Parametric Ideation: Interactive Modeling of Cognitive Processes

Jörg Rainer Noennig and Sebastian Wiesenhütter

Juniorprofessorship for Knowledge Architecture, TU Dresden, Germany
joerg.noennig@mailbox.tu-dresden.de,
sebastian.wiesenhuetter@tu-dresden.de

Abstract. Our paper contributes to discourses on Computer Aided Thinking and introduces new techniques for the modeling of mental processes. The objective of our investigations is to support the description and creation of ideas through physical externalizations of cognition, and their subsequent translation into evolutionary algorithms. Through different types of tangible idea models derived from architectural design practice, we developed spatial representations of complex knowledge dynamics. As a central method we employed Parametric Design, a new way of spatial-architectural modeling.

Keywords: Computer Aided Thinking, Idea Creation, Parametric Design, Physical Modelling, Spatial representation.

1 Introduction

Architectural Intelligence. Architectural design as a form of human creativity may be one of the most complex ways of problem-solving, expressing itself by translating abstract concepts into spatial and embodied solutions. Thus it appears to be an interesting object of research for the fields of Artificial Intelligence and Cognitive Neurosciences, which endeavor in understanding intelligence, cognition and thinking. A recent turn in the intelligence discussion, the notion of "Embodiment" has indicated that our thought mechanisms are influenced to a great extent by the properties of our body - which sheds new light also on the procedures of architectural design as a form of creative intelligence in action. [1]

Architects use physical and spatial models as an externalization of their thought process. We argue that the properties of the models have influence on the thought process itself, and therefore want to investigate how they enhance the formation of concepts and the generation of new ideas. As the embodied, tangible nature of models equips them with distinct features, it appears meaningful to translate such analog models into digital representations.

Parametric Modeling. We will elaborate in this paper on how the concept of embodiment can be translated into computer-aided-thinking-processes. What are the benefits of parametric models, especially in terms of fast reconfigurations of knowledge spaces? To

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what extent may the use of digital models enhance human creativity? These technical issues touch upon further aspects of epistemology: How can knowledge units act as agents within an embodied model? This leads to the adaptation of principles of evolutionary dynamics, as well as to representations of the environment as a setting in which knowledge processes take place. Basically we hold that the translation of abstract concepts into physical models, and further into digital representation may add valuable stimuli to creative thought processes of the "users" of such modeling.

Idea Engineering. Charles S. Peirce, the founder of Semiotics and thus a "co-inventor" of communication and information sciences, had asked more than a century ago: "How to make our ideas clear?" [2] The question is still at stake. Resting on many of Peirce´s concepts, information technology, knowledge management, innovation theory etc. have prospered in the meantime, but relatively little has been achieved on the task of idea clarification. Yet this question is at the center of the before mentioned fields: Without insight into the discovery, explication, and modeling of ideas there won´t be secure knowledge neither on innovation, communication nor education. Therefore, as a starting point, our paper takes up Peirce´s question again, and proposes an outline for idea engineering, or better: architecting of ideas.

In order to systematically model the process of ideation one may follow a Peircean "experimentalist method" too, assuming that knowledge is constituted through a process of scientific guessing (abduction), logical derivation of general models (deduction), and empirical verification by experiment (induction). Short speaking: mental achievements arise from experimental efforts, from re-making and re-modeling.

2 Abduction

State of the Art. Computer application has, without doubt, widely helped to support intellectual and scientific work. Before all it has helped to model the principles of natural, mechanical and informational sciences. In other words: the laws of nature and machines, thus ushering in a boost of technological development in the past decades. However, the immense capacities of computers have not yet solved the problem of thinking itself. Plainly: Although equipped with immense computing powers we still cannot sufficiently explain how ideas are being made and processed. We are in dire need of models to clarify to ourselves the life of ideas.

Discourses. Two more or less competing discourses have predominated the field in the past decades: 1) the application of reasoning machines in Artificial Intelligence, 2) computer imaging in Neurosciences**.** As it comes to the explanation of idea processes, certain fundamental restrictions mark the limitation of these approaches. On the one hand, computer imaging technologies in neurosciences do not refer to the semantics of thought processes. They rather look at the biophysical / biochemical activity of neural structures, yet they can hardly relate the "snapshots" of neural activities to the complex formation of concepts as happening in problem solving, ideation, or imagination.

On the other hand, from the highly differentiated systems of concept taxonomies, classifications, and logical operations as represented in semantic networks and AI procedures, convincing models on the appearance of new ideas could not be presented [4]. Heuristic "invention machines" (like the problem solving routines of TRIZ) do not grasp the dynamic "Eigenleben" of ideas, which is usually based on the very environment they are embedded in, which is continuous and cannot be broken down into distinct paths.

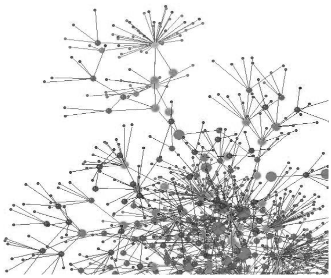

Fig. 1. Semantic Knowledge Representation (Source: Thintek)

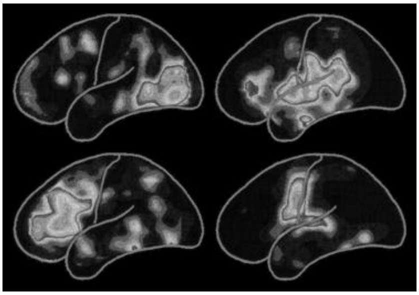

Fig. 2. Knowledge Representation by Neuroimaging (Source: TU Dresden)

Research Goal. Before mentioned question, however, is our primary interest and defines the goal of our investigation: *How to explain, and represent human knowledge processes in their making? How to dynamically model the development of thought?* Our approach, relating to the scope of the HCII conference, combines two arguments.

First, creative mental processes cannot only be represented by computing combinatorics, neither algorithmic nor self-organized. Abstract synthetic structures cannot describe the "invasion of the new", the "spark of invention". Logics are rarely creative. Idea processes need tangible, embodied interaction. Invention is based on problematic collisions with a complex environment, which the world of formal operations is not. Secondly, computers are not to be viewed as *creators or thinkers*, but shall be regarded as support actors in the dramas of scientific work. Computing is different from creative invention, it is massive conduct of logical operations. The core question then is how to relate this abstract logics to human ideation? How to relate computational power to the creative collisions of human bodies with the physical world?

Computer Aided Thinking. Since the 1990s, discourses on Computer Aided Thinking and Computer Aided Invention (CAI) have evolved which recognize the computer as supporting device also for creative intellectual processes. [3] Following this track, and in order to introduce a method for clarifying ideas by way of advanced modeling, we suggest to integrate two architectural techniques as conceptual extension:

- 3D description (spatial modeling)
- Parametric Design (computing environmental forces into shape).

These two means - if structured into a comprehensive method - may support the creation of ideas through physical externalizations of cognitive processes, and translate them into digital evolutionary algorithms. For this, our method employs three assumptions.

1st Assumption: Evolutionary Model. For the creative dynamics of idea generation ("Ideation") we propose an evolutionary approach. The repeated cycling of thoughts can be compared to iterative and mutative principle in evolution, which forms the generative machine for the development of new life forms and species. This assumption is informed by discourses on Evolutionary Epistemology and Biology of Knowledge [5][6].

2nd Assumption: Physical Representation. Research in Artificial Intelligence and Robotics has shown that cognitive processes are linked to physical representation [1]. We hold that creative activities like problem solving, invention, or innovation are strongly connected to "experimental" activities of the body, just as scribbling, sketching, or modeling. In other words, they are externalizations of mental processes into corresponding physical activity. For example, to architects and designers the iterative production of working models and prototypes is an essential part of their creative routine. Here, tangible objects and spatial descriptions are created as representatives of cognitive processes. With their invitation to immediate crafting and interaction, these objects and models enable a far better understanding of the problems at hand, and the uncovering of subsequent solution. Further, their physical composition allows an easy "grasp" and the re-structuring of their cognitive content. The latter, before all, directly feeds into the process of creating new ideas and concepts.

Environment as Condition. As stated above, environment must be regarded the trigger and source of creative invention and ideation. It is hence conditional to include environmental complexity into any model of idea making and processing. In this respect, environment can be either physical and psychological, spatial and social environment, and all combinations of such.

By Way of Body. There are multiple receptors, or sensors, for environmental factors in human cognition - yet almost all of them are bodily. An extensive discourse has formed on the way how the body shapes the way we think. Based on that tradition, our point is: To model ideational processes, a detour through the body is inevitable. There is no apt model of idea processing that does not include as a fundamental constituent a model, or representation, of the body. We may conclude: In order to stir up creativity, environmental information is to be bodily sensed as tangible information.

3rd Assumption: Tangible Heuristics and Algorithms. Above mentioned physical procedures on tangible objects and models may be interpreted as heuristic programs of ideation, problem solving etc. If well observed and formalized, such routines may be translated into computational representation. For the interaction with cognitive items in virtual space, parametric modeling tools like Rhinoceros / Grasshopper, Evolutionary Solvers, Physics Engines (e.g. Kangaroo) present promising opportunities. They provide a wide range of flexibility combined with detailed control in the reconfiguration, and iteration, of thought spaces and their properties.

3 Deduction

Power of Architectural Modeling. Knowledge Architecture´s add-up to the theories of Computer Aided Thinking is, before all, insight into the nature of design processes. We understand "architecting" not only as the creation of houses and cities to be built, but also as a method of knowledge processing, an "epistemic modeling". Architecting is the attempt of bringing together diverse concepts in sound structure, an interactive engineering of complex ideas. We have systematically surveyed and observed the procedures of ideation and concept-development from sketch to building. Of major interest are the features of architectural modeling which bridge the gap between mental processing and physical manipulation, which rework a given context, or environment, into tangible explication of design concepts. In fact, it is a bundle of activities and procedures that may be summarized thus:

- Mind and matter: Simultaneous work on concepts and materials
- Hands-on: Bodily experience, manipulation, grafting
- Pragmatism: No idea without reference to some object
- Spatial: Working in three dimensions + x
- Repetition: Iterative re-making and re-modeling
- Experience: Establishing creative habits and implicit knowledge
- Heuristics: Partly design / goal oriented, partly self-organized

Fig. 3. The tangible intelligence of modeling and crafting

Idea Models. As a routine at TU Dresden´s Knowledge Architecture lab (which also hands out conventional architectural design tasks for buildings) students are asked to develop their design ideas via so-called idea models, that is: condensing their preliminary design concept into a symbolic, tangible icon. As it turned out, these handy models allow complex recognition, easy manipulation, and a quick assessment of design ideas. Certainly the further "clarification of idea" implies more iterative re-modeling. The first version never shows the design in full, yet the recognition of a projects theme becomes astonishingly lucid by this tool. However, the main deficit of this kind of idea modeling is its static character.

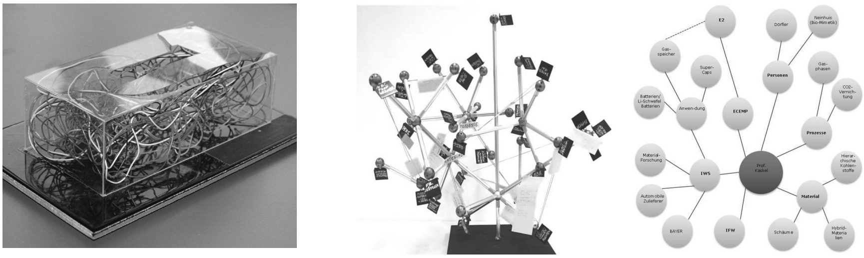

Fig. 4. Idea models for a building design (left), and for a brainstorm talk. The physical talk model (center) translates into digital semantic graph (right). (Source: TUD)

Dynamic Modeling. Based on above mentioned assumptions we propose a modeling framework for the dynamics of ideation that combines the features of physical embodiment on the one hand, and the capacities of computer on the other. At its very heart, this model is manipulative, bodily, and tangible. It rests to a large proportion on self-organization, but frequently shows goal-orientation too. In order to derive a first hypothetical models, we experimented with mechanisms showing the dynamics of growth and reproduction, with „natural phenomena“ of transmitting information” (cell growth, barnacle mechanisms, bee and flower-principle, prey and predator interplay, copulation techniques, population growth).

Dynamic Knowledge Model. We established a simple physical mechanism which distinguishes two dynamic entities: The body - or bodies - of knowledge (red circles in the images below) in contrast to body of the unknown (black). In the course of development of ideas, islands of knowledge appear within the body of the unknown (Fig.5). Certainly these bodies of knowledge grow: discoveries are made, problems get solved. Whether the growing knowledge is of relevance and importance, is another question. This simple form of development applies to micro and macro levels similarly. On micro level it may be ideas that show up in talks or projects; on macro level it may be a depiction of the development of sciences which increasingly discovers and extends knowledge about nature and technology. [8]

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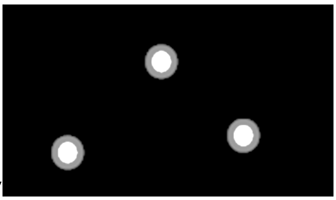

Fig. 5.

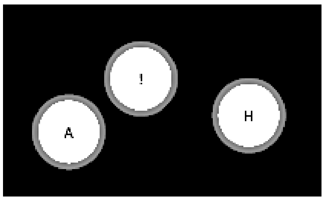

Fig. 6.

Knowledge growth raises the amount of interfaces / contact points to the area of unknown, i.e. uncertainty, open problems, unclarity. Uncertain too is the question whether the body of the unknown diminishes by the growth of knowledge. For example, the development of sciences and technology also create new problems; research is to discover new areas of the unknown. However, the more individual islands of knowledge, experience, insight etc. are being created, the more contact points, or interfaces, there are to the unknown (in Fig.6-7 the red perimeters extend).

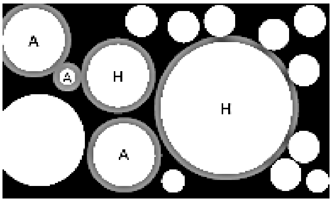

Fig. 7.

Fig. 8.

Further we suggest that advances of knowledge can be depicted by a) Increasing an existing area of knowledge, e.g. extending a doctrine (fig. 5-7), and b) Fusing multiple islands of knowledge into one, e.g. unifying theories or disciplines (Fig.8). In contrast to process (a), which is incremental in nature, the disruptive process (b) represents a genuine “Aha!” effect. It reduces uncertainty by reducing the interfaces to the unknown, by shrinking the perimeter while extending the area of the known (content). - This simple model with its two basic dynamics provides a blueprint for more complex procedures in “idea architecting”.

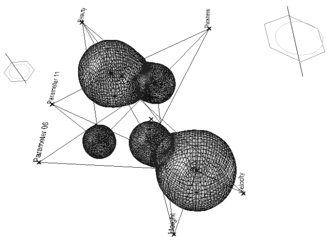

Fig. 9. Simulation of fusion process

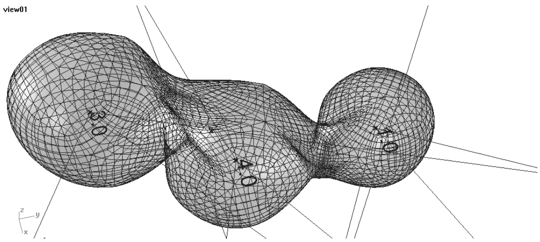

Fig. 10. Minimizing surface as evolutionary goal

4 Induction

Applied Knowledge Modeling. In order to verify the above mentioned model, a series of experiments was carried out. In research seminars various options of physical modeling of knowledge processes were tested. Tangible models were developed for the processes of concept formation, conceptual evolution, cognitive self-organization, among others. Based on hands-on experiments with buildings blocks, fluids, or heaps of powders or grains, some of these models were eventually formalized into digital parametric description. By working with these very tangible matters, creative algorithms and “thought processes” were discovered and thereupon translated into computer algorithms through the architectural modeling package “McNeel

Rhinoceros", featuring a parametric model engine and a visual programming interface ("Grasshopper").

Idea Programming Process. In architecture and planning, an established method for the organisation and structuring of knowledge is the so-called "Visual Programming" technique. The method was originally developed for organizing extensive information for complex projects, such as airports, factories, or highrise constructions. The power of the method - which is mainly carried out by hand drawn images on memo cards - is the rigid formatting of complex data into individual "information bits" indexed with keywords and short sentences. These indices, in fact, provide for a parametrization and operationalization of enormous amounts of data. From observing several programming sessions (discussion panels, workshops) we developed a preliminary model of how to make idea clear, and how new concepts emerge. As it turned out, the procedure can also be used to propel ideation processes.

Particle Field. In a first step, a large number of particularized knowledge "bits" are assembled - thus creating a field condition, a cloud of knowledge units. (Fig. 11) In real programming sessions, this happens by collecting handwritten notes, sketches, memos. All elements are carefully indexed and presented on large panels. (Fig. 12)

Fig. 11. Field Condition: Cloud of information

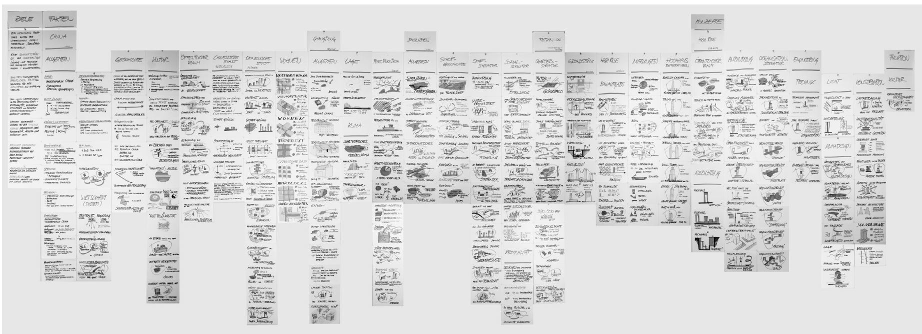

Fig. 12. Manual Programming Chart (Source: TUD Knowledge Architecture)

Mobilization. In a second step, the particles are dynamically set into action, the cloud of "information grain" starts moving, rotating, taking different stages of aggregation. The collection of data turns into an information swarm. - In real-world programming sessions, this is the part when all cards are being moved (sometimes be a number of people simultaneously) in order to search a definite placement, or order of arrangement.

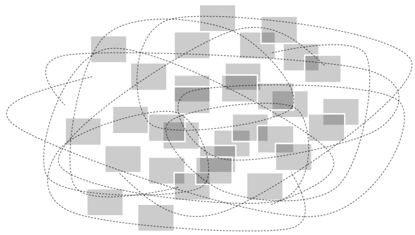

Fig. 13. Swarm Condition: Dynamic information

Anchorage. In contrast to a purely semantic clustering of cards according to their indexes - a process which resemble the "reasoning" of catalogues or search engines - we introduce certain new terms instead. This experimental move is supposed to form "common ground" for the assembled swarm of data, so-called "Test Centers". At this stage, it can be observed how the "intruders" function as anchorage points. If successful, they bring as many as possible of the floating elements to rest, and leave only few free floating. (Fig. 14) Their anchorage quality equals their capacity to match many cards without using the given indexes. In other words: they can include, combine, integrate formerly separate elements without referring to description already attached to them.

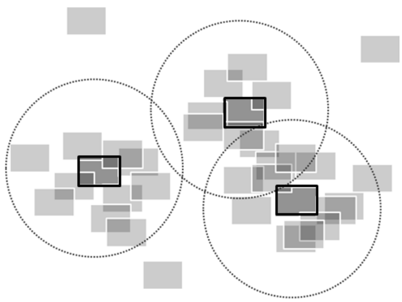

Fig. 14. Anchorage: New terms as gravity centers

If successful anchorage is achieved, new concepts can be stated as having emerged. This relates to the stage of "fusion" as represented in the generic model mentioned before (Fig. 8) - the emergence of new terms equals the merging of formerly unrelated fields, or units. - In real-world programming sessions this step happens when new "Header cards" are being introduced into the large collection of memo-cards.

This action, however, involves the completely re-arrangement of the set of data, which is given usually as chronological, or topical table charts. As regards the experimentally introduced new terms, they turn from "Headers" to "Centers of Gravity".

5 Conclusion

The insight and results of our studies on parametric idea modelling indicate the opportunities arising from a systematic transfer of architectural modelling techniques to knowledge representation. Not only for the description of epistemological concepts the proposed method may be useful. Purposefully developed and applied as a setting to generate impulses for ideation and innovation, it should be of interest in any field of knowledge intensive work (e.g. business intelligence).

As the experiments show, parametric knowledge modeling will hardly cope with capacities of human creativity. Rather it may stimulate creative thought by externalizing human thinking into tangible models, which in turn allow new idea manipulation. Thus the interaction of human mind and ideation algorithms may lead to a promising "ping-pong" relation, a cognitive partnership. Here parametric modeling takes the role of a "Proposal Engine".

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