

A design framework to generate a continuous connection between elements and events

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received April 26, 2022 Received in revised form Nov. 23, 2022 Accepted November 30, 2022 Available online December 31, 2022</p> <p><i>Keywords:</i> Architecture Design exploration Folding Framework Generative design</p> <p>*Corresponding author: Yandi Andri Yatmo Department Architecture, Universitas Indonesia Email: yandiay@eng.ui.ac.id ORCID: https://orcid.org/0000-0001-5393-231X</p>	<p><i>This paper proposes a design framework of Generative Folding as a way to generate continuous connection between architectural elements and events. It argues that Generative Folding has the potential to reveal the complexity of architectural context while also continuously connecting them through proliferative digital tools. The discussion is based on Deleuze's idea of Fold (1991) and Eisenman's logic of Object-Event (1993). The folding and alteration of architectural elements produces various connections and continuity between various kinds of time. The article presents a framework development of Generative Folds based on the identification of the relationship of object-event through folding from literature review and the analysis of continuous connection in the precedent of an architectural project by Peter Eisenman. It also discusses the general technical view of Generative Design and how it can expand architectural design that is based on the exploration of various folds. The findings of this study highlight the potential of further application of Deleuze's Fold through generative design framework which allows new continuous connections to emerge.</i></p>

Introduction

Architecture should reveal the heterogeneity in context through a dialogue of the contradictions within the context (Lynn 1993). This aim is relevant to not only the medium of architecture, but also the program of architecture (Venturi 1977). There should be a reflection whether the current architectural medium has succeeded in expressing those complexities. Moreover, with the growing complexity of functional problems, there will also be new intricacies in current architectural programs. Therefore, it is important for architects to find a way to come up with new alternatives that could reveal architectural complexity without opposing formal systems in context.

The critique regarding architectural heterogeneity triggers a new concept in architecture, where architectural heterogeneities

are intertwined in a logic of and not or (Venturi 1977). The former is focusing on creating connections while the latter describes opposition to the disparities. This concept triggers the crucial theories about complex architecture from Leibniz's monadology logic to 'le pli' or the fold by Deleuze (1993). Folding can be defined as a practice of weaving, folding, and connecting different elements within context (Deleuze 1993; Lynn 1993). It does not only affiliate heterogeneity, but also takes part in generating continuous connections between elements and time within the context (Kipnis 1993).

The result of folding can evoke architectural singularity (Deleuze 1993; Rajchman 2000) which is a state where the architecture is showing a connection with the context but maintains heterogeneity in its own time and event. This understanding triggers the need of architecture that brings through continuous changes—

something that moves within time (Carpo 1993; Deleuze 1993; Eisenman 1993). However, the modern applications of architectural folding have not yet explored how those continuous connections are made and tend to focus on the morphogenesis of architecture. The complexity of context and the development of technological paradigm changes the continuity of folding by providing a proliferative iteration method to come up with various folds at the same time (Carpo 1993). This paper attempts to expand the knowledge of folding by exploring the continuous connection with Generative Design (GD) approach. It argues that the use of GD not only reveals complexity in context, but also generates new possible folds and continuous connection.

Method

This research is a part of design research practice with the aim to develop a design framework that is driven by the explorations of architectural forms. Hence, the practice of design forms the components and operations of the entire research (Verbeke 2013). The design research is divided into two main parts: framework development and design implementation. Due to the limitation of the article scope, this paper will explain the methodology used for the first part of the design research.

The study was initiated by a literature review of architectural folding and precedent analysis by investigating the Rebstockpark Masterplan by Eisenman. The literature review was carried out to identify the mechanism of folding and how it provokes a continuous relationship between architectural elements and events. The literature review was also done to find the knowledge gap in the critical discourse of folding. It does not only help to map and critique the development of the theory and logic but also offer new perspectives of the theory (Wang and Groat 2013).

The application and development of folding theory in architectural practice is further investigated through precedent analysis. The objective of this phase is to study the implementation of the theory in real life context (Wang and Groat 2013).

Rebstockpark Master Plan was chosen as the precedent to be analysed due to its clear delivery of theoretical practice in the design project. The project was investigated through what Deleuze

(1993) called as compliancy - which is achieved through complication and plication of disparate elements in context. The precedent analysis is done by dismantling how complication and plication of elements in the design context are continuously operated. The result of the precedent analysis provides the general operation of folding which is further implemented through Generative Design (GD) method to expand the proliferative nature of the theory.

The technical aspects of the framework refers to the Generative Design (GD) as a general framework to aid the explorative process of folding to come up with new continuous connections. In particular, this research refers to the general GD framework proposed by Mukkaavara and Sandberg (2020) which gives a basis of components and steps for the exploration of continuous connection. The study further develops the framework by identifying how the mechanism of folding and the goal of generating continuous connection will impact the framework components.

Result and discussion

Folding as a way to generate continuous connection

Fold is a form of continuity that is resulted from the act of weaving and connecting disparate and segmented elements (Deleuze 1993; Lynn 1993; Carpo 1993). Folding is introduced as a tool to create a continuous yet heterogeneous system by employing supple layering of disparate elements into smooth and heterogeneous mixture through joint manipulation (Deleuze 1993).

In complex folding, each part of the composition will interact and communicate simultaneously (Lynn 1993). Hence, creating a smooth mixture that connects those disparate elements but still maintains their individual characteristics (Lynn 1993). This state is called as compliancy (Deleuze 1993).

Compliancy consists of two steps: complication and plication. In complication, the elements in context are being assembled into a complex network. Whereas plication is a step in which an external force is being mixed to the complex network (Lynn 1993) which leads to various forms of continuity (Carpo 1993). Moreover, compliancy entails the external forces

by ‘knotting, twisting, bending and folding’ them within the internal elements (Lynn 1993, p.27).

These continuous variations are what we call ‘events’, which are generated from the folding of external forces and complex internal elements. However, ‘event’ is not something that can be represented as an ‘object’ (Deleuze and Guattari 1987). It is more suitable to be defined as a force that creates difference and transformation (Deleuze and Guattari 1987; Lundborg 2009). Hence, ‘event’ will always refer not only to the individual or present state of affairs, but also to the past or future time (Eisenman 1992; 1993) where the state of affairs is transformed (Lundborg 2009).

The connection between events happens not through a unification, but rather based on ‘divergence’ and ‘disjunction’ (Lundborg 2009). Instead of relating to the same events, the connection between events is produced by relating one distinct to another distinct event. This way of connecting is what Deleuze called as the ‘multiplicity of events’ (Deleuze and Guattari 1987; Rajchman 1993).

If any of the elements in the mixture is altered, the nature of the event will change (Lynn 1993; 2004). This relationship creates a dynamic and malleable bond which represents the deformation of elements in context. Folding, therefore, also prolifically generates new connections between disparate elements while at the same time shows a continuous development of those connections. This creates the notion of ‘singularity’ (Eisenman 1992) where the event can be referred to as something that happens immediately, a movement towards the past and the future. As such, the event can also be analysed in terms of different movements, which elude the present as well as the being of the subject (Lundborg 2009).

According to that notion, an object needs to be defined not only through its what and whatness; but also through its transformations and what evokes those continuous changes (Carpo 1993). The concept also evokes the idea of figural space (Eisenman 1993); where the space is constructed of an imitation of the actual place and time and the previous place and time (Eisenman 1993). This creates a continuity of connection between different kinds of time: the narrative time and other time. The next section will elaborate the construction of figural space in the case of the Rebstockpark Masterplan (1990-1991) designed by Peter Eisenman. The use of these cases is

aimed to investigate the implementation of Fold theory and design process in real life context.

Precedent analysis of continuous connection in rebstockpark masterplan



Figure 1. Concept drawing of Rebstockpark masterplan

Source: Eisenman architects

Rebstock Park masterplan is a design proposal for a settlement and industrial space in Frankfurt by Peter Eisenman. The masterplan is divided into four main blocks: Siedlung settlement on the east, athletic field on the west, Autobahn on the north, and industrial warehouse on the south. This division is a response to the context of Siedlungen and the old district in Frankfurt (Corbo 2020).

The project is grounded from the need of reconsidering the perimeter blocks which are often used in German’s settlements. The typology of those perimeters elicits two urban layers: unique repetition of urban transformations and the incarceration of the settlements (Eisenman 1993). The unique repetitions emerged from the perimeters that adapted over the changes of urban street patterns. Eisenman argued that there need to be a reconsideration over the Siedlung type to let new solutions emerge (Eisenman 1993). The reconsideration is related to two aspects: space-time and the repetition of individual elements.

Folding in the Rebstockpark project revealed the singularity within the context which restructured the present space. With this logic, the site worked both as the ground condition and something that has singularity. Hence, the design work would not only follow the condition of the site, but also dug up layers on the site by making the architecture actively contribute to the complexity of context (Paek 2018). Through folding, Eisenman attempted to generate continuous connection between the old and new

urban structure by conjoining different events in context (Corbo 2020; Paek 2018).

In the initial exploration of the project idea, Eisenman used the notion of 'object-event' to break away from the Cartesian grid and promote a new concept of movement and transformation in urban context. The concept originated from the idea that an object always continuously moves, develops, and changes (Eisenman 1993; Paek 2018). Therefore, objects can be defined through how they transform and what impetus triggers that transformation (Carpo 1993). This results in a need for architecture that allows continuous transformation (Carpo 1993) which connects different elements (Deleuze 1993; Eisenman 1993; Rajchman 2000).

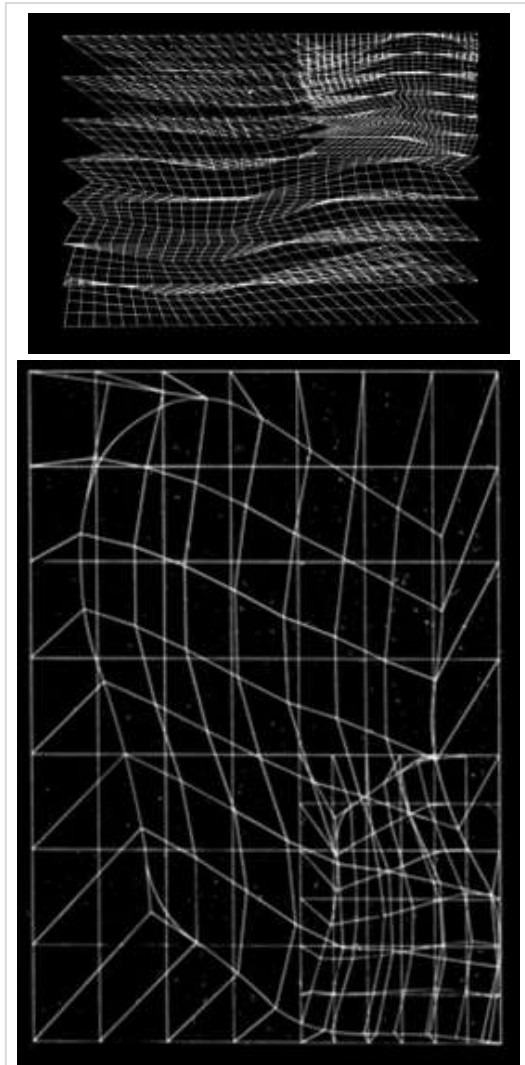


Figure 2. Folding logic in RebstockPark project
Source: Eisenman architects

Folding, thus, cannot be defined as a product, but a process of generating form which galvanises continuous development and transformation (Carpo 1993). This process is implemented to initiate a new technique of designing a new urban context which expresses the old one (Eisenman 1993). The folding is done by analysing the transformation of events in context (figure 2) which triggers the generation of continuous connection between new and old urban structure. In this project, events are defined as the intersection between buildings and the site which have different line intensity and density. Eisenman superimposed all those differences in one plane to show the changes of events. The overlapping creates a multiplicity of lines and planes that shows different territories in context based on different events. This results in various possibilities of events which can be folded and unfolded within the context. The technique also allows Eisenman to convey the complexity and heterogeneity of the context (Paek 2018).

Those territories are then used as a basis to zone the site for the project. Siedlung settlement was located on the east side of the masterplan whose shape and arrangement follow the site boundary and the line area of Autobahn (Corbo 2020). The zoning creates a complex overlapping pattern of straight and curved lines which is used as the grid of the site. The building blocks are then arranged according to that grid and the consideration of adjacent urban context (Paek 2018). Each intersection on the grid is being deflected and rotated in such a way that it produces different spatial experiences. These disparate experiences are the result of a build-up of specific quality and elements in that intersection (Paek 2018).

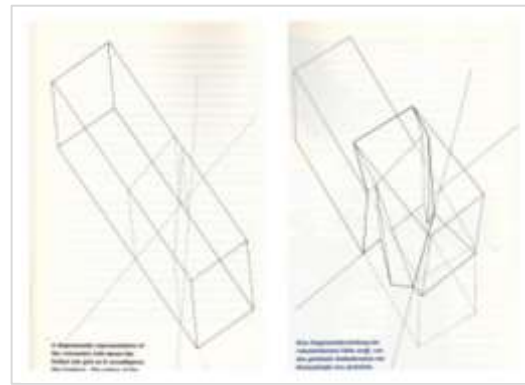


Figure 3. The shaping of building blocks
Source: Eisenman architects

Aside from the zoning location, Eisenman also differentiated the strategy for shaping building blocks on each point of the site (figure 3). The shape of the building blocks followed the rectangular shape with perpendicular lines found in the typical Siedlung. Each of the blocks are placed based on the contour of the site and the new grid. Accordingly, the rotation and unique placement of the building blocks generate new events that are specific to that location.

The study of this project shows that the weaving between object and event could create a nonlinear system which continuously connects elements in context. Some of the techniques used in this project are diagonally confronting, deflecting, and reorienting elements. The techniques create a continuity between elements while also generating the singularity of each event in context.

To connect in folding means to work with other possibilities; not already given (Deleuze 1993; Rajchman 2000). The folded, hence, will produce a singularity, which refers to the possibility in repetition or a multiple for 1 copy to be different from another copy (Eisenman 1993; Rajchman 2000).

The simultaneous production of variants (Carpo 1993) to the development of mechanical contrivances and manufacturing through digital technologies in creating 'smooth transformations' (Lynn 1993; Kipnis 1993; Burry 1999).

However, the architectural development of folding through digital technologies tends to be centered at the generation of new forms or morphogenesis. Digital technologies applications tend to be more on the operative side (Johanes and Author 2018) and were only a minor part of folding critical discourse (Carpo 1993). We argue that there is a need for exploration regarding folding continuity and connectivity in architecture through digital technologies.

As proliferative iteration is crucial in folding, we also argue that digital technologies and computational methods can facilitate the exploration of various folds alternatives through its ability to perform complex elements sequentially and simultaneously (Oxman 2008; Eisenman 2007; Caetano, Santos, and Leitão 2020). We propose to expand the theory of folding through the application of Generative Design (GD) approach.

The application of GD is intended to aid architects in generating alternative design solutions (Singh and Gu 2012; Mukkavaara and

Sandberg 2020) which in this case is continuous connection in context. The nature of GD will not only help to expand the folding and unfolding of events, but also generate new possibilities (Johanes and Author 2018) continuous connections.

Developing generative folding framework

Generative Design (GD) can be defined as an autonomous design approach that employs algorithmic descriptions (Singh and Gu 2012; Krish 2010; Caetano, Santos, and Leitão 2020) that generates multiple and complex design solutions (Krish 2010; Kazemi & Borzian 2015; Oxman 2008). In the GD approach, Kazemi & Borzian (2015) and Shea et al. (2005) put computers as a collaborative partner that lets alternative design solutions emerge based on the initial goal.

Singh and Gu (2012) proposes a GD framework that integrates the process encompassing various techniques used and highlights the evaluative nature in the generative process. Caetano et al (2020) added that it will consequently provide non-traceability and probabilistic results. This is further elaborated by Mukkavaara and Sandberg (2020) by proposing a general and technical workflow of GD (figure 4).

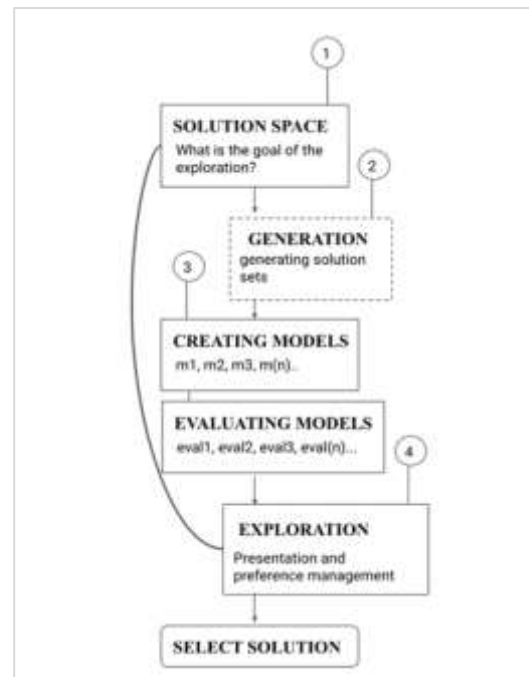


Figure 4. General framework of generative design
Adapted from Mukkavaara and Sandberg 2020

Figure 4 shows a general framework of GD that consists of five non-linear phases. The approach is initiated by defining the solution that is wanted to be achieved from the design exploration. The possible solutions are then generated through the creation of models and then evaluated. When the result is deemed as satisfactory to the determined criteria, the solution can then be selected as the output of the design process.

Therefore, the solution space determines the boundary of design. The purpose of this phase is to narrow alternative solutions that will come out from the exploration. This phase is crucial as it defines the design logic before the generation happens. The solution space consists of three primary components: product definition, design variables, and constraints.

Product in this framework is something that is subjected to the design (e.g., floor plans, sections, etc). Product definition is the process of describing the overall outcome of the product, whether it will be through 3D models, or any other means. This definition will interact with design variables and constraints. The primary guidance for identifying the three components can be from documents or available data sets, related with collected data relating to the goals and general guidelines for the project.

Design variables are values that can be varied and controlled whether in continuous or discrete manners. The variables will be set as the parameters for generating solutions while at the same time define the constraints. Constraints in this framework can be regulations or restrictions that rule the definition of the product.

Solution sets are generated with Generator. Generator can be defined as an algorithm which is based on the definition and boundaries from Solution Space. The solution sets will be generated in the form of models which will be evaluated by the means of the Solution Space. Some metrics are chosen to evaluate each model according to the solution space. The metrics for each model are then visualised through graphs, tables, and 3D Models. The tables and graphs are used to describe the values of design variables and the metrics of each solution. This evaluation is important to filter which solution is deemed interesting or satisfactory based on the solution space while at the same time gives an overview of the solution sets.

The selected solutions then enter the preference management phase where they will be

set as a reference for the next iteration of the GD process. When the next iteration starts, this set of solution references will contribute to the definition of solution space by creating new design variable ranges. This aid to condense the definition of solution space and reduce shorten the exploration process.

We first attempt to identify each of the phases in the general GD framework that can be used to generate continuous connections based on folding logic. It includes defining the solution space, solution sets, models and metrics used to filter and select solutions. The solution space of the generative fold also consists of three primary elements: product definition, design variables, and constraints. As the goal of the design process is to generate continuous connection, the product definition can be in the sense of 3D models, plans, sections, etc that shows how different elements are continuously connected. This definition will also allow the event to be comprehensively communicated and evaluated in the next phase of design exploration. The result of the developed framework is presented in figure 5.

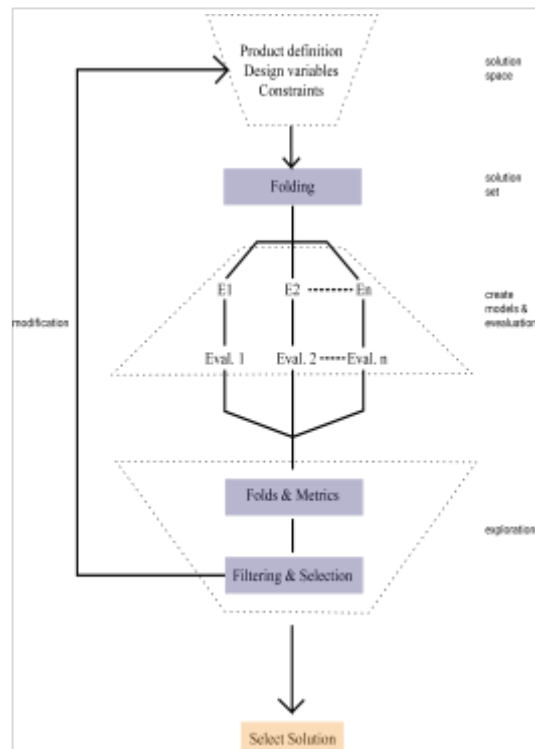


Figure 5. Developed framework of generative folding

Design variables will interact with the product definition and constraint of the design. For

example, if the scope of the project is architectural, the design variable can be the value of the architectural elements. Such as the height of the wall, the length and width of openings, etc. The constraint will be regulations and guidelines that work as a boundary of the solution space. The mechanism of folding; complication and plication, is used as the generator of solution sets. Where it can be specified more on how the folding is done. For example, through superimpose, deflection, and reorientation of elements.

The folding mechanism will then generate models of continuous variations of elements and events which formed from the intricacy of elements in context. These sets of folds between event-elements can be defined as the solution set of the design process. I identify these models as 'E' or events which are put under the phase of model creation and evaluation. Each fold is then visualised with its metrics to show the folded elements, the design variables, and possible events that happen. This visualisation of metrics is a crucial step to evaluate possible events and the continuous connections that emerge.

In this exploration phase, the folds of event-elements will be further analysed and evaluated to see if there are some interesting solutions that are deemed satisfactory based on the definition of solution space. Data from the metrics will also become considerations in filtering the solution as they provide the attributes and properties of the folds. The selected solution can then progress to be developed into a final design.

Conclusion

The result of theoretical and precedent analysis shows that folding galvanises the exploration and generation of difference. The development of technological paradigm brings a new expansion of this nature by enabling proliferative exploration of various folds at the same time. Generative design approach is argued to enhance the proliferative nature of folding through its explorative workflow.

This paper intends to propose how the generative design approach can offer more flexible and proliferative alternatives of continuous connection between architectural elements and events. The paper contributes in expanding a general framework into a design workflow and in informing the technical aspects

of the method. Moreover, the implementation of the developed framework can put forward the role of architectural elements and their connections on events in space. The framework can also further assist in the exploration of non-anticipated object-event, thus contributing to the form generation of architecture that is more responsive to the dynamic of events.

To narrow down the exploration pool, a specific definition of each element of the generative design phase also becomes important. However, as the scope of this paper is limited, a further development of the framework according to goals and chosen design context is needed. The specification of them will provide a clear idea of design variables and constraints of the generative folds. Furthermore, the framework also needs to be demonstrated in a specific design context to evaluate the use of folding in connecting architectural elements-events.

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Author(s) contribution

Zafira Rahmatul Ummah contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Yandi Andri Yatmo contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Paramita Atmodiwirjo contribute to methodology, supervision, and validation.