POCHE'

Polyhedral Objects Controlled by Heteromorphic Effectors

Ganapathy Mahalingam
North Dakota State University

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Abstract: This paper takes the architectural concept of poche' and uses it to explore new possibilities in transforming polyhedra with effectors. In many computer-aided design systems, architectural entities are represented as well-formed polyhedra. Parameters and functions can be used to modify the forms of these polyhedra. For example, a cuboid can be transformed by changing its length, breadth and height, which are its parameters. In a more complex example, a polyhedron can be transformed by a set of user-defined functions, which control its vertices, edges and faces. These parameters and functions can further be embodied as effectors that control and transform the polyhedra in extremely complex ways. An effector is an entity, which has a transforming effect on another entity or system. An effector is more complex than a parameter or function. An effector can be a modelled as a virtual computer. Effectors can take on many roles that range from geometric transformation agents and constraints to performance criteria. The concept of the poche', made famous by Venturi is familiar to architects. The poche' is a device to mediate the differences between an interior and an exterior condition or between two interior conditions. In a poche', the role of the effector changes from being an agent that acts on a polyhedron from the outside, to an agent that acts as a mediator between an interior polyhedron and an exterior polyhedron, which represent interior and exterior environments respectively. This bi-directionality in the role of the effector allows a wide range of architectural responses to be modelled. The effector then becomes an interface in the true sense of the word. This concept will work best in a three-dimensional or four-dimensional representational world but can be used effectively in a two-dimensional representational world as well. The application of this concept in design systems is explored with examples drawn from the work of the author, and practitioners who are using the concept of effectors in their work. A brief discussion of how this technique can evolve in the future is presented.

1. ARCHITECTURAL ENTITIES AS POLYHEDRAL OBJECTS

Architectural entities can be classified as physical or conceptual. Physical architectural entities are made of building materials and have geometric form. Physical architectural entities comprise building materials, components and assemblies. Conceptual architectural entities may have geometric form but are not made up of any material. Conceptual architectural entities comprise entities such as ordering systems and circulation systems. Both physical and conceptual architectural entities have spatial location. Conceptual architectural entities can influence the geometric form and spatial location of physical architectural entities. Conceptual architectural entities, in turn, can be defined by physical architectural entities. Architectural design can be considered as the definition and integration of physical and conceptual entities and fixing their location in space.

In computer-aided design systems, physical architectural entities are represented as well-formed polyhedra. Polyhedra, as their name implies, are volumes defined by a closed boundary of faces. The representation of architectural entities as well-formed polyhedra is called boundary representation. By their definition polyhedra are finite and can be fabricated with material. In their computer-based representation, polyhedra are defined as hierarchical collections of vertices, edges and faces. Of these, the actual variables are the values for the tuples that define each of the vertices of a polyhedron. These variables, in turn, determine the variations in the dimensions and spatial locations of the edges and faces of the polyhedron. Controlling the variables allows a designer to control the various forms that the polyhedra can take. The manipulation of form, which is one of the principal activities of the designer, can be enhanced by creating armatures for the manipulation and transformation of architectural entities represented as polyhedra. The concept of effectors provides one such armature.

2. EFFECTORS

An effector is an entity, which has a transforming effect on another entity or system. An effector is more complex than a constraint, parameter or function. An effector can be a computational entity in its own right. It can accept different kinds of input, perform computations and cause an effect in another entity as part of its output. An effector can be modelled as a virtual computer that can embody both state and behavior (Mahalingam, 1998). Effectors can take on many roles that range from geometric transformation agents and constraints to performance criteria. Multiple effectors can be integrated as a network of effectors that act in a concerted manner to function as a meta-effector. A hierarchical system of effectors and meta-effectors can also be developed that may or may not be concerted in their transforming effects. The overall effect of a hierarchy of effectors, that do not act in a concerted manner, needs to be controlled by a meta-effector.

Effectors change other entities based on computations. Effectors are different from constraints or parameters. Constraints specify an acceptable range of values for a variable, or relationships between variables. When a constraint specifies a maximal or minimal value for a variable, then it is considered a "limit." If the constraint specifies a range of values for a variable that straddles a certain value, then it is considered a "tolerance." The acceptable values for a variable specified by a constraint can be simply declared, or computed based on a function of that variable or other associated variables.

A parameter specifies values for a variable indirectly. The actual values of the variables are computed using the parameter. For example, the parameters for a cuboid are length, breadth and height. Changing these parameters changes the values for the vertices of the cuboid. The values of the vertices are computed using the parameters. A parameter needs an origin in order to compute its effect unambiguously. For example, changing the length of a cuboid can change only four or all eight of its vertices, depending on whether a vertex or the centroid of the cuboid is used as the origin.

A function can also be used to determine the value of a variable, which is usually called the dependent variable. A function can be any mathematical relation and may not require an origin to compute its effect. A function is defined in terms of one or more independent variables. The function may sometimes be recursive and use the variable it is determining in its computation. Effectors subsume constraints, parameters and functions when they are modelled as virtual computers.

When an effector is modeled as a virtual computer, a network of effectors becomes a network of computers. Polyhedra controlled by bi-directional effectors become a multi-layered network. Mathematical models used to model neural networks, parallel systems and 3D graphs are all viable tools to model networks of effectors. In its most abstract and general form, an effector is a relation between two virtual computers. Each virtual computer can change the state and behaviour of the other virtual computer. This relationship can be realised through one or several computational processes.

2.1 Homomorphic and heteromorphic effectors

If the component of a polyhedron being controlled by an effector is the same kind as the effector, then the effector is homomorphic. If the effector is not the same kind as the component it is transforming, then the effector is heteromorphic. To determine if an effector is the same kind as the component it is transforming, it should correspond in form or type. Geometric transformation effectors transforming the geometry of a polyhedron are homomorphic effectors. This is type correspondence. Since effectors are not geometric entities, the issue of form correspondence arises only if there are connected effectors. For example, two effectors joined to form a straight line that transform the edges of a polyhedron are considered homomorphic effectors. Also, a polyhedral network of effectors transforming a polyhedron is considered a homomorphic effector.

3. POCHE'

The concept of the poche', made famous by the architect Robert Venturi, is familiar to architects. The poche' is a device to mediate the differences between an interior and an exterior condition or between two interior conditions. It is usually used to resolve two conflicting requirements or conditions.

In his influential book, *Complexity and Contradiction in Architecture*, Venturi explains the wide ranging implication of the concept of poche' by quoting Gyorgy Kepes, "Every phenomenon - a physical object, an organic form, a feeling, a thought, our group life - owes its shape and character to the duel between opposing tendencies; a physical configuration is a product of the duel between native constitution and outside environment." (Venturi, 1966). Venturi also states that designing from the outside in, as well as the inside out, creates necessary tensions, which help make architecture. He goes on to make a significant and influential statement, "Since the inside is different from the outside, the wall - the point of change - becomes an architectural event." The concept of bi-directional effectors takes the condition of poche' described by Venturi and provides a computational framework to implement the design processes that he describes. For example, the "native constitution" of an entity can be governed by uni-directional effectors, and "duel" with the "outside environment" can be mediated by bi-directional effectors.

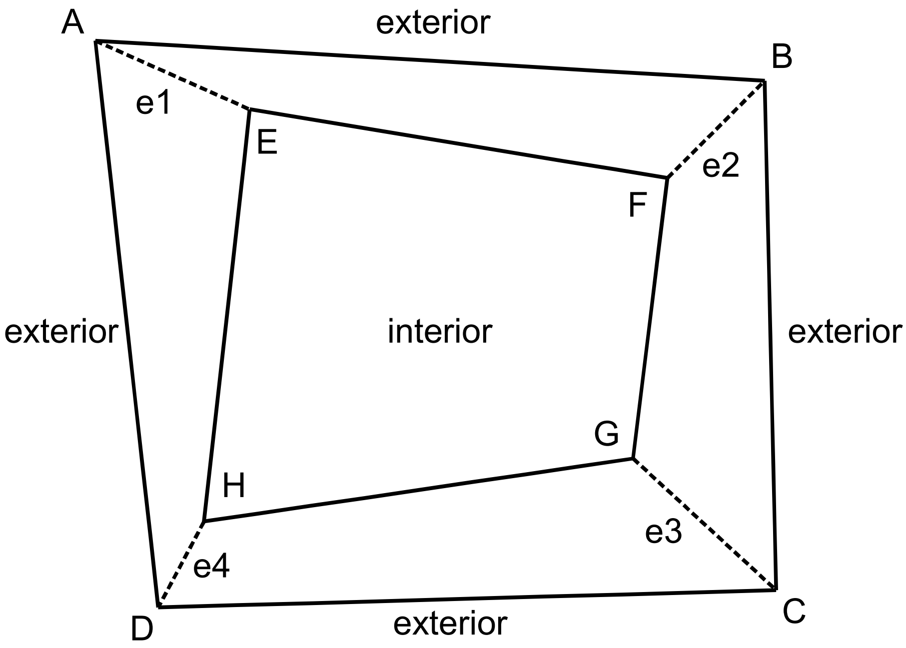

Figure 1. A simple poche' condition with four bi-directional effectors in a two-dimensional representational world

In Figure 1, an example of a poche' condition in a two-dimensional representational world is shown. This figure is not a literal diagram but represents an abstract machine in the Deleuzian sense (Deleuze and Guattari, 1987). ABCD is an exterior polygon and EFGH is an interior polygon. The states of A, B, C and D are determined by exterior contextual criteria. The states of E, F, G and H are determined by interior performance criteria. The four bi-directional effectors are e1 (AE), e2 (BF), e3 (CG) and e4 (DH). The bi-directional effectors e1, e2, e3 and e4 can be parameters, constraints, functions or virtual computers (Mahalingam, 1998). The role of the bi-directional effectors is to mediate and determine the states of the interior/exterior variable pairs that they link. The four bi-directional effectors can be linked to form a polygon of effectors thereby defining a meta-effector that is homomorphic. A meta-effector is a network of effectors. The role of the meta-effector in this case is to co-ordinate the effects of the four bi-directional effectors. Meta-effectors can be constraining agents. If, for example, the above condition represents a single-room structure, then the meta-effector can ensure that a minimum wall thickness is maintained.

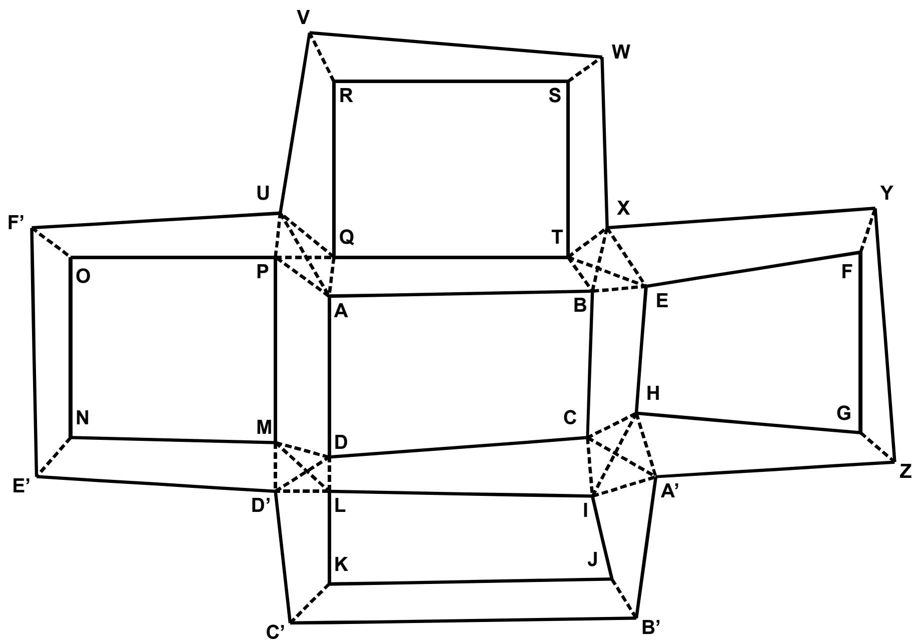

Figure 2. A more complex poche' condition with bi-directional effectors in a two-dimensional representational world

In Figure 2, a more complex, multicellular poche' condition is shown in a two-dimensional representational world. This figure is also not a literal diagram but represents an abstract machine in the Deleuzian sense (Deleuze and Guattari, 1987). There are five interior polygons and an exterior polygon. There are eight peripheral bi-directional effectors and there are four clusters of bi-directional effectors in the interior, each cluster forming a nexus of effectors affecting four variables. In each nexus the state of each one of the four variables needs to be resolved based on the simultaneous effects of the individual effectors. Each nexus can be modeled as a meta-effector. The four clusters that each forms a nexus can be networked as a polygon to create another meta-effector that is one step higher in a hierarchy of effectors. One role of the "nexus" meta-efffectors is conflict resolution at each nexus, to resolve conditions such as spatial overlap. A "nexus" meta-effector can also be used to maintain a minimum separation distance between the variables. Alternatively, a "nexus" meta-effector can collapse into a simple bi-directional effector, suggesting a merging of some of the cells in the multicellular configuration.

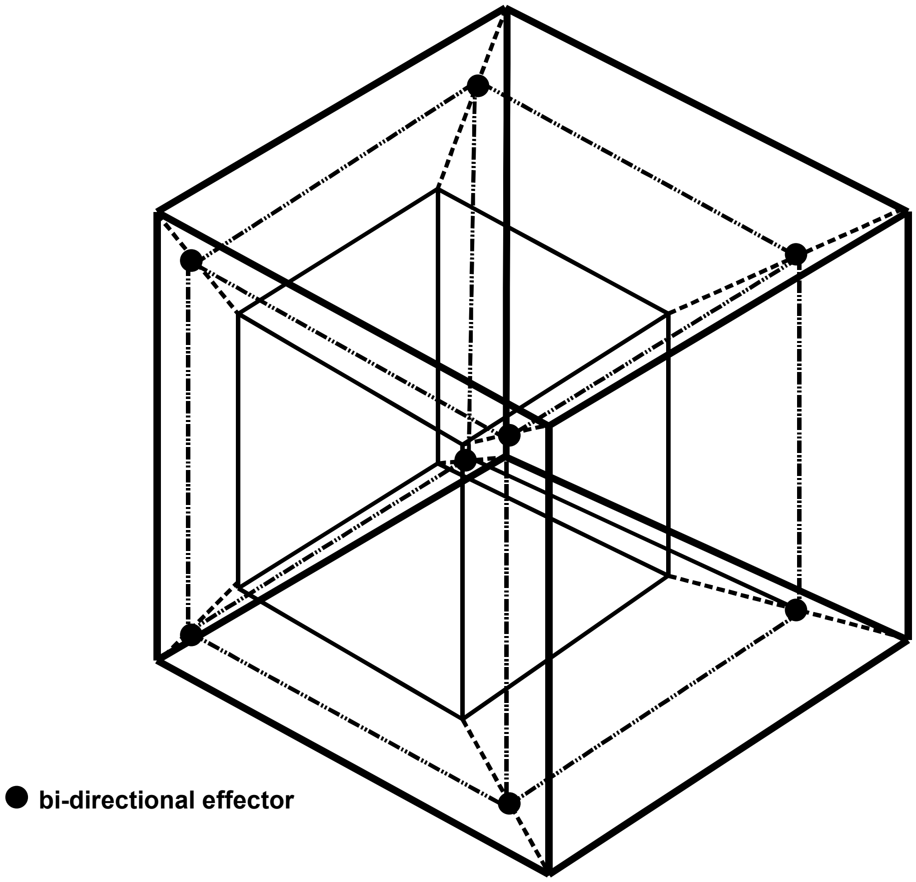

Figure 3. A simple poche' condition with bi-directional effectors in a three-dimensional representational world

In Figure 3, a model consisting of three nested polyhedra is shown. If the polyhedron in the middle (shown in the dash-dot line) is a network of effectors, and the polyhedra on the inside and outside represent interior and exterior environments, then the whole system represents the condition of poche' in a three-dimensional representational world. The role of the effector changes from being an agent that acts on a polyhedron from the outside, to an agent that acts as a mediator between an interior polyhedron and an exterior polyhedron, which represent interior and exterior conditions respectively. This bi-directionality in the role of the effector allows a wide range of architectural responses to be modelled, especially simultaneous responses to interior performance criteria and external contextual conditions. The bi-directional effector can be a mediating channel through which conflicting conditions between interior and exterior environments are resolved (mediated?). The bi-directional effector then becomes an interface in the true sense of the word.

3.1 Application of effectors in architectural design

The application of effectors in digital design processes for architecture holds a lot of potential. Since architectural entities are usually represented as polyhedra, the transformation of the polyhedra by effectors becomes a central part of design processes that shape forms and space.

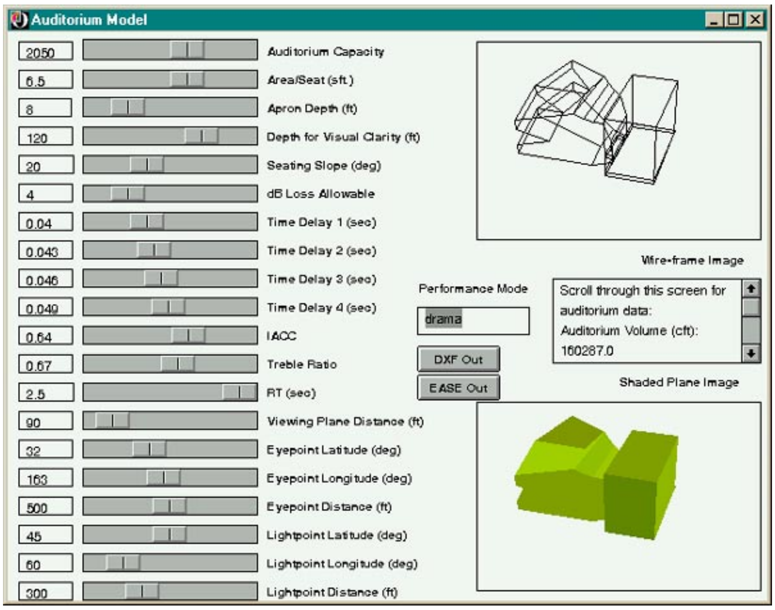

Figure 4. View of auditorium design system developed by the author

The author has developed an auditorium design system (see Fig. 4) where the polyhedral form of a proscenium-type auditorium is generated based on multiple functions of acoustical, programmatic and functional parameters (Mahalingam, 1996). The functions that locate the vertices of the polyhedra that make up the auditorium can be likened to uni-directional effectors. These effectors take the role of functions. The model in the auditorium design system that was developed was inwardly oriented. The design system can now be extended with bi-directional effectors to control an exterior polyhedral form that responds to external site conditions.

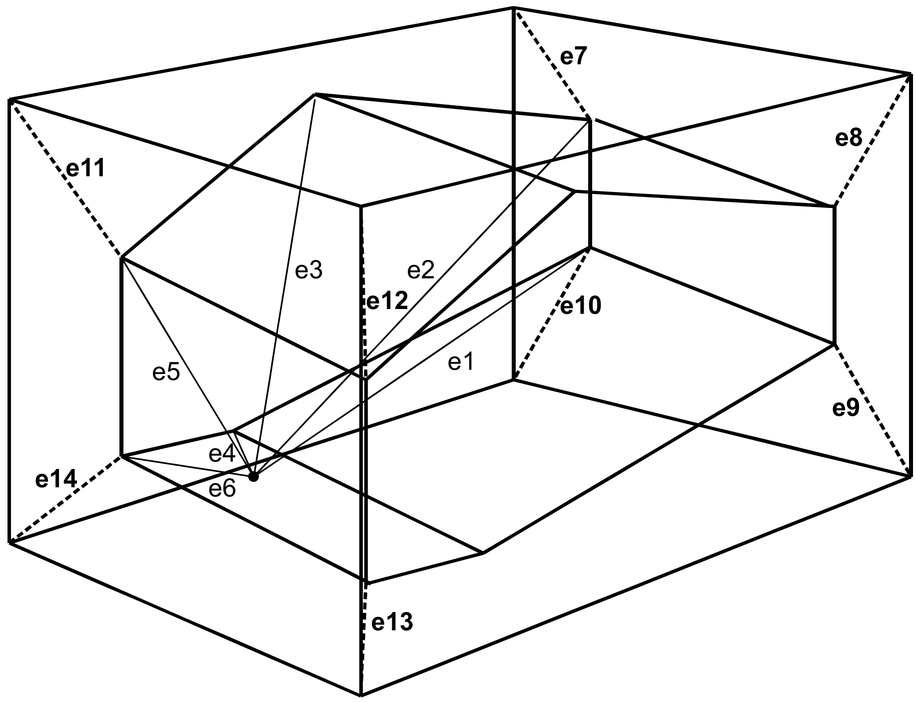

Figure 5. A conceptual diagram of the integration of the concept of effectors in the auditorium design system

In Figure 5, the spatial form of an auditorium seating enclosure is shown. The vertices of the polyhedron that make up the seating enclosure is determined by a set of twelve uni-directional effectors (e1…e6 represent one half of a symmetrical set of twelve effectors). The exterior polyhedron of the auditorium is governed by eight bi-directional effectors (e7…e14). Based on the mediating action of the bi-directional effectors, the exterior polyhedron can respond to site and other contextual conditions, while at the same time responding to the interior polyhedron that is generated by the interior performance criteria. This is just a conceptual example. The complexity of the exterior polyhedron can be increased to address the complexity that a particular contextual condition demands.

3.2 Application of effectors in architectural practice

Recently, a number of projects have been published that have used dynamic and non-linear computational processes to generate architectural designs. A recent issue of *Architectural Design* focusing on contemporary processes in architecture features two projects that can be examined for their relationship to the concept of poche'.

An outstanding project featured in the issue (Architectural Design, 2000), Embryologic Houses by Greg Lynn, uses the concept of effectors, but in a limited way. Lynn describes the underlying concept of his Embryologic Houses thus, "the variations in specific house designs are sponsored by the subsistence of a generic envelope of potential shape, alignment, adjacency and size between a fixed collection of elements." This generic envelope that is subject to mutation is composed of 2048 panels, 9 steel frames and 72 aluminium struts defining a shell. The form and space of the houses are modified within the predefined limits of the components. This is analogous to a polyhedron with a fixed set of vertices, edge, faces and constraints. All the effectors (transforming agents or control points) in Lynn's project act on the generic envelope from the outside and do not mediate between an "interior" and an "exterior" requirement. In fact, the variations in the houses are described as an adaptation to "contingencies" of lifestyle, site, climate, construction methods, materials, spatial effects, functional needs and special aesthetic effects. In the prototyping stage, six houses were developed exhibiting a unique range of domestic, spatial, functional, aesthetic and lifestyle "constraints." How these "contingencies" and "constraints" affect the generic envelope is not clearly articulated, so their role in generating the design cannot be determined. The transforming agents that mutate the generic envelope are causal agents and not mediating agents.

In another project featured in the same issue, Ali Rahim describes the operational principles in the generation of his competition winning entry for a Steel Museum in South Asia thus, "This (abstract machine) was comprised of vectors, fields, pressures and constraints in combination with inverse kinematics, particles and surfaces, embedded within the confluence of virtual matrices." Rahim's abstract machine, or machinic phylum as he prefers to call it, involves the causal transforming effect of particles and vectors (the flock of contaminants) on virtual matrices (the unactivated field) and vice versa. The interaction between the two enables the design. Though there is an exchange between the particles and the virtual matrices, again there is no mediation between an "interior" an "exterior" requirement. The actual spaces for the accommodation of program elements emerge from fluctuating intensities that indicate spatial potential. These intensities result from the indeterminate interaction between the particles and the matrices. The process is akin to crystallisation and annealing, or an act of congealing or solidification. Duration and temporal evolution determine space. There are no desiring, inhabiting forces that create spatial potential, like the need for a pleasant acoustical environment, thermal delight, or a view to the outside. There is a significant absence of interiority in the design generation processes that both these projects use, even though there is a creation of interiors in both of them. The forms and spaces created provide "opportunities" for occupancy, but there are no active occupying or dwelling forces that generate the forms and spaces. The concept of poche' forces attention on this "interiority."

3.3 Future directions

With growing attention being focused on digital processes for architectural design, a well-defined mechanism, or an abstract machine that triumphs over mechanisms (Deleuze, 1988), needs to be developed to generate the process space for these design processes. The concept of effectors provides one such mechanism/machine. Effectors can be configured into various abstract machines that generate architectural designs. The concept of effectors can be the unifying concept that allows the computational modelling of all architectural entities as active agents.

In the editorial to the issue of *Architectural Design* (Architectural Design, 2000) devoted to contemporary architectural processes, an emerging field is defined that optimises the state of the "in-between" as process and "systemic delay" as a major source of creativity. The concept of "in-between", as used in some of the projects featured in the issue, is based on the concept of "tweening" used in animation systems and not on the concept of poche'. The concept of poche' provides a different "in-between" paradigm. Systemic delay is defined as conceptual development in the time lag between an initial idea and its material form. This can also be related to the concept of poche', if the space-time of poche' (in its extreme characterisation, a poche' can be a space-time continuum), is considered a systemic delay between an idea and its realisation in material form.

As such, the concept of effectors and poche' can provide the means to mediate between idea and material form, between inside and outside, between performance criteria and space, in short, any condition that involves the mediation between two (or more) active principles. Though polyhedra are used in the examples in this paper, effectors can be used with completely curvilinear surfaces as well. Also, the polygons and polyhedra are not literal but represent networks of effectors that may constitute abstract machines.

4. REFERENCES

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