D^{do} = *([{rectangle, colour}, {topological relations}]* x *[{division, colour}])*

We now express this representation in the domain of genetics and transform the representation into genes, R^{dN}, and substitute the genetic operators crossover and mutation, P^{dN} for P^{do}. This gives us a gene space and a design space, which is the phenotype space in genetics, design space in design, and an expression process to transform the genes into phenotypes/designs (Bentley, 1999). This results in:

R^{dN} = *[{genes}]*

P^{dN} = *[{crossover, mutation}, {expression}]*

We then add to the evolutionary processes of crossover and mutation available in genetics. We do this by commencing with Cantor's idea that "the real numbers are more numerous than the natural numbers". All evolutionary crossover and mutation processes work in the realm of natural numbers (integers) in that these operations only occur at the boundaries of genes. We asked the question what happens when crossover occurs not only at the boundaries of genes but also within them, i.e., real numbers not only natural numbers. This makes crossover a genetic interpolation process, a process that was not available in the original representation, Figure 4. Any designs are now represented using an F-representation (Pashko, et al., 1995) as real valued functions F(x) such that F(x)>0 is inside the object, F(x)=0 is on its boundary and F(x) <0 is outside of the object.

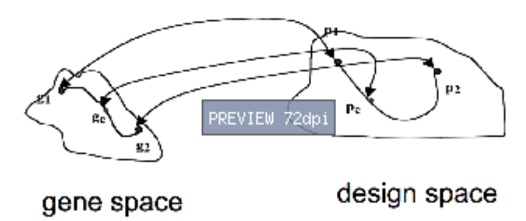

Figure 4. The process of interpolation between two parents results in a continuous path rather than a discrete path between the two parents in both gene space and design space (Gero & Kazakov, 1999).

We now have:

R^{dN} = *[{genes}]*

P^{dN} = *[{crossover, mutation, interpolation}, {expression}]*

As a consequence designs become:

D^{dN} = *([{genes}] x [{crossover, mutation, interpolation}, {expression}])*

We then transform the results in the new domain back into the original domain

$D^{E} = T^{-R}$*([{genes}], [{crossover, mutation, interpolation}, {expression}])*

thus, producing designs using ekphrastic expression.

4.2. NEW DESIGNS DERIVED FROM MONDRIAN-LIKE IMAGES

As described in Section 4.1 we commence with the two Mondrian-like images shown in Figure 3 as parents and transform their representation into the evolutionary domain. We then add the new evolutionary process that turns the trajectory between the parents into a continuous path. This produces a new domain that potentially contains designs that are not in the original domain. The original domain produces designs that are all composed of rectangles. Two examples of designs produced using ekphrastic expression are shown in Figure 5.

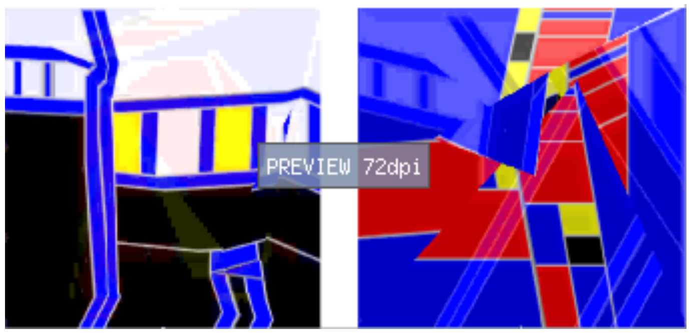

Figure 5. Two designs produced using ekphrastic expression in the evolutionary domain, transformed back into the original domain of shapes.

These designs contain the following elements that are not in the original designs:

- non-straight lines
- non-parallel lines
- triangular shapes
- rhomboid shapes
- "Z" shapes
- novel colours

The six elements listed above that appear in the design in Figure 5 could not be produced by any combination of elements and topological results in the original domain. The original domain contained rectangular elements only and the topological relation of rectilinear division do not offer the opportunity to produce any other shape than rectangles. This demonstrates that ekphrastic expression - moving the representation from one domain to another, operating in that domain and moving back to the original domain - has the capability to produce results that are not able to be produced in the original domain.

5. Ekphrastic Expression Using Genetic Engineering in Genetic Representation of Frank Lloyd Wright Floor Plans

5.1. HOW EKPHRASTIC EXPRESSION IS FORMULATED

The representation in the original domain consists of spaces and their use. This is shown in Figure 6 with the classes of space usage denoted by different shadings and different boundary line colours.

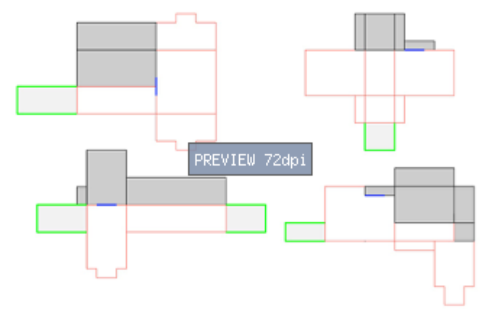

Figure 6. Four exemplary Frank Lloyd Wright Prairie House plans.

These elements and their relationships are the sets of variables that make up the representation of a design - a floor plan, R^{do}.

R^{do} = *[{rectangle, use}, {topological relations}]*

Any design in this domain is the result of a either a rectilinear division process or a combination coupled with a use, P^{do}, operating on R^{do}.

D^{do} = *([{rectangle, use}, {topological relations}]* x *[{[division, combination], use}])*

We now express this representation in the domain of genetics and transform the representation into genes, R^{dN}, and substitute the genetic operators crossover and mutation, P^{dN} for P^{do}. This gives us a gene space of genotypes and a phenotype space in genetics, design space in design, and an expression process to transform the genotypes into phenotypes/designs (Bentley, 1999). This results in:

R^{dN} = *[{genes}]*

We then add to the evolutionary processes of crossover and mutation available in genetics to get P^{dN}.

P^{dN} = *[{crossover, mutation}, {expression}]*

Here we add the new process of genetic engineering to the standard genetic processes, giving us a new P^{dN}. Genetic engineering is the process of locating gene structures in the genotypes of the high performing designs that are not in the low performing design, and then extracting that structure of genes and adding it to the gene pool. This results in both a change in the structure of the gene space and an expansion of the gene space and hence an expansion of the space of possible designs. The mechanics of this new process of genetically engineering genes can be found in Gero & Kazakov (2001). So the new process becomes:

P^{dN} = *[{crossover, mutation, genetic engineering}, {expression}]*

As a consequence designs become:

D^{dN} = *([{genes}]* x *[{crossover, mutation, genetic engineering}, {expression}])*

We then transform the design into the original domain:

$D^{E} = T^{-R}$*([{genes}], [{crossover, mutation, genetic engineering}, {expression}])*

Figure 7 (Left) shows the results of genetically engineering genes from the four floor plans in Figure 6. These are expressed in the domain of the original plans, i.e., as lines with colours that produce rectangles, not as bit strings which is the representation in the genetic domain. Using these genetically engineered genes we can produce new designs in the style of Frank Lloyd Wright Prairie Houses. A genetically engineered Frank Lloyd Wright Prairie House is shown in Figure 7 (Right).

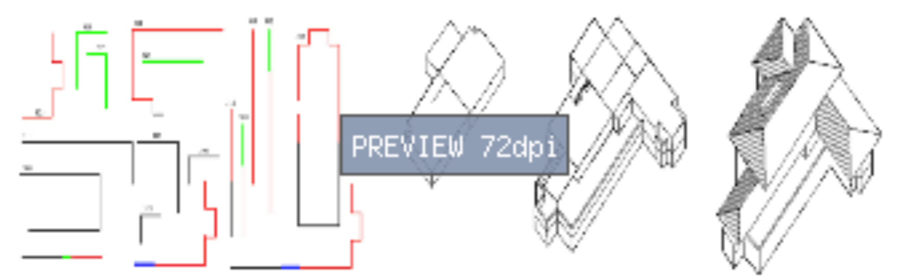

Figure 7. Left: Genetically engineered genes of Frank Lloyd Wright Prairie House floor plans. Right: A genetically engineered Frank Lloyd Wright Prairie House.

6. Discussion

Ekphrastic expression provides a formalism within which we can represent the class of designing that involves not just re-representation in a new domain but also substitution of processes from that new domain for processes in the original domain. In this view re-representation alone is a degenerate form of ekphrastic expression. This approach provides a formalism for computational models of designing that involve re-representation and process substitutions. The example in Section 4 demonstrates re-representation into the genetic domain, use of the processes from that domain and the introduction of a novel process for that domain - interpolation. This produces results that are not predictable when examining the representation and processes in the original domain; specifically the original domain can only produce rectangular shapes but through ekphrastic expression non-rectangular shapes are generated. The example in Section 5 demonstrates re-representation into the genetic domain, use of processes from that domain and the introduction of a novel process for that domain - genetic engineering. This produces results that cannot be directly produced in the original domain of rectangular spaces.

We can view ekphrastic expression as a framework for an otherwise apparently disparate set of design processes that all share the common concept of moving to another domain where operations in that domain do not match those in the original domain, carrying out operations in the new domain and then transforming the results back into the original domain. At a foundational level we can consider the formal modeling in algebra or logic or even in a programming language of designs and designing as a form of ekphrastic expression.

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