Coordinative artifacts in architectural practice

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Abstract: CSCW researchers have increasingly come to realize that the material work settings and the artifacts that populate them play a crucial role in the seamless and effective coordination and alignment of cooperative work. However, while the central role of artifacts in cooperative work has been recognized and applauded, the concept of artifact as used in CSCW is highly problematic as it often presumes mentalist notions of artifacts as simple vehicles of 'information'. This paper is an attempt to depart from these notions. Based upon ethnographic studies of architectural work, we attempt to develop an understanding of the coordinative roles of artifacts which accounts for the multiplicity of artifacts and the complex interplay of particular practices and the specific material forms of artifacts.

1 Introduction

For many years a very large part of CSCW research has been focusing on immediate interaction in small groups, typically co-located. The motivation for this focus has generally been to devise technologies that could help cooperating actors to emulate such interaction over physical distance. Whatever the motivation, however, face-to-face interaction was uncritically conceived of as the paradigm of human interaction, compared to which all other forms of human interaction were taken to be impoverished emulations. The obsession with media spaces and the conversation metaphor that characterized CSCW research for many years bears witness to that.

This is of course a gross simplification of the general situation, as there were clear exceptions from this paradigm from the very beginning. Most significantly, ethnomethodogically informed ethnographic studies demonstrated that material artifacts play a crucial role in coordinative practices and developed important analytical categories for studies of such practices [cf., e.g., 4; 5; 6]. Other ethnomethodogically informed workplace studies similarly drew attention to how actors skillfully exploit the affordances of the material work setting in order to effortlessly and fluently coordinate and integrate their individual activities [10; 11; 33; 35]. Other in-depth workplace studies pointed the same way [9; 17]. These and other findings were reflected in early attempts at developing conceptualizations of cooperative work [24-26], which did not manage to turn the tide, however.

In the course of the following years, CSCW researchers have increasingly come to realize that the material work settings and the artifacts that populate them play a crucial role in the seamless and effective coordination and alignment of cooperative work. The shift of focus is quite remarkable and can be gauged simply by 'comparative browsing' of early and recent CSCW and ECSCW proceedings as well as the ten volumes of the CSCW journal.

M. Blay-Fornarino *at al.* (eds.): *Designing Cooperative Systems: The Use of Theories and Models. Proceedings of the Fifth International Conference on the Design of Cooperative Systems (COOP2002), Saint Raphaël, France, 4-7 June 2002*, IOS Press, Amsterdam etc., 2002.

While one will have to look hard for exhibits of or even references to artifacts in CSCW publications in the first many years, one will not need to search for many minutes to find an abundance of such analyses and exhibits in recent CSCW papers. Obviously, the role of artifacts in cooperative work has become topical.

More than that, whereas social psychology, group sociology, communication theory, conversation analysis, etc. played prominent roles in the early years of CSCW research, the field now exhibits an sharper analytical and conceptual attention to the role of artifacts in coordinative practices.

Although ethnomethodologically informed ethnographic work, as noted above, pioneered the study of the uses of artifacts in cooperative work, the shift is obvious here as well. While the procedures and conceptualizations of conversation analysis, that were so important in early ethnomethodological studies of cooperative activities, are of course 'still going strong', it is worth noticing that studies of conversational interaction are now being framed in broader and more inclusive analyses that place stronger emphasis on the material settings of cooperative work [12; 33; 34]. Moreover, there are now some very systematic attempts to address the affordances of material as opposed to digital artifacts [29].

The shift of focus can also be seen in that conceptual frameworks such as 'activity theory', 'distributed cognition', and 'actor-network theory' have developed significant followings in the CSCW community in recent years. These frameworks surely have achieved widespread circulation because they are seen to meet the demand for a conceptual foundation for CSCW research and design. But they have also gained ground because they, by contrast to social psychology etc., are seen to accord artifacts and their use a crucial role in human action and interaction.

However, the increasing focus on coordinative artifacts has not been accompanied by increasing conceptual clarity. In fact, as far as the 'imported' frameworks are concerned, fundamental conceptual problems have been contracted, so to speak, as part of the bargain. As this is not the place for a thorough discussion of these frameworks, a few, desperately brief comments, merely indicating the nature of these problems, will have suffice.

Activity theory emerged in opposition to and as a break with the fundamental presumption of behaviorist psychology, viz. that human cognition is to be understood in terms of generic abilities. Against these presumptions, L. S. Vygotsky, suggested a conception of human action that was heavily influenced by Marxist theory, arguing that cognitive phenomena such as logical reasoning are grounded in historically evolving and culturally specific material practices. Thus, to Vygotsky and his followers, the skills involved in the production and use of tools, in the techniques of reading and writing, arithmetic, etc. are of central concern to psychology.

Vygotsky's ambition was undermined, however, by his concept of 'psychological tools':

> '1. In the behavior of man we encounter quite a number of artificial devices for mastering his own mental processes. By analogy with technical devices these devices can justifiably and conventionally be called psychological tools or instruments […]. 3. Psychological tools are artificial formations. By their nature they are social and not organic or individual devices. They are directed toward the mastery of [mental] processes — one's own or someone else's — just as technical devices are directed toward the mastery of processes of nature. […] 4. The following may serve as examples of psychological tools and their complex systems: language, different forms of numeration and counting, mnemotechnic techniques, algebraic symbolism, works of art, writing, schemes, diagrams, maps, blueprints, all sorts of conventional signs, etc. 5. By being included in the process of behavior, the psychological tool modifies the entire course and structure of mental functions by determining the structure of the new instrumental act, just as the technical tool modifies the process of natural adaptation by determining the form of labor operations.' [39]

On the surface, Vygotsky's concept of 'psychological tools' is an awkward term for what we now would call sign systems. However, on closer inspection it turns out to be quite equivocal, as it denotes techniques, practices, skills, signs, notations, as well as inscribed

artifacts such as diagrams, maps, and blueprints. More than that, the concept is fundamentally problematic, as it reflects the mentalist preconceptions underlying his understanding of sign systems. Not only does the concept reify the skills involved in speech, writing, numeration, counting, etc., in that it suggests that skillful action is somehow 'determined' by certain mental structures — by subsuming mental as well as material phenomena under the category of 'tools', any notion of materiality is eradicated from the concept of tool. 'Mental processes' are reified while material artifacts are spiritualized. In short, no sooner had the use of artifacts been made a central issue (and rightly so), before the materialist notion of artifact was conceptually dissolved.

This de-materialization of the concept of artifacts has been continued uncritically in the subsequent activity theory tradition. Not only is the term 'psychological tools' in continued use [cf., e.g., 42; 43]. But it is also evident that activity theory, as an intellectual tradition and as a conceptual framework, makes it difficult to address the role of material artifacts in work systematically. In an introductory paper, Kuutti for instance, mentions 'instruments, signs, procedures, machines, methods, laws, forms of work organization' as examples of 'artifacts' [18, pp. 26]. Similarly, following Engeström, Kuutti mentions in passing, without further arguments, that 'An object can be a material thing, but it can also be less tangible (such as a plan) or totally intangible (such as a common idea) as long as it can be shared for manipulation and transformation by the participants of the activity.' [18, pp. 27]. Here the concept of artifact has become utterly vacuous, as it simply denotes anything we can give a name, a point Kaptelinin brings home, unwittingly, by stating that 'Activity theory itself is a special kind of artifact' [16, p. 36].

The 'distributed cognition' framework developed by Hutchins and associates can be seen as a further development of the activity theory framework, in that it insists on studying human cognition in terms of historically and culturally localized practices. As opposed to activity theory, however, Hutchins pays detailed attention to trajectories of action 'distributed' over actors and artifacts in what he terms 'a system of distributed cognition.' [15, pp. 16-17]. In doing so, Hutchins directs attention to the specific format of the artifact and its role in human action.[1]

In spite of this, Hutchins de-materializes artifacts no less than Vygotsky, albeit in a different way. While Vygotsky talked about 'psychological tools' and thus only indirectly dissolved the concept of artifacts, Hutchins does it directly, by conceiving of artifacts merely as vehicles of so-called 'representations' on par with 'internal memories'. Thus, when summarizing their analysis of cooperative work in an airline cockpit, Hutchins and Klausen states:

> 'We can see that the information moved through the system as a sequence of representational states in representational media. From speech channels to internal memories, back to speech channels, to the physical setting of a device. Its representation in each medium is a transformation of the representation in other media.' [15, pp. 27][2]

The notion that an invariant and immaterial being, 'the information', migrates from mind to artifact to mind is extremely problematic. This ghostlike entity that in turn takes residence in people and artifacts somehow manages to maintain its unity and identity. It is not just a mentalist notion, as Vygotsky's notion of 'psychological tools', it is what Taylor and Harris have aptly termed 'telementational' [7; 8; 36]: the transfer of invariant entities from mind to mind or even, according to Hutchins, from 'medium' to 'medium'. The or-

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1 This attention to the specific format is especially pronounced in Hutchins' earlier work [e.g., 13, pp. 47 f.]

2 The same kind of analysis can be found in Hutchins' study of maritime navigation: 'The representations of the position of the ship take different forms in the different media as they make their way from the sighting telescopes of the alidades to the chart. […] Representational states are propagated from one medium to another by bringing the states of the media into coordination with one another.' [14, p. 117].

derly alignment of activities (which we need to investigate in order to be able to support it technologically) is simply taken for granted, like an invisible hand that mysteriously creates order behind the back of the actors. By presuming 'the information' as a unitary entity that propagates in the system while retaining its integrity, Hutchins and associates ignore the practices of producing this continuity and integrity.

The fact that the various 'representational media' are of different nature and have different characteristics is far from ignored by Hutchins. In fact, it is one of his key concerns:

> 'In the cockpit, some of the relevant representational media are located within the individual p[i]lots. Others, such as speech, are located between the pilots, and still others are in the physical structure of the cockpit. Every representational medium has physical properties that determine the availability of representations through space and time and constrain the sorts of cognitive processes required to propagate the representational state into or out of that medium.' [15, pp. 27, 32]

But this recognition of the different characteristics of minds and dials brings us nowhere, as long as the infallible reincarnation of a unitary being, 'the information,' is presumed. By presupposing the order that is to be investigated and understood and in line with the idealistic precepts of cognitive science, the 'distributed cognition' framework tacitly presumes that the artifacts are mere successive representational incarnations of 'the information', or that the materiality of the artifact is immaterial, so to speak.

It is misleading to conceive of 'representations' as cognitive or notional entities; they should rather be seen as and investigated as conventionalized practices of using artifacts.

The point of this argument is not to belittle the value of the contribution of 'activity theory' or 'distributed cognition' to CSCW, but simply to point out that while the central role of artifacts in cooperative work has been recognized and applauded, the concept of artifact as used in CSCW is murky, ripe with all sorts of mentalist and cognitivist precepts.

It is, of course, far beyond the scope of this paper to develop a theory of coordinative artifacts. The purpose of this paper is far more modest. Having pointed out that while the concept of artifact is topical and having argued that the clarity of the concept does not match its popularity, our aim is to try to frame the problem of artifacts in a new way that, as Roy Harris suggests, might be more productive:

> 'The view of human communication adopted here is integrational as opposed to telementational. That is to say, communication is envisaged not as a process of transferring thoughts or messages from one individual mind to another, but as consisting in the contextualized integration of human activities by means of signs.' [7, p. 4]

To do so, we will briefly describe the uses of artifacts in the work of architects. Our attempt at analysis of these practices and what they imply will, generally, be postponed to the discussion at the end of the paper.

2 The work

Imagine a typical architectural office (Fig. 1). It consists of several interconnected large rooms, each with several desks, each of these with a workstation. Most of these desks are covered with materials – plans, sketches, notes, photographs, faxes, books, samples. On shelves are large collections of binders for each of the current projects; in the entrance area a collection of scale models, and on the walls 3D visualizations, sketches, photographs, and newspaper clippings from previous and current work. The walls close to people's workspaces too are used as an exhibition space and decorated with materials from ongoing work.

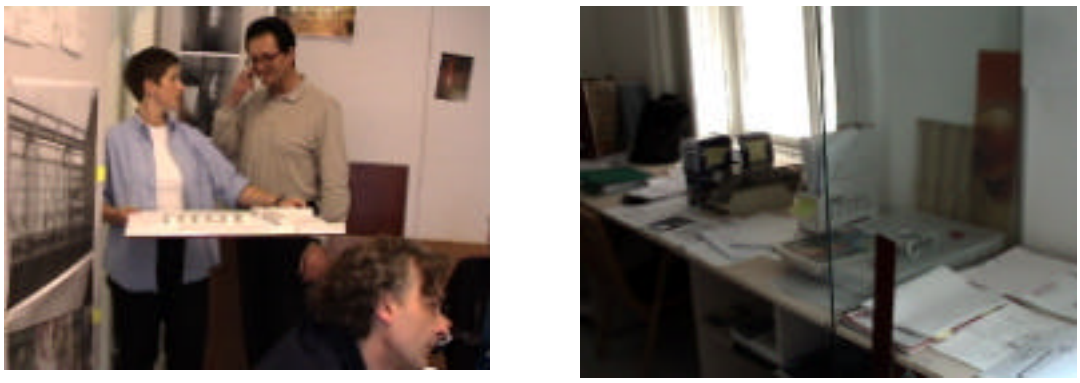

Fig. 1. The architectural office.

The physical layout of the office reflects the character of the architects' work. On the one hand it involves a smaller number of quite large projects, each of which lasts for months if not years and may occupy up to 20 people in the office. On the other hand the office puts in many tenders for competitions for which a design proposal has to be prepared quickly under high pressure.

The architects' work is intensely collaborative. In a large building project various people work on different sections of the building and they may be responsible for particular design tasks. Thousands of documents are created in this process. Most of the internal coordination is done personally. People rush around for communicating design changes, reminding someone of important things to account for, offering explanations, helping to solve an ad-hoc design problem, checking a drawing, etc.

A building project also engages many external actors - technical consultants (for construction, electricity, heating and ventilation, the lighting concept, the facade, etc.), a client and eventually one or several users, several local authorities, a general contractor, building companies, and craftspeople. The architects may have to coordinate the effort and consent of between 30 and 50 different people from different institutions and companies, each with their own professional competences and perspectives. Communication with some of these external specialists is interwoven with planning in an ongoing process. Interactions take place in different forms: asking for ad-hoc advice on the phone, exchanging faxes, email and files, and face-to-face meetings.

In most projects it is the architect who has the responsibility for the planning process and the overall quality of the design. S/he coordinates the planning process with external consultants, local authorities etc. who each fill in their bits and pieces. However, the division of labor within an office and between architects and other specialists may vary, with variations reflecting different political regimes and cultures.

There are many issues of control involved in the division of labor between the architect and all others. Searching for and negotiating technically and economically feasible solutions for a large number of details implies managing a large network of power and dependencies.

2.1 The process

Designing a building involves far more than having a design idea, developing it into a concept and expressing it in a series of sketches and plans. It is the detailed planning of the building's implementation which is at the heart of architects' work. In most countries the planning process is organized into (legally defined) stages with defined products: pre-

design, design, construction planning, etc. Each stage is concluded with the respective set of CAD drawings. In practice stages overlap a great deal.

Planning proceeds in many steps, in intense conversations within the team, project meetings with external specialists, and partly also solitary work. The conversations unfold through 'encircling themes' - addressing a particular issue, trying to clarify the 'facts', generating and testing preliminary solutions. Talking e.g., about the lighting design is connected to a 'journey' through different parts of the building. Many topics are addressed at the same time, as each has implications for many others. While some of these are discussed in detail, others are left open. As there is often a rapid switching of activities, a multiplicity of contexts has to be maintained.

Ongoing work in the office is shaped by the different levels of skill and competence within the team on the one hand, by the natural divisions of a building project into parts (levels, functional parts, infrastructure, design-intensive details of various kinds) on the other hand. At the same time the complexity of the process encourages fluent transitions, and often several people (or no one at all) feel responsible for the same task.

The process is individual, team-based and multi-disciplinary, enlisting multiple professional competencies and perspectives, at the same time. In this process, a principally unlimited solution space becomes more and more focused to be finally fixed in plans representing the artifact-to-be-built. The density of multi-disciplinary interaction and exchange varies from stage to stage and is not the same for all projects. All these exchanges require a considerable amount of mediating and translating which is partly supported by visual and technical conventions and standards.

There is also a critical time aspect involved in design. Negotiations with relevant actors not only involve multiple complex issues but also connect to time consuming procedures, e.g., those of local authorities which follow their own logic of bureaucratic functioning and political compromising. The total time span from preliminary design to construction may be several years and it may happen that well thought out design decisions then turn out to be too costly or no longer technically feasible.

3 Artifacts and practices

Architects work with a large repertoire of artifacts – from sketches, scale models, images, and samples of material to CAD plans, detail drawings, Excel sheets, and Word documents. Many of these artifacts fulfill coordinative functions: As communication objects or 'persuasive artifacts' some may primarily help create a common understanding of a design idea or task, talk about a design in a rich, metaphorical way, and imagine qualities of space and appearance [40]. Some of them act as reminders of design principles, approach, method, open questions. Others help keeping track of activities and materials and again others represent design decisions at a certain level of detail and technical precision.

Corresponding to these various and overlapping functions are sets of interrelated activities. Each artifact is surrounded by particular practices of producing, reading, annotating, modifying, checking, evaluating, etc. For example viewing the central CAD drawing in everyday work often involves making print-outs and/or photocopies in A3 format which are spread out on the table to be discussed, modified on a layer of transparent paper, or annotated with differently colored pens. Copies of these plans may be sent by fax to a consultant for commenting and return with suggestions and calculations.

The following sections describe a set of particular artifacts that have been collected as part of long-term fieldwork in an architectural office[3]. The selection has been made to illustrate the diversity of artifacts architects use and the practices that surround them.

3.1 Conceptual visualizations

First objectivities of a design concept often are represented through assemblies of sketches, metaphorical text, association images, physical models, and photographic material. While some architects use sketches and pictorial material for generating and expressing their ideas, others prefer poetry and metaphorical text, again others build their designs on (historical) research, the assembling of facts or 'datascapes' [21]. Again others work with scale models from the start of a project, working out their ideas by experimenting with different spatial configurations.[4]

The 'Big wall', impregnated with color and light

The façade as screen, colorful patchwork (Charters) - a shimmering surface, bright and transparent, as seen from a distance, its structure revealing itself when approaching.

The movie theatres stones that dip into water - above the surface of a rough, rocky quality, below precious stones that glitter in water – silver, gold, ruby, emerald.

The façade as cutting edge between rough concrete and color.

Fig. 2. A collage of 3D visualization, association image, sketch and metaphorical text.

The collage of 3D visualization in Fig. 2 (which was generated from a first, rough scale model), text, and association image represents some of the central features of the design concept for *Pleasure Dome.* 3D visualization and the image of 'Charters' visualize the idea of a 'big wall, entrenched with color and light'. Sketch and the metaphorical descriptions capture the evolving idea of the building's façade as a cutting edge between the rough

[3] We here report on fieldwork carried out in 'Architekturbüro Rüdiger Lainer'. The artifacts that have been selected for this paper have their origin in several building projects and an urban planning study. We refer in particular to *Pleasure Dome,* an entertainment center in the Gasometer area in Vienna. The projects have been described in [44].

[4] So are e.g., Frank O. Gehry's (handmade) models digitized and then rationalized to achieve repetition without sacrificing form. In the case of the Walt Disney Concert Hall in LA the curved outer surface is covered by a 'skin' of Italian lime sandstone. The computer calculated the most economic way of cutting and producing the complex curvatures. A physical model was computer milled, compared to the original cardboard model and adjusted when necessary [20].

quality of concrete and the lucidity and colorfulness of the glass skin on the one hand, the movie theatres as 'stones that dip into water' on the other hand.

The scale model was built at the very start of the project, and used within the office as well as in meetings with external specialist for visualizing the complex roof situation and internal space of the building. Later a much more accomplished version of this model was used in convincing the key user of the architects' color concept for the movie theaters to be painted in 'silver, gold, ruby, emerald'.

Characteristic of these artifacts is their conceptual, and metaphorical nature. Sketches are quite good at capturing the mixture of symbolic richness and abstraction that allows expressing the qualities of space, light, atmosphere, and materials. Also, abstract 3D visualizations of spaces, places and artifacts may be used for conveying a concept, metaphor or shared cultural symbol. Abstract here does not mean the strive for purity (as in an abstract painting); on the contrary, visualizations like the 3D images produced in *Pleasure Dome* are highly theatrical. They use the language of "artistic impurity, hybridity, and heterogeneity" [22] for communicating certain ideas and qualities of an object. Another feature of these informal representational artifacts is their openness to extensions, modifications, and novel interpretations.

3.2 'Conceptual sheet'

Drawing, sketching, and assembling materials are activities that are often intermingled with talk. This particular example of a 'conceptual sheet' has been taken from an urban planning study. The architects produced it as part of a first planning session. It contains several elements:

The artifact to the left contains, *inter alia*:

- A first work plan – things to do, phases, how to proceed.
- Specification of visual material that should be collected or created (pictures, collages, association images, shadow plans, etc.) - how to represent the design of the urban area.
- Metaphors – how to talk about the urban area.
- A specification of methods – to define spatial qualities, to 'intensify rules', etc.
- Explanatory sketches.
- References to material to look for.
- Names of responsible people.

Fig. 3 Work plan for an urban planning project.

The architects use this type of artifacts in various ways. In this particular project members of the team placed copies of the sheet on their desks, using it as a reminder of design principles and the overall work to do. It served as a template for project meetings. In one of

those meetings the sheet was annotated and enriched. The sketches are pointers to a series of more detailed drawings exemplifying ‘rules’. Finally, the sheet also represents the structure of the deliverable – a project report with different types of visualizations of the urban design.

3.3 The central CAD drawing

In a large building project, different people work on different parts of the building and on different problems. Typically, such a building is made up of 15-20 sections and about 30 plans altogether, including 11-12 floor plans, have to be drafted and coordinated. All plans are drawn with a CAD tool and stored on the central server, using a structured file system with different subdirectories for each project period and with predefined file-naming conventions.

CAD plans (Fig. 4) assume a central coordinating role in the process of planning. They are true ‘boundary objects’ [30; 31], acted upon by all responsible actors and connected to specified procedures of approval and inclusion. First versions are created at a very early stage and they are gradually detailed and modified.

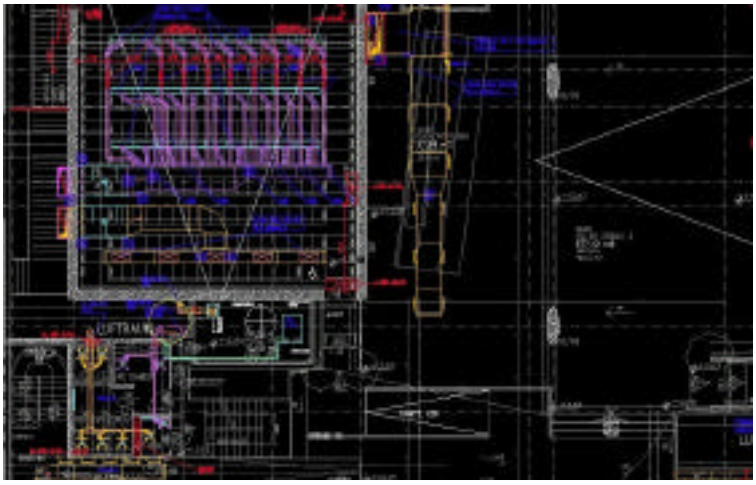

Fig. 4 CAD plan with layers

The CAD plan is the artifact in which all the design decisions that have been worked out in various forms – sketches, calculations, technical descriptions, product specifications, etc. – are recorded and specified. This involves the work not only of the team of architects but of many external specialists.

Within the office, people work on different parts and layers of the central CAD plans. Someone responsible for specific tasks such as ‘fire escapes’ may work concurrently on parts/layers used by others. This requires constant monitoring of concurrency and makes version control difficult.

CAD plans cross organizational and professional boundaries many times. The construction engineer, for example, will view, comment and eventually correct the drawings at different stages of the planning process. S/he will receive the relevant layers of the CAD drawing and work on them. Other specialists may receive a print-out and produce their own drawings, which the architects will view, eventually discussing modifications and alternatives. They then may copy these drawings into their CAD plans or draft their version of the specialist’s suggestion. Again others will receive a photocopy of one of the plans and return it with comments, calculations, sketches, etc. It is the architects who monitor and control this process of viewing, detailing, and adding to.

3.4 Layered artifacts

Architects use a variety of techniques for communicating things that need to be taken account of or changed. Among those are: making annotations on a document, e.g., putting a red circle around a problem, adding details (correct measures, material), marking a part of a drawing with a post-it with some instructions for changes, corrections (e.g., in pencil directly on a plan), sketching either directly on a plan copy or on transparent tracing paper.

In the left-hand part of Fig. 5 is a A3 copy of a CAD plan showing the upper level of the shopping mall in *Pleasure Dome*. This drawing was used in a meeting of the architect with the lighting designer. The lighting designer got to know the building, 'walking through', pointing to particular places and elements, while the architect was thinking aloud, describing the space, listening to questions and suggestions, simultaneously sketching the lighting concept. While talking, the architect developed a notation, using different colors for different types of lighting. This notation was then used in all documents concerning lighting. A common understanding of the concept, including solutions to some practical-technical problems, was achieved. The colored photocopies of the lighting design were then used as part of presentations to different audiences.

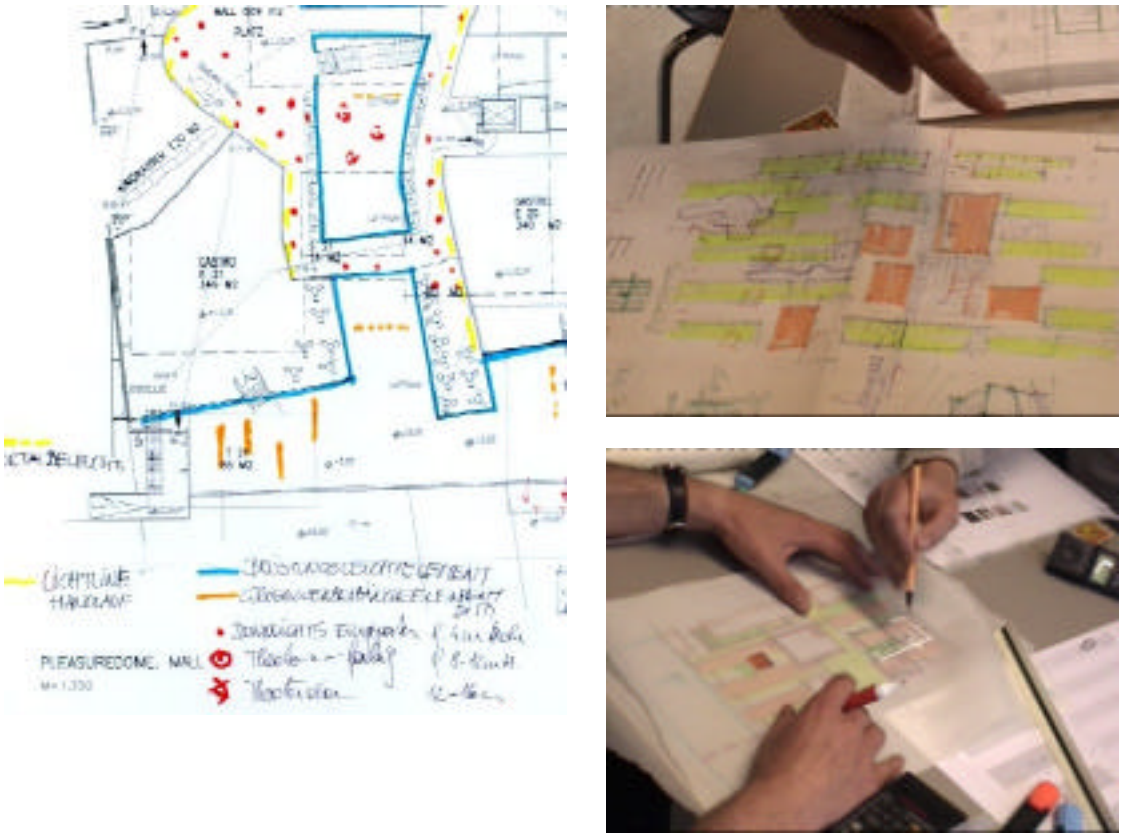

Fig. 5 Layered artifacts

In the top right-hand corner is a drawing for a competition on which the architects toy with different combinations of volumes and voids (in orange and yellow). Below, a blank transparent sheet of tracing paper is placed over a printed plan, and 'anchored' by entering some positional markers. The tracing paper is then used to experiment with design ideas.

Layered artifacts facilitate coordination between activities (and the people who are responsible for them). They, for example, provide a collective or individual space for experimentation and change. The CAD drawing itself is a layered artifact, which builds on a particular mix of codes for functions and materials and has been tailored to a particular divi-

sion of labor. An architect who is experimenting with how to conduct a shaft through an open space may not only produce a series of sketches (some of the on tracing paper) but define a special layer for the drawing (e.g., Mike's layer). This example also shows that layers may denote ownership and/or professional competence (e.g., the construction engineer's).

3.5 Ordering systems: the list of components and detail drawings

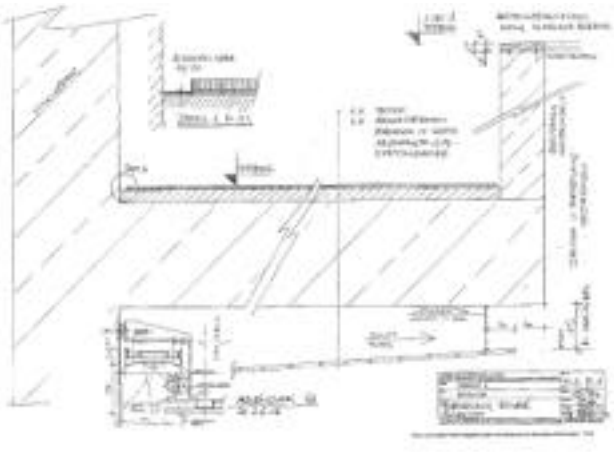

Fig. 6 A detail drawing.

As planning progresses, more and more details have to be specified and filled in. A large building contains hundreds of details, which can either be left open, to be decided upon later by the construction company and/ or craftspeople, or carefully designed. Much of the quality and specificity of a building depends on these details (Fig. 6). Most details are drawn by hand, the main reason being that the computer system requires a level of precision which does not take account of the 'inexactness' of the building materials. Also, detail drawings are of a scale of 1:5 or even 1:1, and cannot be fitted into a CAD construction drawing. There are two types of details. Components (such as the façade elements) are made of different parts, and the architect may wish to design a specific assembly of parts and materials. On the other hand, a building consists of a large number of joints between building elements and materials, which also may be specifically designed.

The plan for a catalogue of components for *Pleasure Dome* was discussed in an internal project meeting:

> R: Planning of details – who has got an overview? – G. is in charge.
>
> R: To have a list of details would be important, including, what is relevant when? – I would like to have a 'total list' [Gesamtliste] and one 'actual list'.
>
> I also would like to have references to 'detail principles' included, e.g., for stairs – Hütte Klosterneuburg, for railings – Absberggasse [references to previous projects].
>
> We need such a list for achieving clarity concerning the details, e.g., everywhere closed metal sheets for the stairs outside – how does this fit with all the other stairs? – Or, we do have so many balustrades, some with glass, others …
>
> The point is to coordinate the details in one's head

The main purpose was to generate a complete list of all elements and components, which then would be used for mass and cost calculations and for the call for tender. At the same time, the list should help to ensure conceptual consistency, i.e., that the same design principles and materials were used in different parts of the building.

G. (who was in charge) started building a Word document (Fig. 7) that lists all the elements and components ('Aufbauten') to be used in the building – (inner and outer) walls,

ceilings, floors, roofs, stairwells, balustrades, etc. This Word list, which was compiled in the office, went through several cycles of discussion and annotations, involving construction engineer and building engineer. Small sketches were made, showing the design principles for some components.

In parallel, the architects began drawing details.

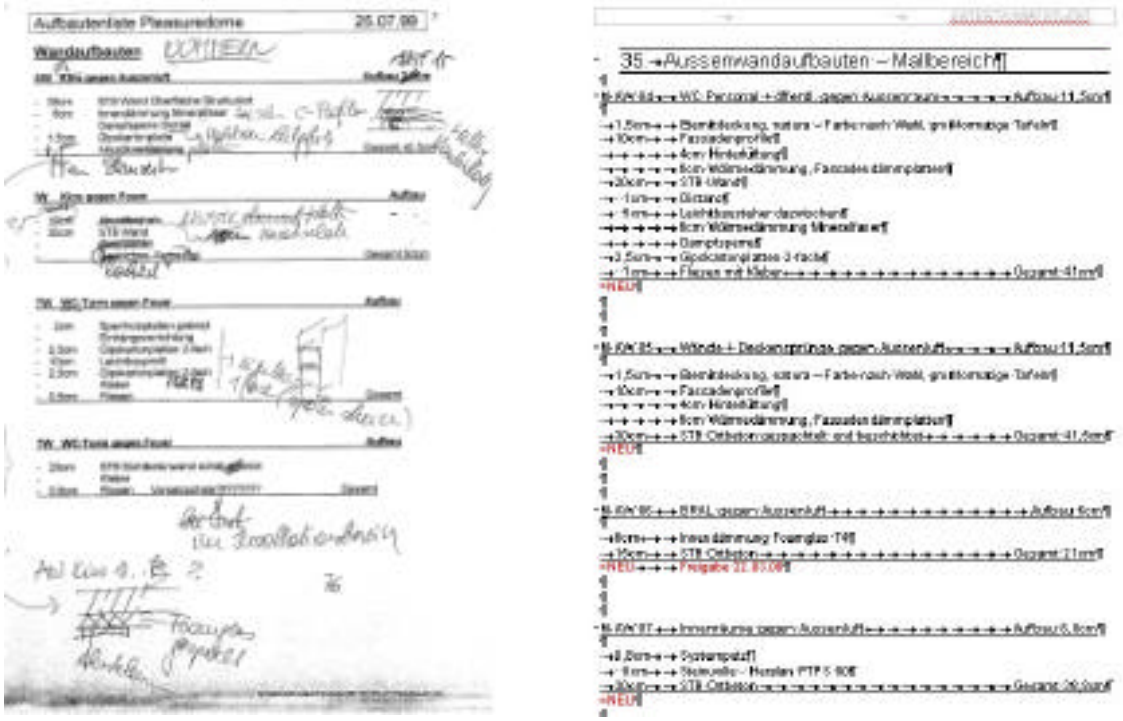

Fig. 7 The list of components – draft and final document

All detail drawings are listed in an additional ‘coordinative artifact’ – the Excel sheet ‘Detailübersicht’ (overview of details, Fig. 8). Each detail drawing has been assigned a 3-digit detail number, with the digits referring to: type of detail (e.g., interior glass elements), part of building (e.g., mall), element or component (e.g., door to projection cabin). Details are referred to within CAD drawings by their number and framed.

The Excel sheet provides an index to the detail drawings which are kept in a binder. Detail list and detail drawings are used together. The binder is located centrally in the room, which is shared by the people working on the construction plans. Whenever someone needs information about details, s/he walks over to the table, searches for the documents, takes them out for photocopying, and places them back in the binder.

The detail list contains information about completion and modification dates and helps maintain an overview of the circulation of detail drawings within the network of people involved in planning and building. People can see on the list which detail needs to be sent to whom, either for comments or for approval. The sheet also tells who received a particular detail drawing.

Ordering systems type of artifacts play a large role in the architects’ everyday work. They are consulted all the time.

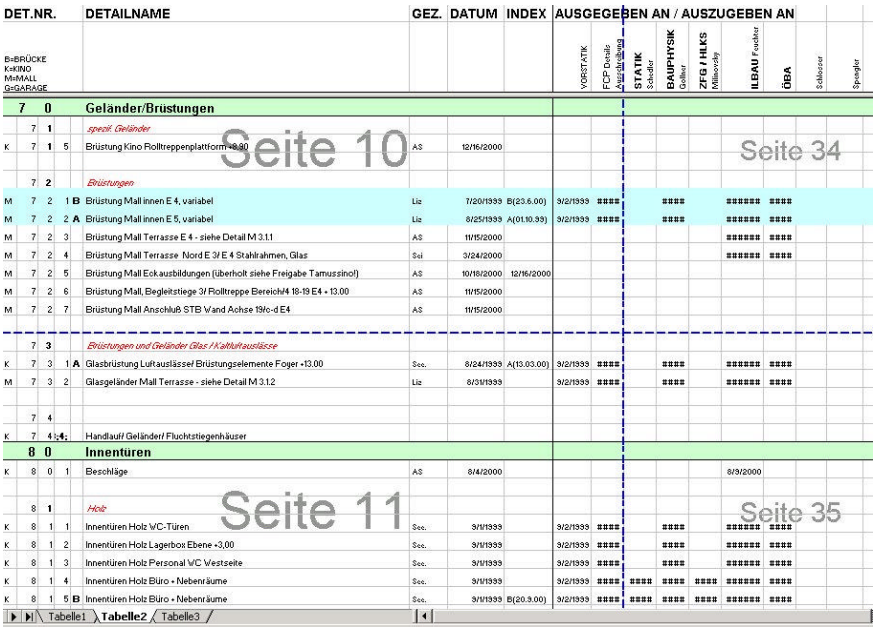

Fig. 8, List of detail drawings

4 Discussion

Our fieldwork material indicates that artifacts play a wide variety of integrative roles in co-operative work and also helps us understand what makes artifacts particularly amenable to coordination. Here we want to very briefly point out a few characteristics of the artifacts found in this setting.

4.1 The multiplicity of artifacts in architectural practice

First of all, the very fact that the setting is so utterly full of artifacts may seem paradoxical, in as much as architectural work is 'knowledge work' *par excellence*. Nonetheless, although as different from a factory or a power plant as imaginable, the setting is replete with all sorts of material artifacts such as drawings, binders, photos, plans, lists, models, i.e., artifacts that, by contrast to artifacts one will see in every office (such as walls, doors, desks, and chairs), are specific to the trade of architects, domain specific, that is. These artifacts are to be found on all surfaces in the office, on walls, shelves, and desks.

In order to understand the plethora of artifacts, one should take into account that architectural work is different from many other types of work insofar as the field of work does not exist, that is does not exist objectively, in advance but is constructed in and through the process of design and planning and, ultimately, construction. Architectural work proceeds through the architects' producing successive objectivations of the design and interacting with them in a variety of ways. That is, the conspicuous display of architectural artifacts can be seen as the fundamental means of making the not-yet-existing and in-the-process-of-becoming field of work immediately visible, at-hand, tangible.

A comparison with radically different work domains such as process control may help to clarify the point. To the operators of the power plant the plant as a whole, the different functional parts, the valves and pumps, the energy transformation processes, the mass flows, the power grid to which it is connected, etc. can be conceived of as their common field of work. It is there, in an important sense, before they start their shift, and it is still there when they go home again. However, due to the sheer scale of the plant as well as due

to the intangibility of the processes, the various representations of the plant and processes in the control room are taken to stand proxy for the plant and processes beyond the control room. For all practical purposes, they work with representations. By contrast, the field of work of architects is notional. Not only does the building not exist prior to their work but only as a result of their work; the objectivations of the design do not exist prior to their work either.

This is of course an exaggeration, as architects reuse previous designs and have a vast array of preexisting resources at hand, such as catalogues of materials, parts, etc on the market. Anyway, the point we are trying to make is that the artifacts that the motley collection of architectural artifacts play a role quite similar to the nuclear power plant and the control room representations of it to the operators. That is, in the absence of a preexisting, material field of work, architectural representational artifacts constitute the field of work of architectural work. Thus, as objectivations of the construction-in-the-making, architectural artifacts are the immediate object of architects' work. In the absence of the building, they are what is looked upon, inspected, gestured at, discussed, modified, annotated, etc. In short, they provide a rich resource for orderly interaction.

These similarities notwhithstanding, the fact that the field of work of architects is notional and the artifacts merely objectivations of things-to-come and as such representational artifacts, has important implications. Representations are not the real thing, of course; they are fundamentally 'under-specified' [32] with respect to that which is represented. Representations are local and temporary constructs [2]. And representations are conventionalized practices based on rules of mapping and translation between representation and the object that is represented. Consequently, the infinity of affordances and cues offered by the preexisting objective field of work of plant operators is not available but has to be painstakingly emulated by a rich variety of sign systems, notations, and other conventional practices. Thus, architects' 'conceptual visualizations' as well as their CAD drawings describe the building-in-design on multiple levels of detail, completeness, and 'technicality', using different visual languages. These rules may have to do with scale, with material (with a notation denoting the different kinds of materials), construction, etc. The plethora of artifacts is an expression of the abstractness of representational artifacts and of their limited scope.

To architects this 'under-specification' of representational artifacts is of particular relevance, as one can see from 'conceptual visualizations' such as sketches and association images. Connected with this is the 'openness' of such artifacts to facilitate and accommodate the contributions of others, and thus to stimulate their imagination and to eventually perceive the novel within the familiar, to discover relations between seemingly incongruent objects and notions – to relate the 'unrelatable', and to jointly take a step further in the design process [41].

4.2 The coordinative roles of artifacts

This multiplicity of coordinative artifacts in architectural practice amply demonstrates that artifacts have characteristics quite distinct from mental constructs and that the use of artifacts cannot simply be grasped and understood in terms of 'representational media' or 'precomputation'.

There is no question, of course, that an artifact can serve as an representation of something else. A signature on a piece of paper can be taken to represent the handover of property from the signatory party to another party. A map can be taken to represent a particular territory to the extent that one can use the map to measure distances between e.g. crossroads and plan a journey in detail. This is trivial. There is also no question that artifacts can be used to express ideas and plans and other mental constructs. The sketches and drawings

of the architects evidently express ideas the architects had ‘in mind’. This is also trivial. But these artifacts do not simply serve as containers of preconceived ‘mental constructs’. The relationship between cognition and drawing is infinitely more complex than that [1; 28]. Sketching and drawing are also activities of exploration and testing.

In addition to or, rather, *by virtue of* their representational role, the artifacts we have described serve a coordinative function. As they are being used (or not used) in the cooperative effort, their changing state (or static state) offers cues to other actors as to the intentions of the actor or actors effecting the changes. As we can see from the examples of ‘layered artifacts’, the simple fact that, say, a particular drawing is open in front of a colleague who has placed a transparent overlay on top of it, that the colleague is bending forwards while sketching some modifications on the overlay, may or may not have implications for a colleague working on an intersecting task. The simple fact that a pile of plans is marginally positioned on a desk, as opposed to centrally, may indicate that the architect at that desk may have finished working with them but is not quite sure that she will not need them again. In general, the state of artifacts in the work setting — especially artifacts and other features of the field of work — provides an infinitely array of signals and cues for cooperating actors to effortlessly apperceive the intentions of colleagues, the challenges and problems they are facing, etc. That is, the coordinative role of artifacts is not incidental. It is because these artifacts serve as objectivations of the design-in-progress that they have coordinative functions: architectural work is for all practical purposes done with, on, by means of these artifacts and is thus made immediately publicly visible to competent members.

Furthermore, there is a specific class of coordinative artifacts that have deliberately been designed to serve coordinative purposes, such as the list of details and the list of detail drawings. We have elsewhere suggested to call functional complexes of such artifacts and protocols (comprising various artifacts, classification schemes, notations and other protocols) ordering systems [27]. In the case of architectural work, the binder system, the layer organization of the CAD system, the plan identification system (comprising plans, the code for numbering, and the circulation list), and the system of interconnected lists of components and detail drawings are clear examples of such complexes of artifacts and protocols. Their primary function consists in enabling actors to maintain some kind of order in the vast collection of distributed items required to objectify the in-the-process-of-becoming field of work. That is, their coordinative function is different from that of sketches, drawings, models, etc. They are not objectivations of things-to-come but rather normative constructs governing the distributed activities of the project.

4.3 The materiality of artifacts

Expressing an idea or a plan in a material artifact involves practices that transcend what can be subsumed under conventional notions of representation etc.

Material artifacts are publicly accessible. Their state can be inspected by other members. Where they are located can be observed by and made sense of by members. What others are doing to an artifact can be noted and made sense of. As persistent graphical objects, architectural artifacts and configurations of such artifacts can be visually taken in simultaneously, at a glance. They thus offer modalities of interaction that are fundamentally different from the sequential order of speech and action. Artifacts are tenacious and their state and the configurations in which they have entered may transcend the situation at hand and may be instrumental in imposing order beyond the horizon of the immediate situation. In contrast to a digital text or image, a material artifact bears witness to its history, it shows wear and tear. A print-out of a CAD drawing which has been annotated carries the history of past work as well as the marks of the contributions of different people, as identified from their

handwriting or from the color of the pencil. The faded color on a binder tells about age, hand-written additions to the label on its back indicate that the classification has had to be extended, etc.

The use of coordinative artifacts is connected to their specific physical and graphical form. The way in which elements of text, sketches, and arrows are laid out and organized in the conceptual sheet (Fig. 3) is meaningful and may indicate relevance. A CAD drawing consists of a great number of conventions, notations, and layers, from which the different professions involved in the planning process extract the information they need. When it is plotted out in large format, an experienced architect my identify on the spot an unresolved problem in the myriad of lines and signs. Closer investigations would need to consider in detail the conventions of notation, format, and syntax underlying their form and use, such as the specific techniques involved in working with maps, charts, matrices, trees, or linear text [cf. 7, pp. 91 ff et passim; 23; 37; 38].

We are, of course, not alone in pointing to the materiality of artifacts. Many authors have for instance suggested to use Gibson's [3] concept of affordances. Sellen and Harper have for example pointed out that the affordances of paper versus digital documents are quite different and have indicated some of the affordances of paper [29]. Similarly, Latour [19] not only speaks of the 'immutability' of inscriptions on paper, but also of their mobility, due to the paper's flatness, small scale, and inexpensive reproducibility. This involves and enables a totally different set of practices than those connected with, say, an inscription in marble.

While the concept of affordances of artifacts is fundamental to an analysis of the use of material artifacts, it is not sufficient for addressing the very intricate interrelationships and interactions between the materiality of artifacts upon which inscriptions are made and the logic of the sign system that is being applied.

Not only are different scripts adapted to the nature of the surface upon which it is being inscribed, as argued by Roy Harris: "The use of wax tablets in ancient Rome, baked clay in Babylon, pattra in India, tortoise shell in China, is not unrelated to the form of some of the scripts developed in those regions" [7, p. 30]. It is untenable to conceive of the 'information', the 'content', the 'message' etc. as invariant, irrespective of the technique of inscription: 'Writing with a reed stylus on wet clay is manifestly such a different enterprise from operating a modern printing press that it becomes legitimate to ask: is there any semiological unity underlying this diversity?' [7, p. 7]. That is, in order to understand the uses of coordinative artifacts in cooperative work we need to investigate in detail the techniques and practices of using ordinary as well as representational artifacts. This work has hardly been undertaken yet.

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