GIGA-MAPPING: VISUALISATION FOR COMPLEXITY AND SYSTEMS THINKING IN DESIGN.

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ABSTRACT

Designers and design is facing ever growing challenges from an increasingly complex world. Making design matter means to cope with these challenges and to be able to enter new important design fields where design can play a crucial role. To achieve this we need to become better at coping with super-complexity. Systems Oriented Design is a new version of systems thinking and systems practice that is developed from within design thinking and design practice. It is systems thinking and systems practice tailored by and for designers. It draws from designerly ways of dealing with super-complexity derived from supreme existing design practices as well as refers to established perspectives in modern systems thinking, especially Soft Systems Methodology, Critical Systems Thinking and Systems Architecting. Further on it is based on design skills like visual thinking and visualisation in processes and for communication purposes. Most central are the emerging techniques of GIGA-mapping. GIGA-mapping is super extensive mapping across multiple layers and scales, investigating relations between seemingly separated categories and so implementing boundary critique to the conception and framing of systems. In this paper we will present the concept of GIGA-mapping and systematize and exemplify its different variations.
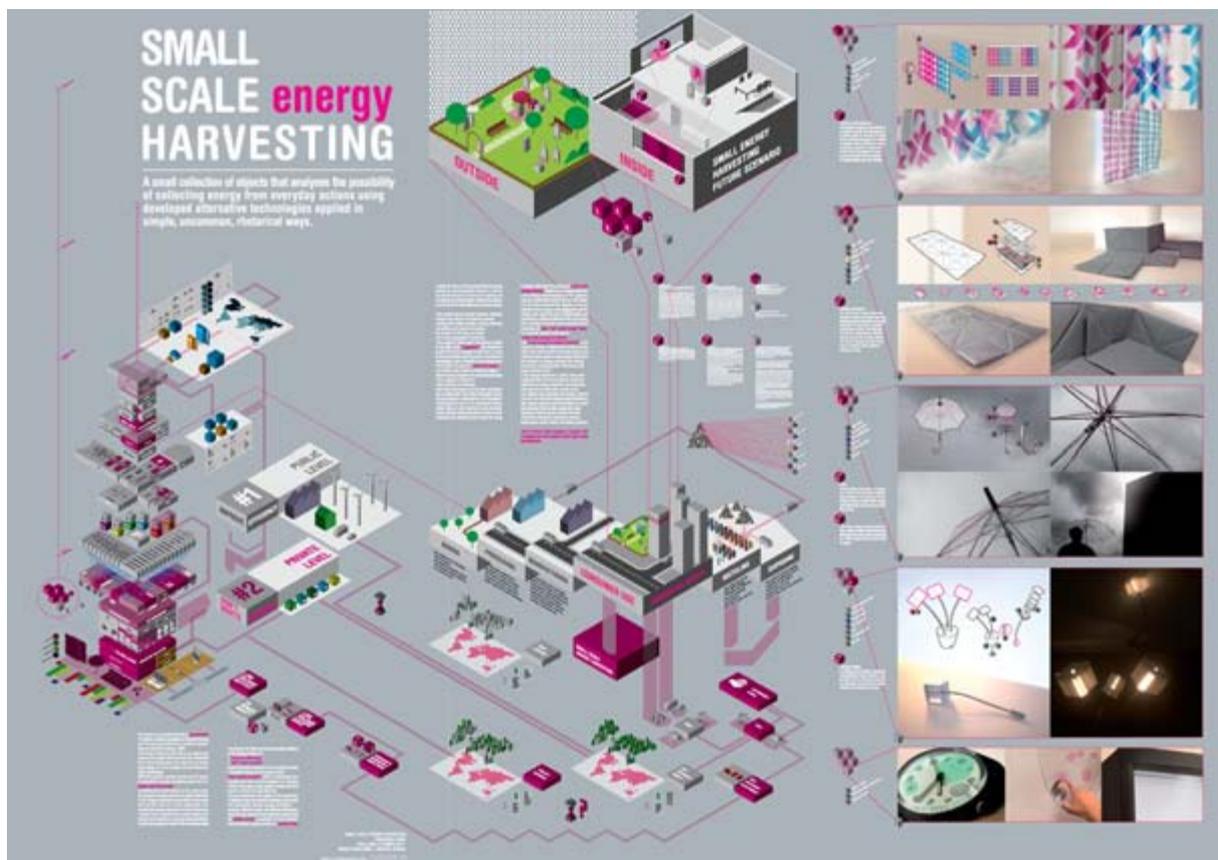
Fig 1: A mixed GIGA-map of the possibilities for distributed small scale energy harvesting and how this would impact human behaviour. Zoom in to see some more details. (Student: Francesco Zorzi 2009)

INTRODUCTION

This paper presents research by design on one of several particular techniques (GIGA-mapping) developed for and within an emerging approach to design for complexity called Systems Oriented Design. The background and status of the research into Systems Oriented Design (SOD) and some of its different aspects has been reported on before and will not be discussed in depth here (Sevaldson 1999 a,b, Sevaldson 2000, Sevaldson 2001, Sevaldson 2005, Sevaldson 2008 a,b, Sevaldson, Hensel, Frostell 2010, Sevaldson & Vavik 2010). The scope of the paper is limited to the special theme of GIGA-mapping though the wider context and the relevance of this approach are touched upon as far as the format of the paper allows doing so. Another limitation to this paper is that it merely gives an overview and a series of examples and a general discussion on GIGA-mapping. In a forthcoming article we will report on the techniques and details of GIGA-mapping as a design activity.

Systems Oriented Design as well as GIGA-mapping has been developed by the author and colleagues at the Oslo School of Architecture and Design. During the last ten years we have investigated methods and techniques that address the challenge of complexity in working with products, services, large scale systems, information, media types and representations of design processes. The presented studies are bottom up research based on findings from mainly master level student projects in collaboration with partners from business and organisations, and in workshops for several consultancies and organisations.

This initiative has been driven by the increasing complexity that confronts designers individually and the design profession in general. Very severe and crucial problems need to be solved in the future and designers are in a special position to make a difference to make design matter. Designers work with many levels of innovations and they are inherently trained to work with very complex problems in a holistic manner. But designers need to become better at dealing with complexity. This is rarely trained especially and it is our intention to contribute to improve this field of design practice.

SOD is systems thinking tailored by and for designers. While this research started from within experimental design in the *OCEAN design research association* (1995) it was reaching a new stage when we started to address and relate complexity in design with systems thinking in 2005. Today the research refers to three main conceptual frameworks:

- Design thinking and design practice
- Visual thinking and visual practice.
- Systems thinking and systems practice

These will shortly be described below, only touching upon issues I found especially relevant for the theme of the paper.

GIGA-mapping, the topic of this paper is embedded in this context of design, systems thinking and visualisation. GIGA-mapping is creating an "information cloud" from which the designer can derive innovative solutions. While mapping in general is a way of ordering and simplifying issues, so to say "tame" the problems, GIGA-mapping intends not to tame any problems. GIGA-maps try to grasp, embrace and mirror the complexity and wickedness of real life problems. Hence they are not resolved logically nor is the designerly urge for order and resolved logic allowed to take over too much and hence bias the interpretation of reality.

DESIGN THINKING AND DESIGN PRACTICE

Design Thinking has been defined as inseparable from design practice (Lockwood, 2010, Cross, 2007, Cross, 2011, Brown and Katz, 2009). Research by Design manifests the nature of Design Thinking. New knowledge emerges and is externalized before, during, and post practice (Sevaldson 2010). Synthesis is the central aspect of design thinking. The process of synthesising, though debated, remains enigmatic and resists strict methodological framing. I base my conception of this process very much on the five stage model by Wallas (1926), later by most writers reduced to four stages. The four stages are Preparation, Incubation, Illumination, and Verification.

Incubation and illumination is found and described by an overwhelming majority of very creative people (Csikszentmihalyi, 1996). Though both incubation and illumination resist a deeper understanding beyond what can be derived from observations and testimonies, nevertheless we can influence the process of synthesis. Incubation is typically a process where complex information is processed over time. It is in the preparations, the information collection and in the tentative, iterative, and heuristic development that we can do things differently. Incubation and illumination is then not really phased but appears more or less integrated in preparation and verification activities.

VISUAL THINKING AND VISUAL PRACTICE

Visualisation, visual thinking, descriptive and generative diagramming are central in this heuristic process. Visualisation is a field described by e.g. David McCandless (2009).Visual thinking is earlier described by Rudolf Arnheim (1969), and diagramming e.g. by Tufte (1983). While

infographics are mostly occupied with communicating information to a passive audience, visualisation in GIGA-mapping intends to be applied in processes as well as for communication and involves participation and collective production of information.

I will return to this topic when discussing it in relation to GIGA-mapping.

SYSTEMS THINKING AND SYSTEMS PRACTICE.

The aim of the reported research is to develop systems thinking as a design proprietary knowledge and to develop it as a skill and a practice.

Designers are to a certain degree trained in working with "wicked problems" (Buchanan, 1992, Rittel and Webber, 1973) and to generate holistic resolutions from complex project information. Designers are often positioned very close to decision making. Designers do often also have a special holistic overview spanning from technical, via socio-cultural aspects to economic aspects. This provides the designer with power to induce change.

Recent developments with impacts of globalisation and requirements to sustainable production pose increasing challenges to the designer. It is required that designers respond not only to singular aspects of the design task, like the concept, usage and shape of the product and service, but also that they increase their understanding regarding e.g. technology, client-specific frameworks, cultural aspects, market analyses, sustainability and ethical concerns. In practice some of these requirements tend to be emphasised on the cost of others. Often the holistic perspective is sacrificed because of a lack of ability to maintain complexity though-out the design project. The ability of designers to address many aspects simultaneously and to generate holistic, and at their best, synergistic responses is in fact a type of soft systems practice. This has been recognized by others who made an effort to systematize and learn such abilities. One example is Mayer and Rechtin (Maier and Rechtin, 2000, Rechtin, 1999) who have coined the term Systems Architecting. The term is used in a new type of project management profession working along with the traditional project managers not to replace them but to supplement the hard logistics with more artistic, intuitive and holistic perspectives. The term Systems Architect is inspired by the building architects ability to keep a holistic overview, to negotiate the views of experts and to hold the threads of a complex project together. If we look into 'normal' design education and practice, it is apparent that we do not really live up to be honoured like that. We do not teach and develop those assumed advantages of the design professions very actively. We do not have good concepts for dealing with super-complexity. Systems thinking is one of few general frameworks to deal with complexity. It is used in most sciences

and practices where different variations and approaches to systems thinking are developed. Systems thinking in design is currently not very widely spread though there is a growing attention. But there were a number of people who have referred to systems thinking like Rittel, Alexander (1964), Harold Nelson and Erik Stolterman (2003) Glanville (1994) Jonas (1996) and others. Though a handful design thinkers have made some substantial contributions to systems thinking in general, hardly anybody has developed a systems practice from within design, specially informed by design thinking and design practice. This is remarkable when we compare us with other fields where proprietary adaptations of systems perspectives are normal. We find those in engineering, sociology, management, military operations, psychology, economy etc. But not in design. When we want to build the proprietary version of systems thinking and systems practice in design we need to build on the inherent abilities of designers to cope with complex problems.

FRAMEWORK
Parts of this new framework of SOD has been defined in earlier publications and will only be referred to very shortly here (Sevaldson, 2008b, Sevaldson, 2009b, Sevaldson, 2009a, Sevaldson et al., 2010, Sevaldson and Vavik, 2010). Its theoretical basis is found in systems theories especially Soft Systems Methodology (Checkland, 2000), Critical Systems Thinking (Ulrich, 2000, Midgley, 2000) and Systems Architecting mentioned before, and especially in the reinvention of diagramming in architecture as a generative tool (Allen, 1999, Berkel and Bos, 1999, Davidson et al., 1998, Eisenman, 1999, Massumi, 1998, Sevaldson, 1999a, Somol, 1998, Bettum and Hensel, 2000). This shift freed the diagram from sheer representation and clarified its potential for being a central device in generative and creative work.

SOD brings together these different design and systems practices with Critical Systems Thinking, foresight and scenario thinking. Critical Systems Thinking applies different systems frameworks critically in relation to what purpose they are serving. Design practice has especially much to contribute to established systems thinking. Significant is the ability to incubate and synthesise solutions within fields and applications where there are no singular and clear responses to be found, and where the value of responses is evaluated iteratively through practice and by gathering experience, expertise and intuition over time.

METHODS
The work presented below is Research by Design conducted over the last years by the author, colleagues and students at the Oslo School of Architecture and Design and in the framework of the OCEAN design research association. In an

earlier paper the author has described seven modes of practice research in design (Sevaldson, 2010). While earlier studies were of the type six, *Experimental Design Practice*, where *the practice is experimentally changed and modified to explore and develop specified investigations, research questions or effects* the research into Systems Oriented Design is of type seven. This is *The inductive and iterative theory-driven & theory-driving experimental design research practice* (pp.28). This indicates that the development of a new design technique is conducted in an intimate relation between different modes of practice and different modes of reflection. For further elaboration on Research by Design methods and perspectives please review these publications (Sevaldson, 2000, Sevaldson, 1999b, Sevaldson, 2010).

It is from the practice of GIGA-mapping that we have gathered the experience we needed to start systematising it in this paper. The approach to analyse this research by design is a soft categorizing of the different maps we have produced with students and colleagues and business associates. The sorting is done according to two types of criteria: the structural and graphical type of maps and the functional usage of the maps.

GIGA-MAPPING: VISUALISING FOR COMPLEXITY

One of the most important, but also underdeveloped, advantages of designers regarding design for complexity is that they have special abilities to use visualisation as tools for analyses, as process tools and for communication. Visualisation and visual thinking has increased in importance after design computing has become standard (Sevaldson, 2001). Visualisation in design is used for representation, drawing sketches and renderings of possible solutions. More recently visualisation in design has been inspired by information visualisation and visualisation of dynamic actions like e.g. service design blue prints and story boards. Most of these applications and other uses of diagramming in design do have specific limitations to theme and scope. Service design blue prints are mostly framed by the emerging disciplinary boundaries. Information visualisation as a field is almost entirely concerned with communication and less with processes. The use of diagrams in design projects as well as in design research is not well developed and in many cases there is a wide spread misuse of diagrams like the Venn diagrams or Pournelle diagrams leading to oversimplification of complex problems.

With GIGA-mapping we intend to brake these diagramming clichés as well as other schemata and prejudices. GIGA-mapping is a tool to increase and aid our capacity to grasp and work with super complexity. Visualisation skills can also be used in more abstract phases of the processes. Fields of

knowledge can be visualised so that a better overview is achieved. The complexity of a problem can be mapped out and visualised. Structures of systems and processes can be diagrammed. Very valuable are the tentative iterative "not-always-knowing-what-one-is-doing" states of sketching and visualisation. The potential of true visual thinking emerges not only from documenting thoughts but by visualising and dynamically forming the analyses and developing the thinking from the visualisation. Generative visualisation is one of the central advantages of the designer.

THE RELATION TO OTHER WAYS OF DIAGRAMMING

GIGA-mapping is nothing principally new. We find similar approaches like mind mapping or concept mapping. Especially the Rich Picture introduced by Checkland (1981) is relevant as a predecessor of GIGA-mapping, especially because it was introduced as a means of working with Soft Systems Methodology, e.g. human activity systems. The intentions of the Rich Picture are pretty much similar to the ones of GIGA-mapping. The difference are qualitative and quantitative rather than principal. They are found in the practice. The way the Rich Picture is practised is still quite limited in scope and numbers of issues on the plate. Its main aim is to create an overview, ordering and simplification. Also the Rich Picture is mainly practised as an illustrated network diagram.

GIGA-mapping breaks the barriers of information quantity by separating the process tasks and the communication tasks. The GIGA-map needs in its first phases only to communicate to its creators. This allows for a dramatic increase of information amount, since creating the map internalizes far larger information amounts than what would be the case when approaching it as an outsider. Also the graphic means and the designer's ability are central. The GIGA-map is regarded as a design artefact itself. This nested design process has proven to be very efficient in getting at grips at a higher level of complexity.

Another way that GIGA-maps might differ is in the fact that they should layer many types of information. Categorically separated information channels needs to be interrelated.

Yet another difference is the multi scalar approach in GIGA-mapping, spanning from the global scale down to small details.

RUPTURES IN THE DESIGN PROCESS

A central aspect of working with very complex tasks is to keep as many aspects of a problem field in play for as long as possible throughout the process. A natural progression in the design process is narrowing down aspects and possible solutions towards the end of the process where the windows of opportunities are closing and when the resources invested are increasing and errors would have

increasingly serious consequences. This process is often hampered with problems. One problem is that the amount of information is so large that not everything is properly taken into consideration. Small issues that seem unimportant can become crucial for the process at certain moments. If they are forgotten because of sheer information overload, the result can be a costly rupture in the process. Another typical rupture may occur when the client organisation is not understood properly. Different sections of the organisation are not always well coordinated which can lead to ruptures in the design process. An early anchoring of the project in the relevant sections of the organisation can be crucial. Such sections would be marketing, economic, strategic management, technology and production.

Another example of ruptures is caused by problems occurring in the implementation phase when the product or service system is to be launched into the real world where it becomes a player in complex emergent systems like stock markets, trends, raw material markets etc. A careful early forecasting of the implementation phase and investigations into worst case scenarios and risk evaluation might induce early interventions in the design that could prevent some of these problems.

To help avoid such ruptures, and to engage with as many as possible issues and keep them in the play as long as possible, the author has developed the concept of the Rich Design Space (Sevaldson,

2008a). GIGA-maps are the central device in the Rich Research Space which includes social spaces, media spaces and physical spaces. All information throughout the process needs always to be highly accessible to remain active for a longer period in the process. This allows back tracking and rechecking information at any time to reduce risks of errors.

Designing "builds" material for decision making. This material is both textual and visual, abstract and figurative. The complex information in a design process should be "alive" throughout larger parts of the process ether spontaneously or at checkpoints or iterations.. This means that designing generates information that will modulate itself along the process.

Re-examining the design material at points of iteration will help secure that the information is brought into play and developed while it is updated and re-understood through the designing process (Fig. 2).

GIGA-mapping is the central tool for such sampling, re-aligning and synchronizing of complex information through out the design process.

Needless to say the suggested techniques will not entirely remove any ruptures, but they ensure that a proper effort is made to avoid them as much as possible or to be prepared for them should they occur.

Fig 2: Diagram of a guided process for design process iterations. The spiral diagram indicates how the design process went through four iterations where the same themes or issues where rechecked. These were Project description, Ideas, Research, Matrix, Dinners, Sketches / testing, Evaluation and Specification. Not all of these were re-examined for each iteration. Some issues required more rework in the iteration and the rework would vary in different stages. This diagram was directly used as a process tool to check each stage in iterations. Zoom in to see details. (Students: Balder Onarheim, Pål Espensen, 2008)

BEYOND THE HORIZON

GIGA-maps are ultimately tools for drawing systems boundaries. Boundaries are needed to frame the system. They define the simplified and manageable framework for the design intervention. But simplification is often done too early and too quickly. Before one can draw the boundary of a system or frame the problem we need to unfold the field way beyond what we assume is the horizon of relevance. Only when we know the landscape past that horizon we can withdraw and draw the boundary in an informed manner. Small things far out on a chain of effects can become crucial to make a project live. We need to find those crucial triggers that are not immediately visible. GIGA-mapping ensures that all efforts are taken to track down what is relevant and to include it in the design. This approach is our answer to boundary critique, a well known perspective in systems thinking (Midgley, 2000).

TYPES OF GIGA-MAPPING

There is no definite number of types of GIGA-maps. I arrived at a tentative list of maps by going through a large number of GIGA-mapping exercises. It is possible and probably beneficial sometimes to design a new type specially adapted to the problem at hand. Possible mappings include:

- Hierarchical maps: Mind maps

- Non-hierarchical maps: Concept maps

- Time based maps: Gantt

- Time based maps: Timelines (non-Gantt)

- Time based maps: "Key Frame Mapping"

- Time based maps: Flow charts and similar.

- Time based maps: Digital animated maps.

- Time based mapping: Story boards.

- Image maps: Qualitative information in maps,

- Images, video,s soundtracks.

- Spatial maps: Geographic maps or construction plans. Flow patterns.

- Intensity maps: Gradients and interpolation of continuous intensity fields.

- Mixed maps

USAGE OF GIGA-MAPPING

Our bottom up and practice based research on GIGA-maps compiled a possible list of the following functions:

- Learning: Mapping and coordinating pre-existing knowledge.

- Research: Including and organizing knowledge gained from targeted research.

- Imagination: Generative, iterative design.

- Management: Working with the involved organisation as a complex social organism.

- Event mapping: Working with orchestrating of complex events.

- Planning: Registering, describing and modifying complex processes.

- Innovation: Defining areas and points for intervention and innovation.

- Implementation: Engaging in all details and agents ecologies and environments of complex implementation processes.

A MATRIX OF GIGA-MAPS

The matrix below shows how the different mapping types have been preferably combined with the different themes (Fig.3).

	Research	Learning	Generative	Management	Event mapping	Planning	Innovation	Implementation
Mind maps	X	X						
Concept maps	X	X				X	X	
Gantt diagrams				X	X	X		X
Timelines		X		X	X	X	X	X
Key frames		X	X		X			X
Flowcharts						X		X
Animations			X		X			X
Story boards			X	X	X		X	X
Image maps	X	X	X				X	
Spatial maps	X		X		X	X		X
Intensity maps	X		X		X		X	
Mixed maps	X	X	X	X	X	X	X	X

Fig. 3: The matrix shows the different types of design activities and types of maps and suggests what type of map is best suited for what activity. This is suggestive and not to be taken as a rule.

ADDITIONAL FUNCTIONS OF GIGA-MAPPING
The matrix is far from exhausting the functions of GIGA-mapping. There are many functions that are generic and applicable across all types of maps. Amongst them are: 1) Building expert networks and communicating with them, mapping a field involving stakeholders; the GIGA-map can be used to define where expert knowledge is needed; 2) Defining the boundaries of a system in an informed manner as mentioned before; and 3) Visualisation and communication of the final projects.

APPLICATION AREAS
In the following section we will go through a series of examples to demonstrate some of the usage areas mentioned in the matrix. The samples are following the same order as the matrix above. Because of issues of confidentiality most of the mappings with professionals cannot be shown.

RESEARCH
A good way to build knowledge for a project is to start with mapping out the things one already knows and what one assumes. This is a superior tool to register and coordinate knowledge form several collaborators and to jump-start the project.

When this first mapping is done the maps are used as starting platforms to do literature and internet search for missing information which is filled into the map. The next step is to define spots and areas where more substantial knowledge is needed. This indicates how to compose an ideal expert network for the project and helps meeting the experts well-prepared. New versions of the mapping are produced including the experts contribution. Then the maps are used to define zoom in areas and zoom out areas. These are areas where a shift in resolution is needed to grasp more detailed insight or to get a more global overview. Finally areas for innovation are searched for.

Example: Research mapping for the design of an electric car: The example shows the areas that need to be researched in a design process for an electrical car (Fig. 4). The diagram does not show the necessary research itself but it shows the themes that need to be researched. The unique quality of this map is that it immediately gives an overview of the extent of the task and then will help planning the research phase in a more realistic manner and it ensures that the needed knowledge level is achieved as fast as possible. It also helps to sort the research into the areas that need to be researched in depth and those where one can rely more on experts.
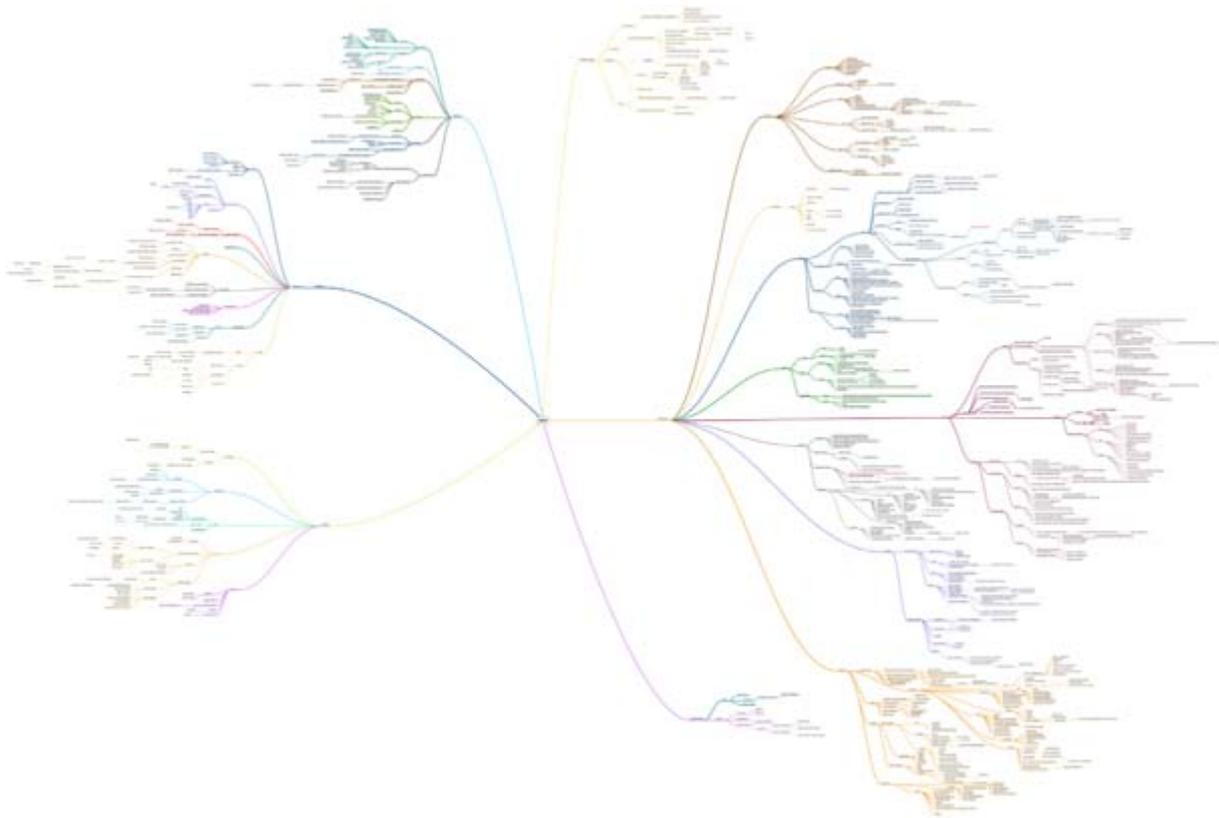
Fig. 4: Research mapping: The GIGA-map shows the mapping of the needed research to design an electric car. The map shows all the market-related, cultural, user-related inputs to the left and the technological requirements to the right, forming a double mind map with two focal centres. The map was first developed in the soft ware MindMap and later refined in Illustrator. Zoom in to study details. The visibility of the details is limited in this format but it gives an impression of the amount of information that was included. (Students: Thor Henrik Bruun and Fredrik Bostad, 2010)

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LEARNING

GIGA-mapping and a systems-oriented approach is very useful for extreme learning situations. It helps to map out the knowledge field early, to jump-start targeted quick research and to start with establishing the expert network early. GIGA-mapping helps to take an active role with the experts and to pose well-grounded questions. It also helps to make scenarios for problems one might face ahead.

Example: Story porcelain lamps. The case of the porcelain lamp indicates a very fast learning process, where a new material technology had to be learned and where there was no time for trial and error (Fig.5). The learning process started with, and was very much dependent on, a "meta-map" that depicted a narrative travel through the learning process. The challenges were extreme: To learn a very difficult material and material technology, to design a product for this material, to produce molds and prototypes and to test sandblasting on the material to create patterns, something that hardly was done before in this way. The early establishment of an expert network was crucial. Though the experts initially were very skeptical to the success of the project, the process was successful and the porcelain Lamps produced within the deadline, the Milan Fair 2010.
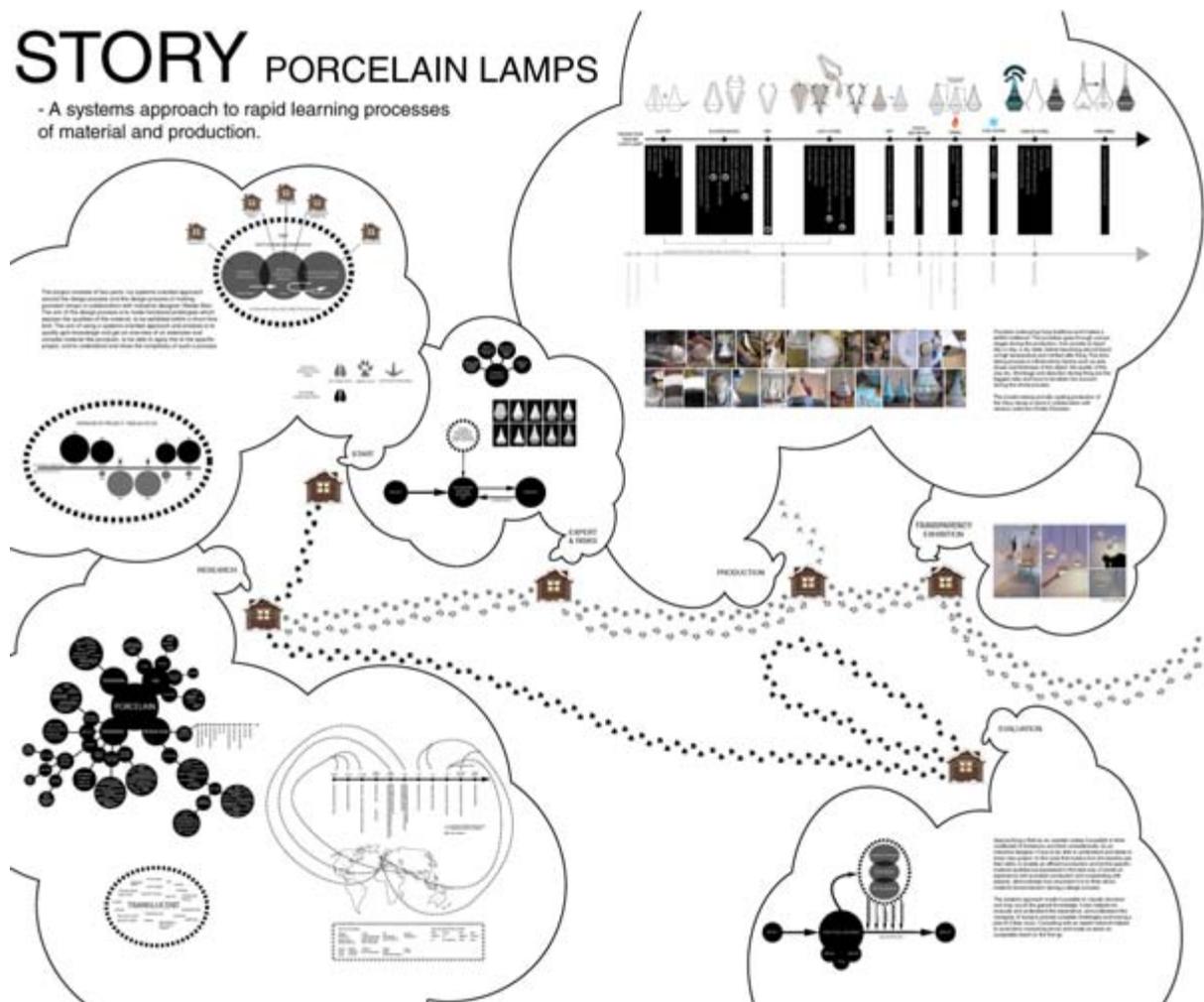
Fig. 5: The map shows the interlinking of several stages and maps in a systems oriented learning process. A for the student unknown material (porcelain) was researched and learned in an exceptionally short time. Porcelain is a very difficult material and the learning process was successful so that the final product, a lamp, was exhibited at the Milan fair after a period of only three months. The map shows start-up activities, research, experts and risk evaluation, materials and technology and evaluation activities. It also demonstrates a mixing of different mapping principles applied at different stages of the design process. Zoom in to see details. (Master's student: Ida Noemi Vidal, with Vibeke Skar ,2011)

GENERATIVE DIAGRAMMING
Generative dynamic diagramming is used for mapping out and manipulating information that is imaginative and will form structural bases for design. Generative dynamic diagramming is closely tied to design computing, and animation processes. This emphasises the flexible and dynamic features of the information field. Also such diagrams often operate on field intensities rather than on entities and relations.

This strand of research is now about to be taken up again and related to GIGA-mapping in future planned projects.

Example: Ambient Amplifiers (Sevaldson and Duong, 2000a). This urban project was based on seed-information that was tentatively fed into a process of generative diagramming. Then these diagrams were interpreted and formed the template for design intervention. The process of interpretation was highly informed by an extensive research of the site (Sevaldson and Duong, 2000b) touching all kinds of issues from social structures, topographical features, political intentions and understanding the main actors at the site (Fig. 6).

The uniqueness of this approach is bringing together generative visualisation based processes with large amounts of real life information.
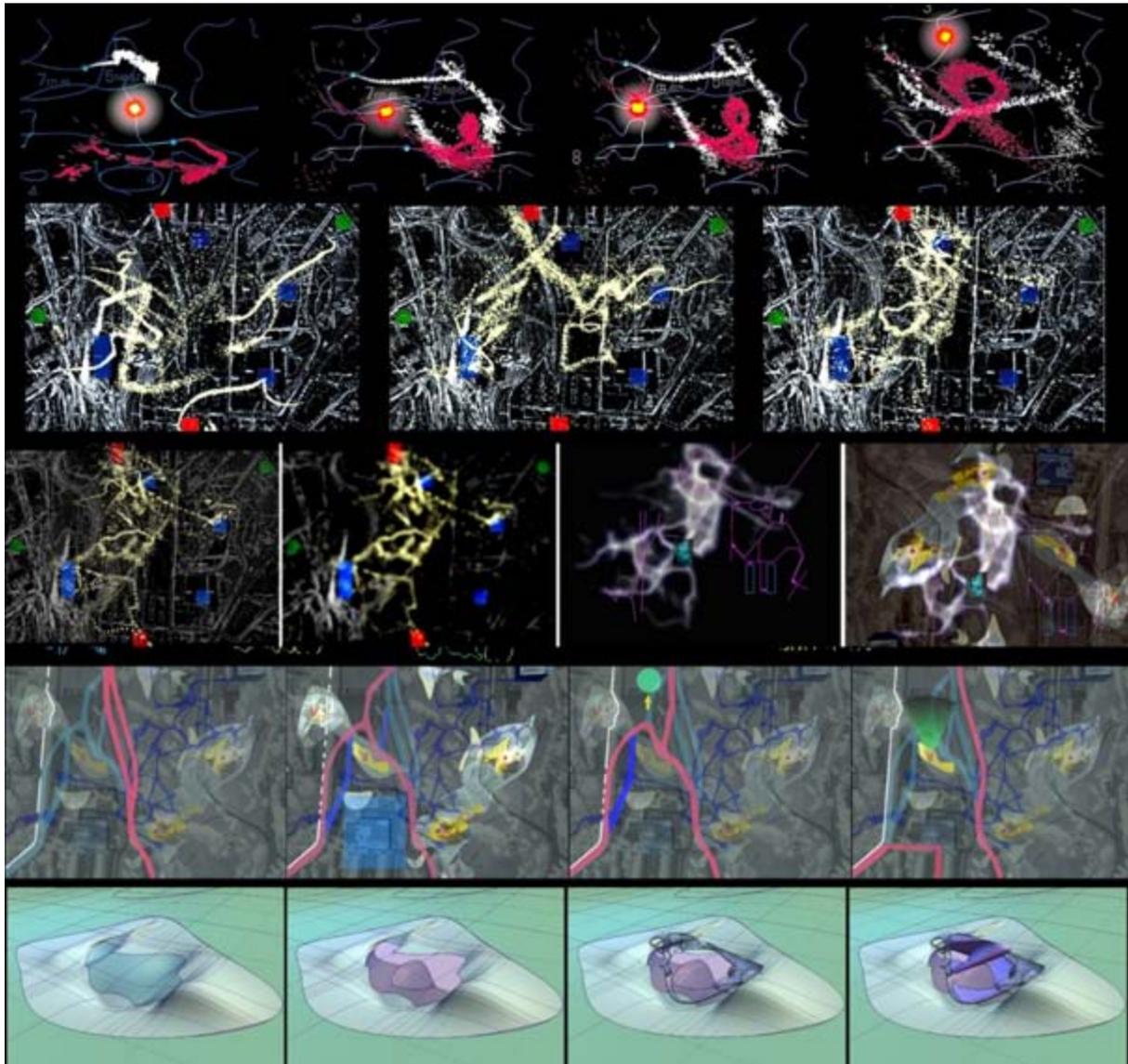
Fig. 6: Ambient Amplifiers: The project started with un-programmed spatial structures generated from an intricate setup of particle animations derived from the topographic model of the site and the influence of the main institutions (top row). Through several graphic stages (second row) the generative diagrams were slowly programmed by using them to inform the design interventions for the site (third row). These were a freely distributed path / play surface (fourth row, dark blue) a programmable road system (light blue and red) a flexible fence to the botanical gardens (white) and a system of "islands" (yellow) as institutional devices for collaboration between actors on the site. These are shown in the four different stages in the lower row. This process of interpretation was informed by a big amount of back ground information. (Author, 2000).

MANAGEMENT
GIGA-mapping, and especially time-line mapping showed to be an excellent tool for meetings that are addressing especially complex issues, like strategic discussions, cooperation and processes. The meeting format allows dropping a written agenda. By only agreeing upon a theme the issues are unfolded in collaboration around the map. The meeting becomes open ended but still focussed and communication is very much eased when the map is used actively.

GIGA-mapping is used with success in groups where they help to establish a shared image of the complex field at hand. Mapping is then a social activity where all should contribute.

Example: Mapping of research landscape at Institute of Design Oslo School of Architecture and Design. The mapping produced a new information access to the richness of the research landscape. The first map was organised in a clustered fashion that goes beyond the established types of maps. On the global level it is structured like a concept map and on the local level, for each cluster built up around each project, it is organised like a mind map (Fig. 7). It revealed the complexity of each research project and its layering and how they are theme-wise related. It created the bases for more synergies and the foundation for building overviews, consensus, relate knowledge activities, for resourcing and to plan for future projects (Fig. 8). The process demonstrates how different types of maps are useful to depict the same information and read it in different ways.

Fig. 7: GIGA-map that was a product of a two hours workshop unfolding the complexity of the research activities at the Institute of Design at AHO. Each project (depicted in black frames) is surrounded with a network of collaborators, experts and financing bodies. Zoom in to see details. (Design research colleagues, AHO, 2010).
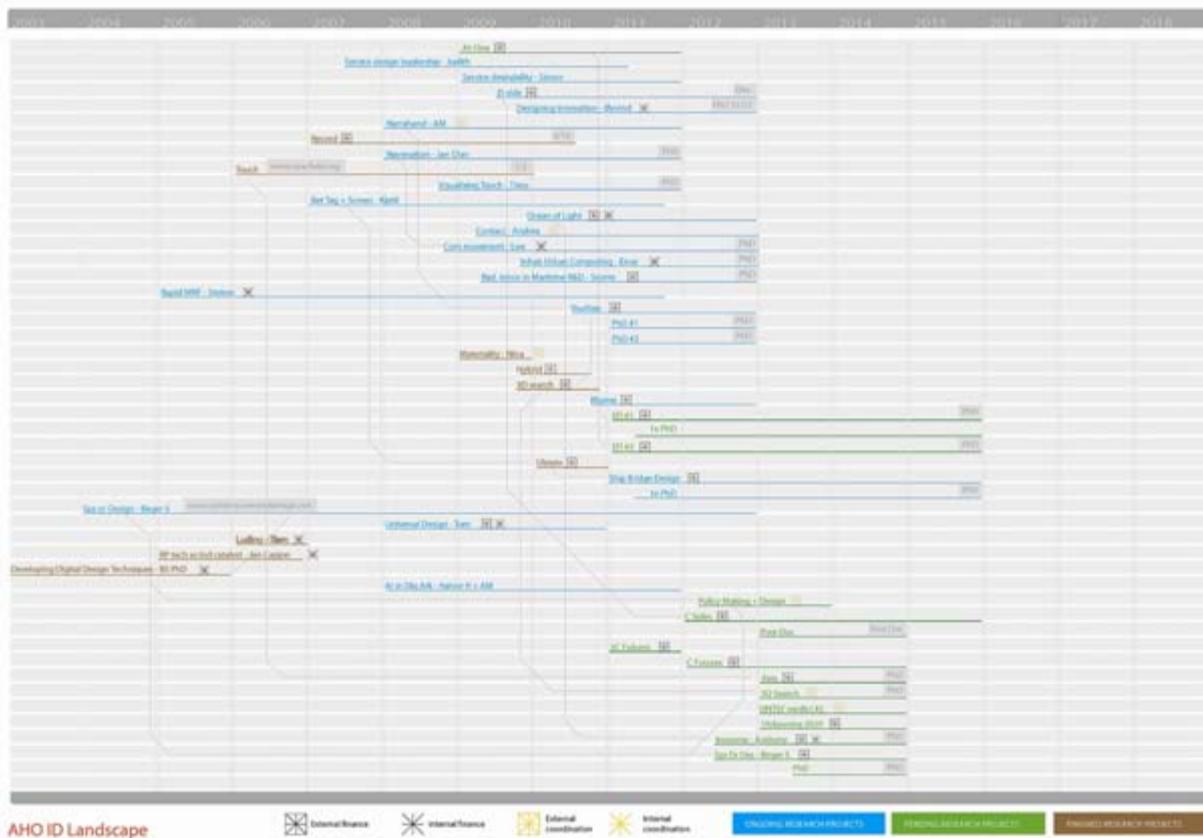
Fig. 8: At a later stage the projects where mapped along a time line in a "quasi-Gantt" diagram. This would draw the picture in a different way, loosing some information but displaying other. (Design research colleagues, AHO, Adrian Paulsen, 2010).

EVENT MAPPING
Mapping out events on spatial maps will provide the information needed to create well-timed experiences and to produce worst-case scenarios to prevent disasters from e.g. crowding.

Example: Miniøya festival for children. In the Music festival for children it was essential to avoid crowding. Therefore the project intended to plan for a careful orchestrating of resources and attractors throughout the event. When a special popular group was on the stage several other actors were triggered to prevent over-crowding. Additional attractors where activated elsewhere to "stretch" the field of spectators so to avoid too dense crowding. Also the security staff was directed to the needed points to be ready for preventive action. It was possible to forecast and orchestrate the distribution and densification of crowding by looking at the spatial map and a time line with the activity program of the festival simultaneously. The achievements and innovations were: Crowd management through attraction control and balancing. The activation of several operational levels when needed. Just-in-time security management. Mapping of events in the form of snapshots was developed further and later lead to the concept of "Key Frame Mapping" (Fig. 9).
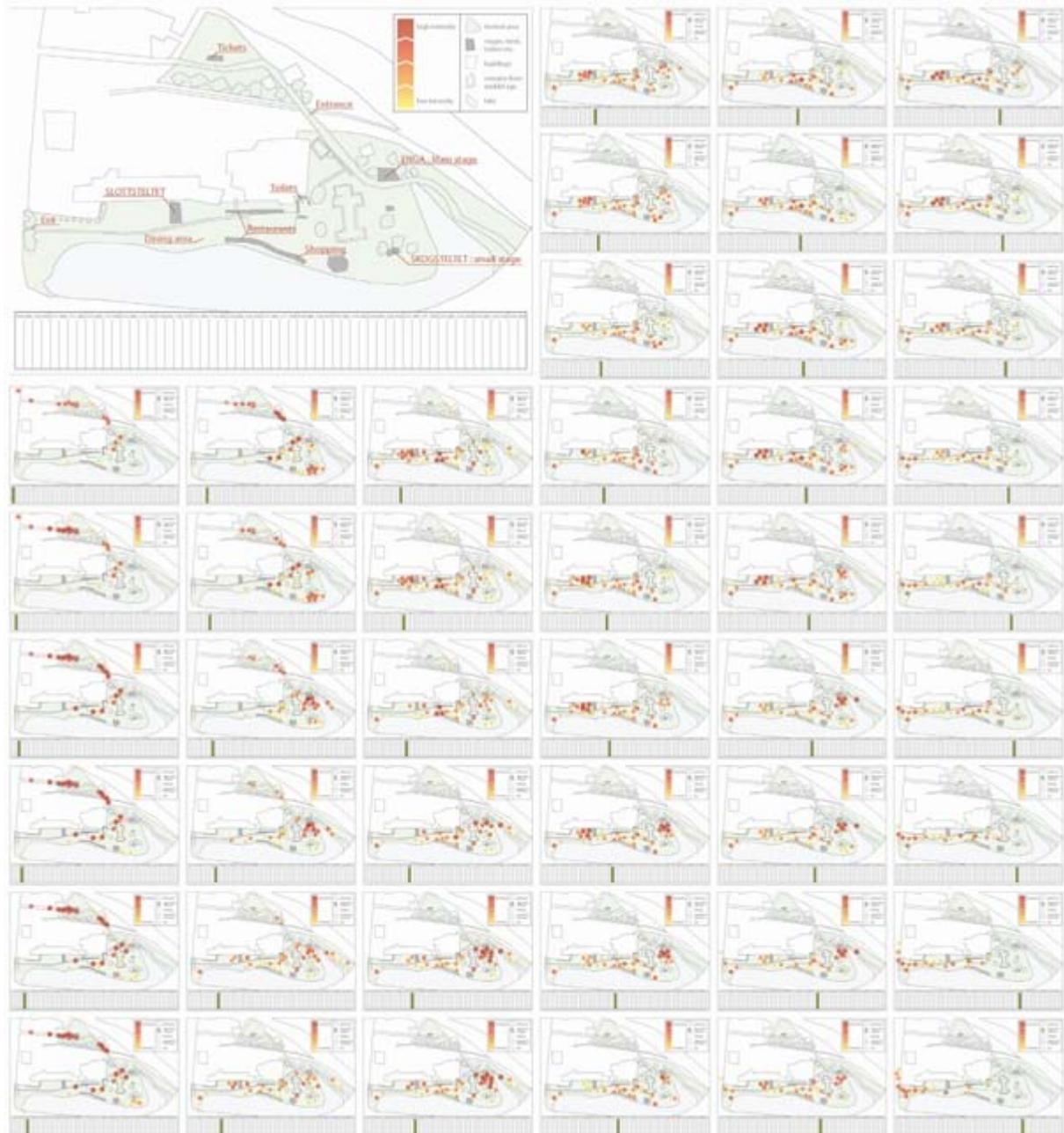
Fig. 9: Event mapping in scenario snapshots. "Key Frame Mapping" showing many different imaginable scenarios of crowding on a festival for children. Each "key frame" indicates a particular scenario between which it is possible to interpolate. Zoom in to study the variations. (Student: Ingunn Hesselberg, 2009)

SEQUENTIAL ANALYSES AND SCENARIOS
The mapping out and unfolding of complex sequentially ordered scenarios can be diagrammed in several additional ways. Typical are Gantt diagrams, Flow charts and Pert diagrams. Also casual loop diagrams are used to find feedback loops. Most often one is better off in a design project to disregard strict diagramming rules like the flow diagram conventions.

Example: A suggestion for an oil spill prevention system based on risk calculation and social networking. The example shows a diagram that is treating sequential analyses in a designed way where rich information is combined. The analytic and systemic approach led to an innovative solution that coordinates all stakeholders and that makes risk evaluation accessible and useful so that the stakeholders can act for prevention rather than for repairing damages (Fig. 10).

Fig. 10: The GIGA-map shows a sequence of a typical oil spill disaster. This sequence is the key to map out and understand all actors, communication channels, technology and procedures involved and to pose critical questions for improving the response to oil spill disasters. This chart takes some features of the traditional flow chart breaks its conventions and adds new information in the form of a mind map structure and additional diagrams. (Student: Adrian Paulsen, 2010

PLANNING
GIGA-mapping is very useful for super-complex planning of processes.

Example: Training software. The intention in this case was to use the addictive features of computer games for reinforcing physical activity. Levelling points, goals, social networking and status are built into the game in a similar way as in a massive multi player on-line game. The orchestrating of progress was developed along a complex mixed time line diagram. The result was an innovative genre-blending new software. Mixed time line diagrams are useful to work with when orchestrating complex multi-layered events that stretch over a long period of time (Fig. 11). (Student: Erik Falk Petersen).

Fig. 11: The shown GIGA-map is based on a Gantt diagram principle but has added qualitative information. The map, arranged along a time line, mixes elements from Gantt with other diagramming and qualitative information in the form of images. Zoom in to see details. (Student: Erik Falk Petersen, 2009).

INNOVATION
GIGA-mapping leads to innovation because of the unfolding of potential points of interventions.

Example: Fire Rehearsal Centre. Through GIGA-mapping the student discovered the psychological aspect of fire prevention equipment. This equipment is by most people used very rarely or never. But it still plays a role even when not in use by providing a psychological effect of security.

Through GIGA-mapping the focus-point was moved from the fire situation to a point before an eventual fire. This could easily become a fire prevention project, but the new angle of approach was the psychological factor. By addressing the user's knowledge and skill the feeling of security was improved by rehearsing (Fig. 12).

The result was a genre-crossing mobile edutainment centre for practising and testing all kinds of fire equipment (Fig. 13). A trustworthy financial model included co-financing from insurance companies, product manufacturers, fire prevention organisations, government and individual users of the centre. (Student: Heidi Borthne).
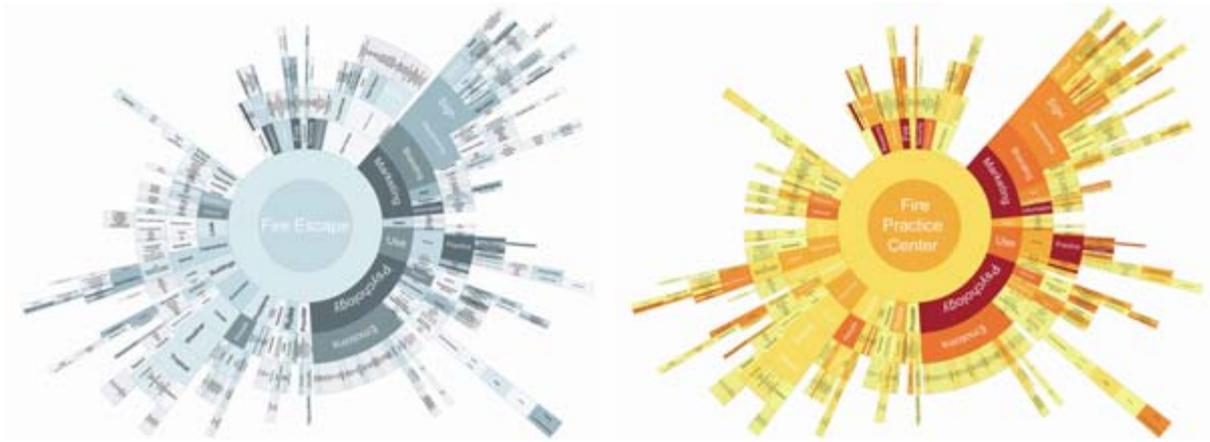
Fig. 12: The GIGA-map to the left shows the initial research where the redesign of fire products was at stakes. The systems analyses revealed other points for innovation with a bigger potential for having an impact. Especially the psychological factor was identified as important. The focus was moved towards prevention and education addressing the psychological factor by providing confidence. The GIGA-map to the right is redesigned with this new focus. The resulting new map was different from the original one in only a few areas. Zoom in to see more details. Some information is too small to see in this format. (Student: Heidi Borthne, 2009)

Fig. 13: The suggested training centre. This was a mobile unit designed to fit into a standard container size. Activities like testing escape ladders and ropes, jumping onto fire escape cushions and finding the way in smoke filled labyrinths are indicated. (Student: Heidi Borthne, 2009)

IMPLEMENTATION
Implementation processes are super-complex because it is in this process the design intervention meets real life. GIGA-mapping is useful for creating very complex implementation scenarios.

Examples: Customized aid for disabled children in development countries. In this unique concept, learning processes in developed countries and developing countries are tied together, to create synergies and to enable mutual knowledge transfer. The aim is to provide highly customized aid for disabled children. The higher education system in Norway is suggested to cooperate with local organizations and homes for disabled in Uganda to achieve this. The implementation is designed down to the smallest detail in a circular GIGA-map (Fig.14). It is circular because the process is started with repetitive iterations engaging in new sites over time.
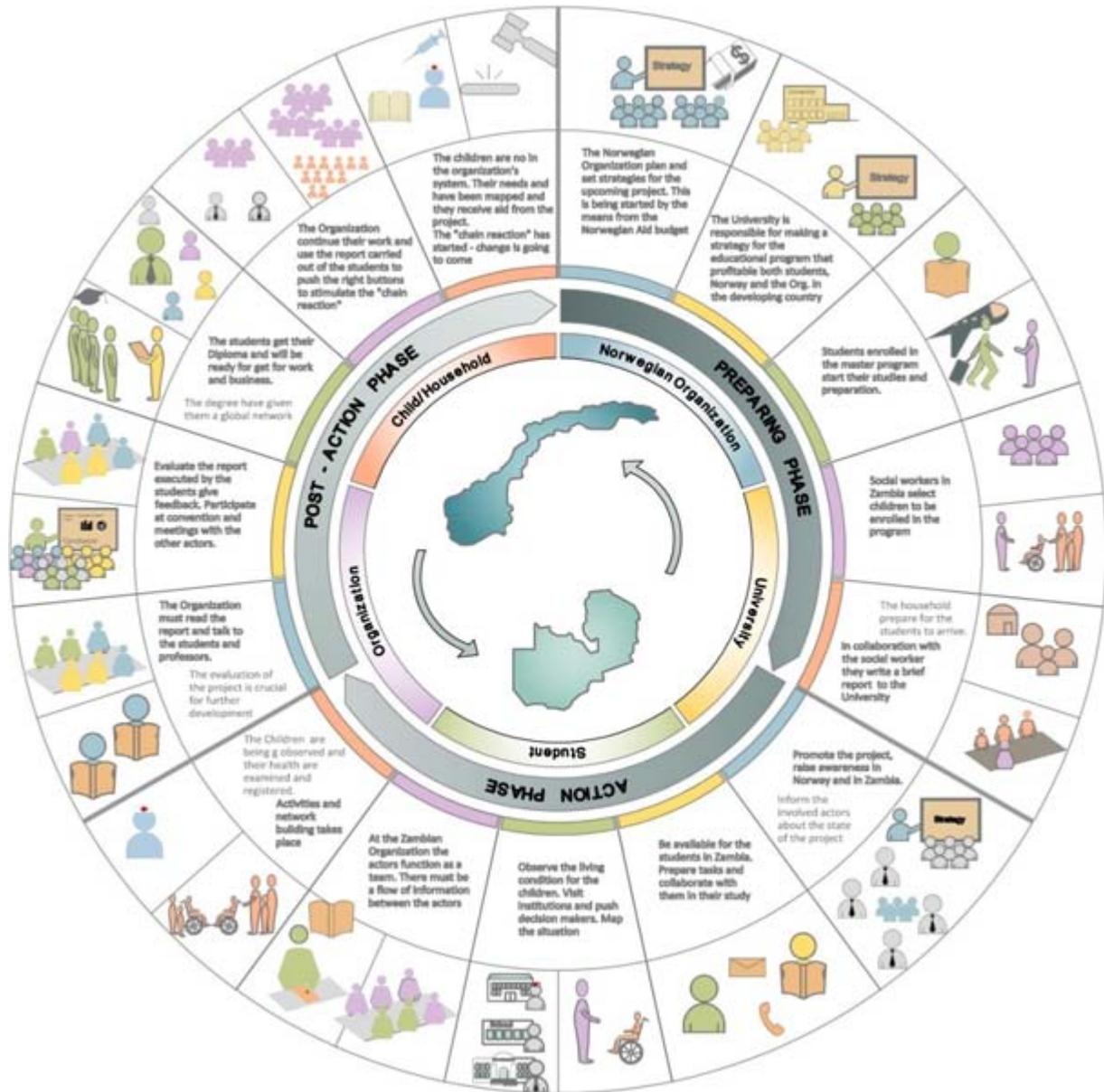
Fig. 14: Synergistic education system for disabled children in developing countries. The implementation follows a series of defined steps and is restarts with reusing experience for the next project when finalized. (Student: Terese Charlotte Aarland, 2009)

CONCLUSIONS AND FURTHER RESEARCH

The research by design presented here has generated new knowledge on visualization of super-complexity in design. GIGA-maps are rich multi-layered design artefacts that integrate systems thinking with designing as a way of developing and internalizing an understanding of a complex field. It also is clear that the research needs further development and registration. Still some major realisations have been made and tasks for further investigations are uncovered. These will be reported on in forthcoming publications.

Typically, the shown examples are not "pure". They are categorised according to their most dominating feature, but it is important to recognise that all examples do break established diagramming conventions. As a consequence, they mix and juxtapose information sets and ways of visualising this information.

Conventional diagrams (with numerous exceptions) tend to represent information in far too limited ways. They work like diagrammatic "strait jackets" on the information because they tend to lead towards a tidy sorting and "over-designing" of the information. The conventions strive for categorical clarity on the cost of interlinked richness. Their main purpose is to communicate information. This limitation is not useful when dealing with super-complexity as a process, where much larger complexities can be handled by the involved parties. Mixed diagramming techniques and frequently inventing new ways of depicting information are crucial in GIGA-mapping.

The innovations found in the processes and modes of mapping are not only that very rich diagramming and visualisation are useful in complex processes, compared to less rich visualisation, but that they also demonstrate the necessity of interconnecting and juxtaposing information that is categorically separate, and to investigate and create their connections. Investigation, research, involvement, action, generation and creativity are interlinked and facilitated through the GIGA-map.

GIGA-mapping has shown, by ways of varied Research by Design experiments that it can play an important role in the challenges increasing complexity poses to designers. It is a tool for generating concepts that are very well rooted in real life conditions. It incorporates design thinking and intuitive approaches to systems thinking and it is a good tool for rapid learning and for collaboration.

Future challenges are:

Pedagogical challenges: The challenges of teaching design students to work with and within super-complexity needs further addressing. These problems have been touched upon earlier (Sevaldson, 2008b). These problems seem partly to be on an individual level (individuals vary greatly in their ability to cope with super-complexity and systems thinking) partly in the field (design education is not geared towards systems thinking) and in the specifically developed techniques (e.g. SOD needs better pedagogical approaches).

Development of practice: The practice of GIGA-mapping is not yet fully developed and errors and pitfalls not fully investigated. Though some experience that is not reported here is registered, it needs further research.

Validification: GIGA-mapping needs to be fully tested and further developed in business and out of the academic context. The reported research is moving ever closer to the state of real life implementation and has already been tested amongst consultants and in companies, and will be tested in a large innovation project in the near future.

Synthesis: A critical point is the process off deriving emergent points of interventions potential innovations and synthesising new solutions and synergies form the maps. Though quite some achievements have been reported it still needs to be reported in a larger amount and to a deeper degree.

Building criticality: The GIGA-mapping technique would benefit from a critical modus e.g. a way of triangulating different information sets to reach more robust renderings of super-complexity. Though this is already addressed within the multiplicity of GIGA-mapping and the relations to Critical Systems Thinking, this needs further development.

Additional development of the techniques needs to be reported. Amongst this is the further development of GIGA-mapping techniques according to the following lines:

• An investigation and further recapturing of generative dynamic diagramming techniques and how they can better merge with the current developed GIGA-mapping.

• Further investigation into the use of software for GIGA-mapping, including the benefits of using interactive maps and animation.

• Reporting on the practice of GIGA-mapping where many approaches and techniques have tentatively been defined and tried. These need further development and systematisation to prescribe and open out for practices of GIGA-mapping in design.

This paper presented a series of cases where the ability to handle large amounts of information has been shown to be beneficial for innovative yet realistic design suggestions. The training of how to handle super-complexity is urgent within design so as to meet the challenges posed by globalization and sustainability. Improving these abilities and skills are crucial for designers to be able to make substantial contributions to society and in the process also gain in their own importance.

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