

# Structuring of Teaching and Learning Situations in Architectural Education

## *Using and Integrating Digital Analysis within Interactive Genetic Algorithms*

*Matthias Kulcke<sup>1</sup>, Wolfgang E. Lorenz<sup>2</sup>, Gabriel Wurzer<sup>3</sup>*

*<sup>1</sup>Hamburg University of Technology/HafenCity University Hamburg <sup>2,3</sup>TU Wien*

*<sup>1</sup>matthias.kulcke@tuhh.de <sup>2,3</sup>{lorenz|wurzer}@iemar.tuwien.ac.at*

### **BACKGROUND**

In the search for a deeper understanding of aesthetic quality in architecture, complexity of a design provides a possible area of comparison. In further detail, varying degrees of complexity may serve as comparable characteristics regarding different design proposals, either observed in the design as a whole or over different scales (fractal characteristics). Thus, using different methods to determine complexities can lead to a deeper insight concerning which role each of them plays in the overall aesthetic quality of a given design. One well established method to describe complexity represented as density and distribution of significant lines of a design across different scales is the fractal analysis method box-counting (Lorenz 2012). The authors propose an additional method, called gradient analysis, as part of a greater palette to aid design aspect-analysis.

### ***Gradient analysis***

Gradient analysis is an additional method for architects, designers as well as students and scholars to analyze and subsequently influence the degree of proportion-complexity of a design (Kulcke et al 2015, 2016). This method is based on the assumption that redundancy reduces the complexity of an objects' appearance. However, the reduction of complexity is not a quality per se; the matter at hand is for designers to achieve a balance between redundancy, which provides readability of form, and complexity to sus-

tain interest in it. Moreover, the authors are aware that, concerning this balance, many different levels of comparison exist, including, among others, the variety of material and colour combinations. However, for the moment the authors decided to focus on proportion, expressed by a gradient which is defined by two points (diagonal of a rectangle).

The basic idea of redundancy-analysis by gradient-comparisons led to a computer program called 'gradient analysis', which pairs every significant point of a design with each of the other points, comparing the gradients of the lines defined by each pair. By doing so emphasis is put on similar relations rather than specific relations (e.g. Wagner, 1981). Moreover, relations are not weighted depending on distance and/or visual highlighting e.g. in form of material edges, since Gestalt perception does not necessarily require edges (Kulcke et al, 2015). The weighting of different perceptual relations will be subject of future studies.

The result of the measurement is a list of pairs of points (coordinates of corners or intersections of lines) and their gradients, given as angles. In addition to the angle redundancy quotient a length redundancy quotient is also determined. The angle-redundancy quotient  $R_\alpha$  is defined by the number of different angles  $C_r$  divided by the total number of angles  $C$  (formula 1; Kulcke et al, 2015):

$$R_\alpha = \frac{C_r}{C} \quad (1)$$

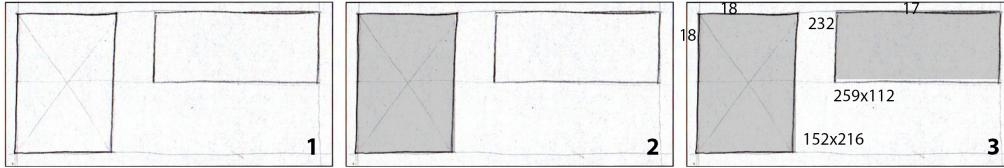


Figure 1  
Scan and retrieving  
rectangle  
measurements

with  $r$  being all repetitions and  $C$  being calculated as follows (formula 2; Kulcke et al 2015):

$$C = \left( n \cdot \frac{n-1}{2} \right) \quad (2)$$

with  $n$  being all single connections. The length redundancy quotient is calculated in an analogue fashion. In both cases, a tolerance coefficient takes into account that slightly differing angles or lengths may be perceived as similar and that the drawing of the object may not be accurate. The tolerance coefficient includes all angles inside a certain range, i.e. angles that stay within that range are counted as a repetition of the angle they are compared to.

### Interactive genetic algorithm

In order to create a responsive system to be used within a design- and/or learning process the gradient analysis has been integrated in an interactive genetic algorithm (IGA). Within the IGA it serves to determine the fitness value of a given object evaluating the degree of proportion complexity and to create variations with an optimized degree of proportion complexity. In principle, the algorithm consists of the following steps:

1. Generating the first population of  $n$  parents: Currently two different designs each of which is defined by significant points.
2. Encoding: The coordinates of all significant points are translated into binary code.
3. Crossover: Two encoded parents are cut at a definite point and their parts are exchanged.
4. Mutation: Digits are swapped at a certain position.
5. Fitness values: Angle redundancy quotient and length redundancy quotient are calcu-

lated to determine the segment size on Goldbergs weighted roulette wheel (step 7).

6. User-choice: The user can favour a result for Goldbergs weighted roulette wheel.
7. Generating the next population of  $n$  parents: The next generation depends on the result of Goldbergs weighted roulette wheel (Coates 2010, König 2010) and another user-choice.

Some of the steps above are determined by users' choice and/or including randomization. The process is repeated until a satisfying solution is reached.

### IGA WITH GRADIENT ANALYSIS IN THE WORKSHOP

In the workshop participants extensively test the interactive genetic algorithm and thus also the integrated gradient analysis in a given framework. Since the software is undergoing a process of permanent evolution, particular attention is paid to the analysis and discussion of the results. Another focus is laid on the discussion of possible integrations into learning environments.

The presented method of analysis to evaluate a certain layer of design quality is used exemplary to test the integration of design analysis via an IGA into a design learning context. Alternative methods for evaluating design complexity, like easy access fractal analysis (Wurzer and Lorenz 2017), may also be integrated into a similar design process. Participants are held to adapt the process to their analytical focus or expertise within their own teaching environment.

### The process

The design process as considered in the workshop consists of three phases:

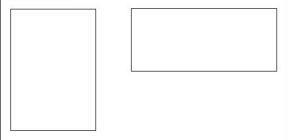
1. Freehand form development by sketching objects into a given rectangular field plus image enhancement and measurement extraction (Figure 1).
2. Evaluating the intuitively chosen proportions by using the gradient analysis IGA (Figure 2) and semi-automatically producing alternative versions on the basis of proportion analysis (Figure 3).
3. Comparing and choosing the final version, thus optimizing or confirming the initial design gained by sketching.

Figure 2  
IGA user Interface and first population of n=2 parents (n=2; showing just one of the two parent), displaying fitness values

Gestalter\_in:  
Vorname:  Name:

Breite (max. 511) Höhe (max. 255) Verschiebung:  
 b1:  cm h1:  cm x1:  cm y1:  cm  
 b2:  cm h2:  cm x2:  cm y2:  cm  
 b1:  cm h1:  cm x1:  cm y1:  cm  
 b2:  cm h2:  cm x2:  cm y2:  cm

0.4090909091



### The workshop content

As preparatory steps the participants are familiarized with the general theoretical approach of proportion complexity and proportion optimization. Then they are taught to use scanning and an image enhancing process allowing to feed the intuitively reached object into the web application to apply the IGA for proportion optimization. The actual task is presented as a design task to develop a prefabricated concrete façade module with two openings, especially focusing on a pleasing design considering the placement and size of the windows or doors. The height and width of the desired element are given, participants are asked to choose the openings boundaries as parallels to the rectangular boundary of the overall object. The participants are advised to draw a mini-

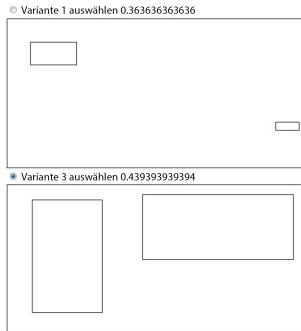
mum of six variations and encouraged to optimize a favoured first design by iteration i.e. by sketching it again with alteration of measurement, but preserving the general idea of the previous design. After choosing two favourite designs from the sketching phase, these are scanned (Figure 1) and opened within the image enhancing software. The sketched and digitalized rectangles receive an overlay of digital rectangles as a means to retrieve the measurements of the openings. These are chosen by the participants who visually control the process, especially regarding if the overlay rectangles still represents or even better their design aim. The measurements of the favoured two variants can now be entered into the user interface of the gradient analysis IGA to serve as parents (Figure 2), as the starting point for the interactive genetic algorithm. Again in several cycles the proportions of the openings within the facade element are optimized, chosen by the numerical gradient quotient and visual appearance (Figure 3). After several cycles the participants receive an output of the favoured solution of each cycle out of which again two favoured designs can be chosen. These are then put to comparison to the top design solution from the first phase of sketching. Finally each participant presents his or her work and voices the choices he or she has made on the way toward the final design.

### Advanced Task

The integration of user choices remains an important focus as the developer intend the tool to be utilized as a cognitive and analytic aid during the design process and not as an automatic design generator. For the workshop the software has been developed further in order to allow users to manipulate elements of the IGA themselves while producing design variations e.g. implementing their own cross over masks (Coates 2010, König 2010).

To gather and evaluate the feedback (of students) a qualitative approach is in development. The status quo is using narrative interview technique and computer aided qualitative content analysis. It is part

of the workshop to discuss the optimization of and alternatives to this feedback-process.



## PREVIOUS TEST CASES

### *The implementation in the learning environment*

The approach has undergone first testing with students in the winter semester 2016/17. The students' feedback is taken into account to optimize the process and the interactive algorithm (Poirson et al 2010) for further implementation in design education. A crucial point is the carefully adjusted use of different media (sketching in combination with analyzing/choosing within the GUI of the IGA). On the basis of testing the IGA within the learning environment changes have been made to the algorithm to optimize the design process. The comparability of the task is significantly changed by seemingly small alterations, respectively given rules and constraints, regarding the task.

To gather and evaluate student feedback a qualitative approach is in development. The status quo is using narrative interview technique and computer aided qualitative content analysis. It is part of the workshop to discuss the optimization of and alternatives to this feedback-process.

## DISCUSSION

Allowing participants to use edges that are not parallel to the boundaries of the rectangle, using rounded

corners or organic freeform is of course possible. But this should be done in a way that every participant is aware of that possibility, to ensure comparability for later discussions of the results. A possible variation is also to allow for teamwork and to propose to participants to marry their own favourite design from sketching to one chosen from a colleague, thus building the initial pair for the IGA.

## REFERENCES

- Burke, A 2008 'Reframing "Intelligence" in Computational Design Environments', *First International Conference on Critical Digital: What Matter(s)?*, Cambridge (USA), pp. 359-366
- Coates, P 2010, *The Programming of Architecture*, Routledge, New York
- Herr, CM and Karakiewicz, J 2008 'Towards an Understanding of Design Tutoring: A grounded study of presentation materials used in tutorial conversations', *Proceedings of CAADRIA 2008*, Chiang mai, Thailand, pp. 321-327
- Kulcke, M and Lorenz, WE 2015 'Gradient-Analysis: Method and Software to Compare Different Degrees of Complexity in the Design of Architecture and Designobjects', *Proceedings of eCAADe 2015, Volume 1*, Vienna, pp. 415-424
- Kulcke, M and Lorenz, WE 2016 'Utilizing Gradient Analysis within Interactive Genetic Algorithms', *Proceedings of eCAADe 2016, Volume 2*, Oulu, pp. 359-364
- König, R 2010, *Simulation und Visualisierung der Dynamik räumlicher Prozesse*, VS Verlag für Sozialwissenschaften, Wiesbaden
- Lorenz, WE 2012 'Estimating the Fractal Dimension of Architecture: Using two Measurement Methods implemented in AutoCAD by VBA', *Proceedings of eCAADe 2012*, Prague, pp. 505-513
- Poirson, E, Petiot, J, Aliouat, E, Boivin, L and Blumenthal, D 2010 'Study of the convergence of Interactive Genetic Algorithm in iterative user's tests: application to car dashboard design', *Proceedings of IDMME - Virtual Concept 2010*, Bordeaux
- Wagner, FC 1981, *Grundlagen der Gestaltung – plastische und räumliche Gestaltungsmittel*, Kohlhammer, Stuttgart
- Wurzer, G and Lorenz, WE 2017 'Cell Phone Application to Measure Box Counting Dimension', *Proceedings of CAADRIA 2017*, Suzhou, China, pp. 725-734

Figure 3

Two examples of first cycle and user choice (bottom) for next cycle, displaying fitness values