Automation and Robotisation in Construction and Transition Management

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I. Introduction

A number of problems in the construction industry could be solved with the aid of automation and robotisation technologies. There are indications that automation and robotisation processes are similar to transition processes. Recent years have seen a good deal of research into these kinds of often complex processes and how to manage them. This knowledge may provide the inspiration required to solve the problems in the construction industry through an increase in the exchange of available (tacit) knowledge. This paper looks at this issue at the level of multidisciplinary, collaborative expert designers.

II. Problems

The problems today in the building industry are that the client and society do not get the value they want. Clients are users, investors, owners, lessors and producers of real estate objects. Their values are profitability, usability, flexibility and quality. Society wants to save energy and avoid waste and pollution.

- Some problems underlying those mentioned above may be:
- A lack of specific working methods for expert designers to work with one another and with clients.
- A lack of suitable competences of the client and expert designers that enable them to work with one another.
- Innovative behaviour shown by expert designers and clients goes unrewarded
- Government regulations often discourage innovation behaviour.

The characteristics of these problems are:

- The players are not always the same people.
- The perceptions of the designers differ too much.
- Many different kinds of expert designers are involved.
- The expert designers are not involved all the time.
- Solving the problems requires a lot of time.
- The government plays a significant role.

These characteristics are typical of transition processes.

III. Automation and robotisation

The design and construction of buildings requires a great many tasks to be outsourced. Three kinds of tasks can be distinguished: physical tasks, cognitive tasks and organising tasks. These tasks can be performed by workers, equipment, computers and means of communication. Robotisation can be described as shifting the physical and cognitive tasks from workers to equipment. Mechanisation only shifts some of the physical tasks (Van Gassel 1995). Automation shifts some of the cognitive tasks and organising tasks from workers to computers and means of communication. In this way, industrialisation can be described as shifting tasks from the construction site to the factory.

The problem description uses the term expert designer. Dreyfus (2003 cited Dorst and Reyman 2004) describes it as follows 'The real expert designer responds to specific situations intuitively and performs the appropriate action straightaway. There is no problem-solving and reasoning that can be distinguished at this level of work. This is actually a very comfortable level to be functioning on, and a lot of professionals do not progress beyond this point.'

To shift the physical, cognitive and organising tasks from workers to equipment, computers and means of communication requires knowledge of materials, construction products, ergonomics, drive technology, machine controls, remote control, sensors, computers/software and means of communication. Knowledge of these technologies is only present as tacit knowledge in a wide-range of expert designers involved in multidisciplinary collaboration.

Working on the development of automation and robotisation technologies is not enough by itself. These technologies will also have to be geared to the wishes of the clients. Section 5 of this paper looks at how this collaboration can be organised and managed.

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A. Developments

In the ISARC 2004 paper, Balaguer (2004) sees a trend in the area of automation and robotisation in the construction industry: a transition from hard to soft robotics. Soft robotics includes the following technologies: on-site sensory data acquisition and processing; human operator field safety and security, chip-based process control, etc. This transition is achieved by the intervention of numerous non-co-ordinated players (architects, builders, suppliers, etc).

In the proceedings of ISARC 2004, Yamazaki (2004) used the terms technology and knowledge fusion. He defines these as follows: 'Technology fusion is an emerging methodology designed to integrate potential technologies among different disciplines, and it is also viewed as an effective approach to assisting construction firms to respond to the difficult environment in which they are operating. Knowledge fusion is also an emerging methodology designed to improve organisational knowledge creation ability that has been introduced to the construction industry by dynamically transforming an organisation's implicit and explicit knowledge.' He further concluded: 'To promote technology fusion, it is essential to have a structured way with a clear goal, concept and strategy.'

Maas en Van Gassel (2005) stated that there is plenty of room for improvement for clients in all process elements of construction projects by using construction engineering technologies, construction management methods and ICT tools.

Transition management will probably facilitate the application of automation and robotisation technologies in the building production process.

IV. TRANSITION PROCESSES

Transition processes are not easy to describe. This paper describes the transition process concept in greater detail in a number of different ways by posing certain questions.

What are the transition basics?

The Dutch 'Competence Centre for Transitions' sums up the following themes: system approaches and dynamics, transition management, sustainable development, working across disciplines, working with futuristic views, dealing with uncertainty, learning by doing and changing without power. (Senternovem 2005)

What are the characteristics of transitional thinking?

Transitional thinking is characterised by the recognition of both strong and weak signals, thinking in the short and long term, multi-domain thinking and thinking at multi-levels of scale.

What are the characteristics of transitional action?

Transitional action focuses on: anticipatory and innovative thinking; long-term action, system innovation instead of system improvement and learning processes.

What are the phases of a transition process?

Generally speaking, there are four transition phases:

1. A predevelopment phase. There is a balance and the status quo does not change.
2. A 'take-off' phase. The system starts to shift.
3. An acceleration phase. Structural changes take place.
4. A stabilisation phase. A new balance is reached.

(Rotmans, 2000)

What other descriptions are comparable to the transition process concept?

The concept can also be described as: a process of social change, a break in the trend, system innovation and a paradigm shift. It is a process in which the players hold different views, come from different areas of expertise and act at different times.

Rotmans ultimately arrives at the following description of a transition: A structural social change that results from processes affecting one another and developments that strengthen one another in the areas of economics, culture, technology, institutions, nature and the environment.

A. Managing transition processes

Managing transition processes cannot be compared to managing a normal process. A transition process requires an evolutionary approach. The transition managers are confronted by a wide range of aspects that have to be taken into account. A few characteristic aspects are:

- System analysis. This is necessary to define and delineate objects and relations.
- Competent partners. Ensure you have people with the right competences.
- Do and demonstrate. Do not only theorise.
- Social learning: Learn together by means of interaction and reflection with others.
- Arena. Develop activities within a wide range of groups: small, specialised or multidisciplinary groups.
- Dealing with uncertainty. The process cannot be controlled directly but runs its own course.
- Linking and embedding by means of strategic thinking and acting.
- Context: Look for opportunities, e.g. within existing policy.

(Joustra 2005)

Transition management does not focus on goals for each period but for several periods at the same time and in the long term. The long-term perspective is the course for the short-term actions. (Rotmans et al, 2000)

Transition management has similarities to Lean Construction Management. The International Group for Lean Construction (IGLC) formulates their views on Lean Construction in the following way: 'Our goal is to better meet customer demands and dramatically improve the Architecture, Engineering and Construction (AEC) process and product. To achieve this, we

are developing new principles and methods for product development and production management specifically tailored to the AEC industry, but akin to those defining lean production that proved to be so successful in manufacturing.' (IGLC 2005)

B. *Micro level*

A transition process can be considered at various levels:

- Micro (people, organisation)
- Meso (sector, national)
- Macro (national, international)

In this paper, we concentrate on the micro level. What is transition management at the level of designers and teams in which they work together?

Sub-questions at this level are:

- How do multidisciplinary expert designers work together?
- What competences are required for this collaboration?
- Are working methods required for this collaboration?
- How do you coach multidisciplinary design teams?

V. WORKING METHOD FOR MULTIDISCIPLINARY COLLABORATIVE DESIGN TEAMS

A. *Multidisciplinary collaboration*

Kvan (2000) distinguishes between the terms collaboration and co-operation. He notes that 'co-operation' relates to working together for mutual benefit, while 'collaboration' relates to working together to achieve shared goals. Kvan also distinguishes closely coupled design processes from loosely coupled design processes, where participants each contribute from their particular domain expertise at moments when they have the knowledge appropriate to the situation. In a closely coupled design process, the participants work intensively with one other, observing and understanding one another's moves, the reasoning behind them and the intentions. Kvan's description explains the meaning of multidisciplinary collaboration.

B. *Design meetings*

Reymen (2001) described 'a design session as a period during which one or more designers are working on a subtask of a certain design task', and 'a design task at a certain moment to meet the design goal at that moment, starting from the current design situation. A design task is executed by design activities.' We use some concepts from these descriptions to explain what we mean by a design meeting, viz. a set of prepared design activities executed by a group of designers to work face-to-face on a design task with the help of a coach and support systems to reach a transferable design result.

In 'The creative workshop method', Emmitt (2004) distinguishes six types of workshops:

- (partnering) building effective relationships: teambuilding, common goals, ethics in co-operation, roles and partnering agreement
- vision: basic product values, knowledge and experience, whole-life approach
- realism: fulfilling project values, design alternatives, project economy
- criticism: presentation of conceptual design, value reflection
- design planning: production information, delivery, value engineering
- planning for execution: process plan to map the various production activities

This development of a working method will focus on the 'vision' type of workshop, where the designers sit at a table. This type of workshop requires a shared understanding between the designers of product and process. In his comment on the 'vision' workshop, Christoffersen (2004) mentioned the following aspects: frame and process, dreams and visions, value debacle, value base and evaluation of the 'building effective relationships' workshop. What, then, are the design activities to acquire a shared understanding of 'vision'?

C. *Design group and coaching*

Expert designers working together during a meeting form a cross-functional group. In subsequent meetings, the composition of the group can be different. This is why we do not focus on teamwork or team development with the relevant aspects as forming, storming, norming, performing and adjourning (Robbins 1998, p. 242) within a programme of design meetings. What we do is focus on an effective and efficient group process and try to achieve that by careful preparation and coaching within the context of *one* meeting. The role of the coach is crucial. The task of the coach is 'a style of support, in which the expert designers come into action by themselves' (Lingsma 1999, p. 12).

D. *Design activities*

During a design meeting, a coach can let the designers perform a wide range of design activities, which are necessary to attain a certain design result. The following sections describe a number of activities from a literature survey that may be suitable for 'vision' design meetings. The survey is based on the existing insights and theories of cognitive processes, such as perception (verbal, visual and tactile), communication, (creative) thinking, (experiential) learning and (interdisciplinary) collaboration.

By harnessing people's creativity, Sanders and William (2001) identified several forms of human behaviour: Say (say, think), Do (do, use) and Make (know, feel, dream).

Each level of knowledge (explicit, observable, tacit and latent) requires a carefully chosen technique (interviews, observations and generative sessions) (Sleeswijk Visser et al. 2004).

Sanders (2001) writes: 'The creativity-based research tools enable creative expression by giving people ambiguous visual stimuli to work with. Being ambiguous, these stimuli can be

interpreted in different ways, and can activate different memories and feelings in different people. The visual nature liberates people's creativity from the boundaries of what they can state in words. Together, the ambiguity and the visual nature of these tools allow people much more room for creativity, both in expressing their current experiences and ideas and in generating new ideas.'

Creativity techniques make tacit knowledge of designers explicit. Root-Bernstein et al. (1999) used a trans-disciplinary view to define creativity: 'Creative thinking in all fields occurs preferably before logic or linguistics come into play, manifesting itself through emotions, intuitions, images and bodily feelings. The resulting ideas can be translated into one or more formal systems of communication such as words, equations, pictures, music or dance only after they are sufficiently developed in their prelogical forms.'

To express the latent and tacit knowledge of the designers, creative thinking with the aid of creative techniques is useful for a vision-based session. The purpose of a 'vision' design session is to reach an agreement between the different designers about the process and product. This means that the designers create and share knowledge. In educational terms, they learn from one another. A generative or creative technique to help achieve this purpose should be a philosophy called 'serious play'. Serious play is a serious activity to create innovative ideas.

Schrage (1999) describes the essentials of serious play as follows: 'Serious play is about improvising with the unanticipated in ways that create new value. Any tools, technologies, techniques or toys that let people improve how they play seriously with uncertainty are guaranteed to improve the quality of innovation. The ability to align those improvements cost-effectively with the needs of customers, clients, and markets dramatically boosts the odds for competitive success'. John Varney (2005) gives a special meaning to 'serious play', SERIOUS refers to the left brain (logical, analytical, fragmentary, mechanical, efficient) and PLAY to the right brain (imagination, pattern-forming and recognising, holistic, organic, effective).

Papert (1999) says, 'Constructionism is the idea that knowledge is something you build in your head. Constructionism reminds us that the best way to do that is to build something tangible – outside your head – that is personally meaningful. Furthermore, that knowledge is best constructed in a social context where the participants make something sharable.'

In his inaugural lecture, Martens (2005) says that people use two complementary means for communicating ideas, opinions and interactions. 'Descriptions' for spoken and written languages and 'depictions' for gestures, drawing a picture, images and sketches. The last means is helpful for forming opinions and ideas, where the opinion is not determined by externally agreed interpretation. In our view, it does not stop with drawing pictures, but constructing objects is also a helpful means. It is probably a matter of tactile intelligence or tactile thinking as a counterpart to conceptual thinking. Donald Schön (1992) tells us that 'Design knowledge is knowing-in-action'. Constructing with materials helps the designer express the knowledge that he cannot say.

E. Designers' interaction circle

Designing is a social process. This means that designers communicate with one another. A designer shows what he thinks (by acting) and gets a reaction from another designer (by reacting). What a designer thinks is based on his mental model, a representation of reality that is built in order to understand, predict and explain the world (Badke-Schaub 2004). By integrating acting (doing, skills), reacting (feeling) and thinking (knowledge), the experience can grow (Dewey 1958) and the mental model change. Reflecting is a special kind of experience, namely an experience with regard to one's own experiences. It is a crucial phase in a learning process (Kolb 1983) and in a design process.

The acting and reacting activities can be performed in a wide range of languages (Birkhofer and Jänsch 2003, p. 106) and can be disturbed by a specific barrier around the designer. Buciarelli (2002) called this the 'object world'. Designers can have their own language, tools, codes, unwritten rules and scientific paradigm. The acting and reacting activities are described in detail in the designers' interaction circle (see figure 1). We call a coherent collection of acting and reacting activities a working method.

F. Particular working method

Researchers believe that designers who work together effectively produce more knowledge and share more tacit knowledge, and that it is necessary to organise and manage the design process (Friedl 2001). One of the possibilities of the above is to make use of a working method specifically for a face-to-face 'vision' design meeting with expert designers.

The particular working method is a set of coherent design activities, which consists of a wide range of acting and reacting languages and has been developed on the basis of the following design parameters:

- Using the rational and tacit knowledge of the designers
- Using the left and right brain alternately
- Using description and depiction
- Using a wide range of intelligences
- Using visual and conceptual thinking
- Learning from one another
- Taking time for reflection
- Constructing metaphoric objects with one another

- Working in a generative and focusing mode
- Taking time for incubation

Two parameters need some further explanation.

'Visual thinking is thinking in images and events. It can be described as spatial thinking. Visual thinkers prefer to organise their world with non-linguistic means. They see mental images or situations and events, in which several things are visible at the same moment, interact with one another and form a meaningful entity. It is simultaneous, non-verbal thinking, a manipulation of spatial events. Most visual thinkers have a holistic cognitive style, which means that they are 'good' in not losing themselves in details, in the discovery of co-ordinating relations and in giving personal, biased total descriptions of problems.' (De Groot and Paagman 2003, p 85) This description may indicate that building designers are more visual thinkers than conceptual thinkers.

Design meetings held with expert designers have shown that for complex design tasks, the designers need an incubation period to find ideas and concepts (Van Gassel and Rutten 2004).

A wide range of design activities can be developed using these design parameters as a basic premise. A division into the following categories can be made:

- Constructing objects
- Writing
- Mapping
- Sketching
- Storytelling
- Playing, acting
- Reflecting
- Releasing and relaxing

At the Eindhoven University of Technology in the Netherlands, the Construction Management group is currently developing, testing and applying a working method that meets the specifications described above.

VI. CONCLUSIONS

What is the significance of transition processes with regard to automation and robotisation in construction? In the previous sections, we have explained what transition processes are and what we mean exactly by automation and robotisation. By getting multidisciplinary expert designers to work together in the right manner, there is a good chance that more automation and robotisation technologies are used in the building of objects and that they can contribute to solving the problems identified. Knowledge of and skill in transition management are very useful in this regard.

VII. REFERENCES

Badke-Schaub, Petra. Strategies of experts in engineering design: between innovation and routine behaviour. In The Journal of Design Research, Volume 4, 2004.

Balaguer, Carlos (2004) Current trends in robotics and automation in the construction industry: transition from hard to soft robotics. In the proceedings of ISARC 2004, Korea.

Birkhofer, Herbert and Jänsch, Judith (2003). Topic II: Interaction between individuals. In: Lindeman, Udo , ed. Human Behaviour in Design. Berlin: Springer, 105 – 120.

Bucciarelli, Louis L. (2002) Designing Engineers. The MIT Press.

Christoffersen, Anders Kirk, (2004). Presentation workshop Lean Construction. Danish Technical Institute, Kobenhagen.

Dewey, John (1958) Experience and Nature,

Emmitt, Stephen, Dag Sander, Anders Kirk Christoffersen, (2004). Implementing value through lean design management. Proceeding IGLC2004, Kobenhagen.
www.iglc2004.dk

Friedl, Gebhart, (2001). Modelering van het ontwerpproces, een proceschereografie. ADMS publicatie 15, TU/e.

Gassel, Frans van (1995) A method for analysing mechanised and robotised production processes on the building site. In the proceedings of ISARC 1995, IMBiGS Poland.

Van Gassel, Frans, Paul Rutten (2004) Workshop ontwerpbijeenkomsten bij Heerema. Centre for Building and Systems, Newsletter, no. 4.

De Groot, R and C.J. Paagman, (2003). Denkbeelden over beelddenken. Een beeld zegt meer dan duizend woorden. Utrecht, uitgeverij Agiel, the Netherlands.

IGLC
www.iglc.net

Joustra, Douwe Jan (2005) Transitiepapers 1 - 5 (Transition papers 1-5), Ministry of Housing, Spatial Planning and the Environment (VROM).

Kolb, David. A, (1983) Experiential Learning: Experience as the Source of Learning and Development. Prentice Hall

Kvan, T. (2000). Collaborative design: what is it? Automation in Construction, **9**(4) 400-415.

Lingsma, Marijke (20010. Aan de slag met teamcoaching. N. Nelissen Soest.

Maas, G and F. van Gassel. The influence of automation and robotics on the performance construction in Automation in Construction 14 (2005) 435 – 441.

Martens, Jean-Bernard, (2005) Visual interaction: between vision and action. Inaugural lecture at the Technische Universiteit Eindhoven.

Papert, S., (1990). A critique of technocentrism in thinking about the school of the future. MIT Epistemology and Learning Memo No. 2 Cambridge Massachusetts Institute of Technology Media Laboratory.

Reymen, Isabelle M.M.J., (2001) Improving design processes through structured reflection: a domain-independent approach. PhD thesis Technische Universiteit Eindhoven.

Robbins, S.P. (1998). Organisational behaviour: concepts, controversies, applications. 8th ed. Upper Saddle River: Pretence Hall.

Root-Bernstein, R. and Root-Bernstein, M., (1999). Sparks of Genius: the 13 Thinking Tools of the world's Most Creative people. (Houghton-Mifflin, New York).

J. Rotmans, R. Kemp, M. van Asselt, F. Geets, G. Verbong and K. Molendijk (2000) Transities en transitiemanagement: de casus van een emissiearme energievoorziening Transitions and transition management: the case of a low-emission energy supply), Maastricht, ICIS.

J. Rotmans (2003) Transitiemanagement. Sleutel voor een duurzame samenleving (Transition management. The key to a sustainable society), Assen, Van Gorcum.

Sanders, E.B.-N, C.T. William, (2001). Harnessing People's Creativity: Ideation and Expression through Visual Communication. In Focus Groups: Supporting Effective Product development. Langford J. and MCDonagh - Philip D. (Eds) Taylor and Francis.

Senternovem www.senternovem.nl/competentiecentrum_transities/transitiebasics/index.asp

Schrage, Michael, (1999). Serious Play: how the world's best companies simulate to innovate., Harvard Business School Press.

Schön, Donald, Designing as reflective Conversation with the Materials of a Design Situation. Research in Engineering Design (1992) 3:131-147.

Sleeswijk Visser, Froukje, Pieter Jan Stappers, Remko van der Lugt, Elizabeth B.-N. Sanders. (2004). Context mapping: a hands-on introduction, TU Delft. Handout Workshop.

Yamazaki, Yusuke (2004) Future innovative construction technologies: directions and strategies to innovate the construction industry. In the

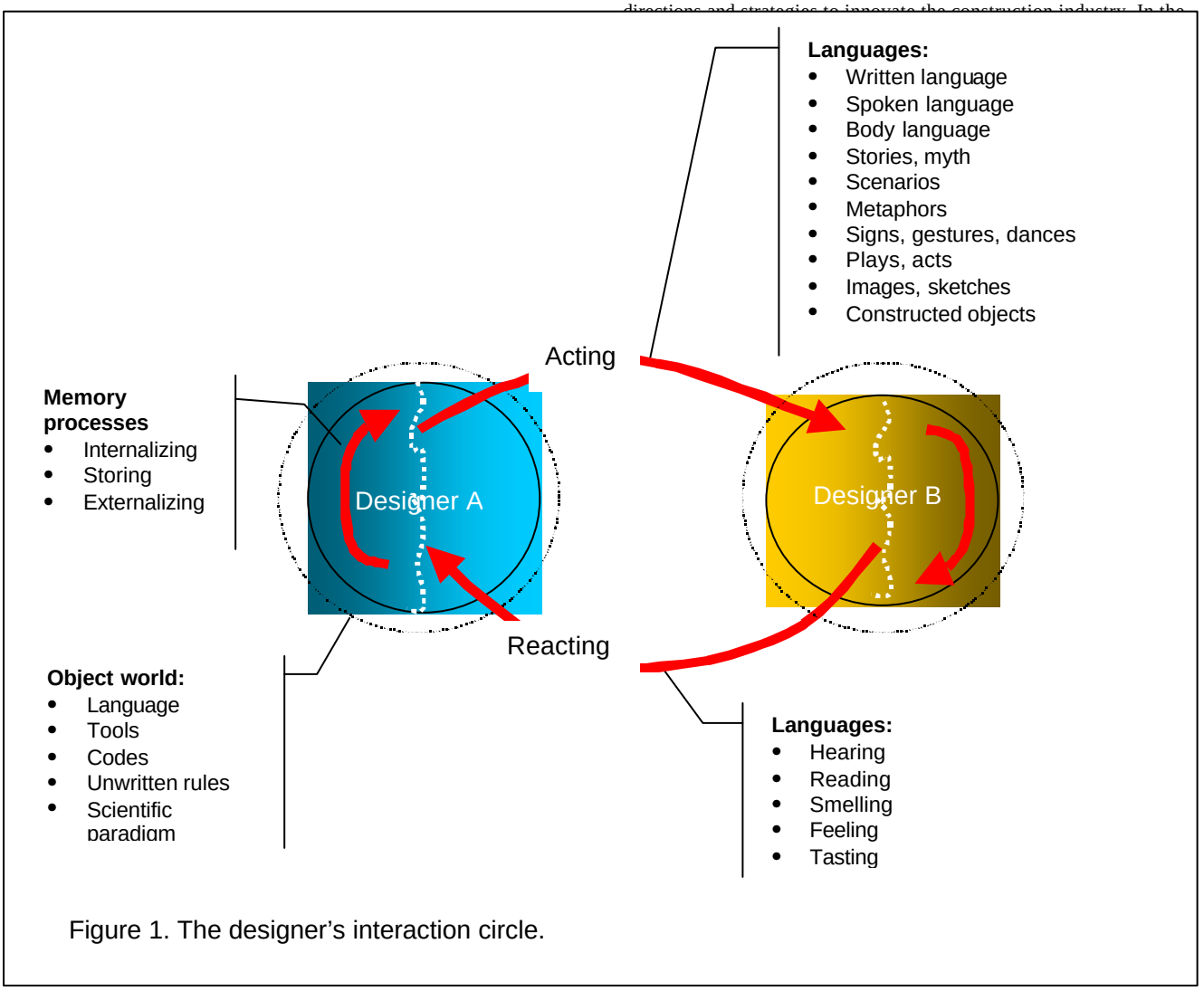

Figure 1. The designer's interaction circle.