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A Time Dimension for Computer Aided Architectural Design Systems

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Abstract

With the aid of CAAD-systems several design stages can be recorded. With them the design process that was followed can be set down and reconstructed too. If these different design stages originate from one and the same file, they can easily be compared with each other. These were the starting points that led to a research into the possibility to record all design data, generated during an architectural design process, in one information system in a 'temporally' coordinated manner. For this we should be able to record and reproduce the design stages as well as the processes that led to them. The central issue in this research is the way in which temporal aspects of design information can be registered in the architectural data system. The infinity of the size of the information system and the finiteness of the capacity of recording media should be taken into account here.

This initial paper deals with the presentation of an original idea concerning the possibilities and restrictions of computer systems as tools for the design process. Before long research results in the form of a functional design and a first prototype can be presented.

A Time dimension for Computer Aided Architectural Design

During a design process emphasis is laid on an actual description of design information in e.g. drawings. Any developments or changes are incorporated in these drawings.Therefore the origin or the history of the design can only be reconstructed from dated prints of the 'original' drawings With the aid of CAAD-systems more or less completed stages of design are described as well. Just like the drawings mentioned before, these descriptions are mainly used for the presentation of a design at the end of a design phase. [Joseph, 1991] [Vermaas, 1990]. Anyhow, they are not (yet) suited for the presentation of the design process that was followed. The first thing that sparked off this research was the assumption that with the help of CAAD-systems several design stages

can easily be recorded and that thus the design process might be partly reconstructed and evaluated.

Design information is only up to date for a short time.Continuous modifications during an architectural design process give it a temporal character. Changes in design data can be kept up to date by CAAD-systems through transformations of the design stages. Different stages in every phase of the design e.g. can be recorded in different design (sub-)files. The validity or the currency of certain design data do not have to correspond with the duration of e.g. a design phase or the validity of a certain design stage. Therefore you can generally call the choice of (sub-)files in this context arbitrary. Certain design data may be present in more than one (sub)file, with all the subsequent problems. Information may be redundant in different files and (sub)files may be incomplete or inconsistent. As a matter of fact, the relationship between (sub)files can only be indicated with the help of a 'directory'-structure, filenames and/or maybe 'extension's, and also with the aid of program-dependent 'references'. A second cause for our research can be found in the assumption that it should be possible to store all design data in one information system. The main section of such a system would be formed by a coherent data file larger than any of the sub-files, but considerably smaller than a fusion of the different sub-files.

As the recording of several design stages and a reconstruction of a design process can only effectively take place if all design data have been recorded in a well-coordinated manner in one coherent file, a symbiosis has taken place between the two above mentioned reasons for this investigation. Resulting from the desire to also be able to give presentations of design processes, the starting point for this coordination was that the introduction of a time dimension and consequently the possibility of a temporal coordination, would be a great step in the right direction. Another starting point here was that numerous design stages too can be registered and reproduced with the aid of temporal properties of design data. [Hee, 1985], [Rolland, 1988]. Since these stages originate from one and the same file, we finally assumed that it should therefore be possible to have different design stages compared with each other. A lucid comparison of design stagse together with a presentation of the design process may support the evaluation of the quality of a design and its evolution

The architectural information process as a practical problem

A consequence of the drastic fragmentation of the building-industry is that the design data are rather fragmented and differentiated as well. Therefore communication and consequently the transfer, the interpretation and the tuning of the data play an important role during a design process. Especially because of the fact that in the building industry construction preparation and the actual

work in progress are still dealt with as crafts, the transfer of data takes place with difficulty, the information on hand is interpreted loosely and the tuning of data is unsatisfactory. The easiest thing to do therefore, is to examine and evaluate each design individually. Comparisons with other designs are left undone so that it cannot be decided objectively whether a design change is an improvement or a deterioration. Moreover, you are not able to consider the design process objectively, which might lead to an refinement or even optimization of it.

Research and development in the field of architectural computer applications pay explicit attention to the integration of multidisciplinary design information during the building process.[McCullough, 1990], [Schmitt, 1992], [Wagter, 1992]. On (inter)national levels, as in ISO/STEP and EDIBUILD, normative work is done to achieve arrangements and standards for an integrated structure for design data. The work done in these workinggroups is rather extensive and expensive and there is a growing reserve concerning the practicability of the final results to be expected. This may serve as an illustration of the great complexity that you come across when you try to achieve automation via systematization in the building industry. For the time being, the prospect to realize integration of e.g. design data in the building industry seems to depend on the possibility to transform the building trade into a building-industry. And in our view, instead of data integration, the first aim should be a conscious segregation of building information with regard to the different disciplines as well as to time. Coordination of data concerning the different disciplines can be done by the building manager. The temporary and time-dependent information can be coordinated with the help of information technology. Needed for this is empirical research into the building information process itself. (Figure 1) It must be determined who needs what and when. Such a research needs an instrument to record processes in such a manner that they can be compared. At first sight other media, like video cameras, are not considered for this purpose because of 'analogue' data recording. The use of computersystems for discrete 'digital' registration and reproduction of different process stages is more obvious.

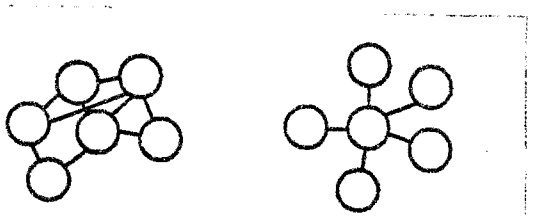

Figure 1a: Segregated and integrated informationprocess in architecture

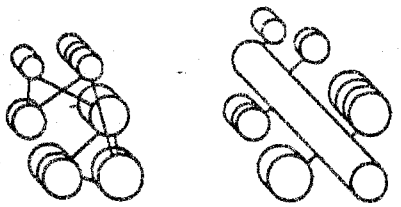

Figure 1b: The same information processes in time perspective

For communication and coordination during the building process complete and consistent data files should be available at certain moments. Limited or inferior definitions of the necessary contents of data files may lead to efforts to record as many data as possible as early as can be. 'The limitation of matter reveals the master'. If, among other things, you want to restrict the size of building or data systems, or avoid redundancy of information and possible mutation mistakes, it is better to record as few data as possible in data files and this preferably at the latest stage possible. The 'Just in Time principle' is also important for 'Information Planning' or 'Information Logistics'. [Hee, 1985].

The state that a building was in, can always be registered afterwards. How and why this came about is something that, most often, can only be partly retrieved and this then, in general, with great difficulty. This applies to a design too. Usually much attention is paid to the presentation of the state of affairs. You can only find few examples where the development of the design is explained and, for as far as we know, this is often based on an analysis (with some architectonic purism) afterwards. Recording several design stages might contribute to a more unambiguous registration and a better evaluation of the way a design proposal has been achieved. Linking remarks and commentaries to these proposals by means of a temporal relation, may also increase insight into the backgrounds and motives concerning certain design decisions. This may lead to a better coaching of future designers or students by a possible comparison of differing design stages and examination of the followed procedures. It may also lead to more insight into methods of working for the benefit of empirical research into design processes and possibly to an easier identification of design rules.

A temporally coordinated data system as the solution

The aim of the research is to propose a facility to record, in a temporally coordinated manner, all design data generated during an architectural design process in one informationsystem.

With all design data is meant the kind of information to register and reproduce all design stages in a declarative way.This information consists of data on architectural objects in different phases of the design process. These data may predominantly be graphic data concerning the components that constitute these objects on different levels. They may also be alphanumerical data on the attributes which may be relevant for the different architectural design domains. Design stages may be design versions, design variants and design studies. Design versions succeed each other during the design process. There may be several design variants of a certain design version at the same time. And, to be complete, various design studies may have been made for design variants. (Figure 2). With temporal coordination is meant the ordering on the basis of aspects being temporary or time-dependent. Temporal coordination of design information creates the possibility to distinguish between retrospective, current and prospective design data. Retrospective design data give a review, current data deal with the up to date information and prospective design information provides a preview, like e.g. with the aid of an expiry date for certain design data or a maximum application period for an object. [Hee, 1985], [Benthem, 1983], [Whitrow, 1965]

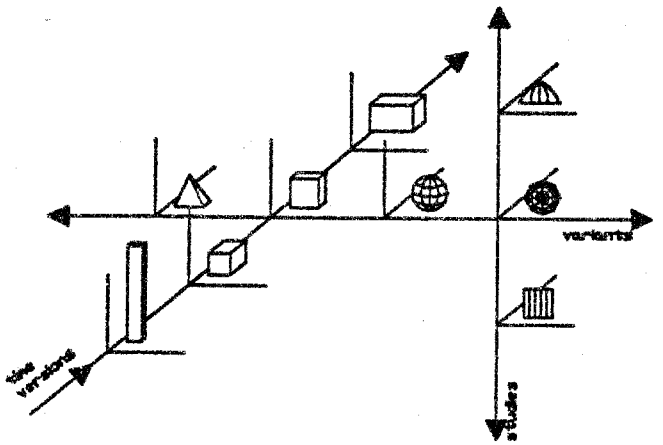

Figure 2: The relationship between design versions, variants and studies

Because of the recording of all design stages, it must also be possible to register and reproduce in a procedural manner the design processes that led to these stages. With a design process is meant here making a design for an architectural object in different steps and phases. By recording a number of successive design stages, the design process too is implicitly, and in a more or less discrete manner, recorded in the information system. By selecting and sorting the design stages, the process may also be reproduced again.

Such an information system should make it possible to have the computer compare different design stages. If you want to compare design stages it must be possible to select the desired stages first on the basis of temporal properties of the design information. After such a selection it must be possible to at least determine for two or more design stages the subtractions, an intersection and/or what these stages look like when united.

To be able to select, sort and compare different design stages, knowledge should be gathered about how temporal properties can be linked to design information when it is being registered. For the determination of possible temporal properties the 'logic of time' or 'temporal logic' can be used. Here you can find back definitions and indications concerning time lines, points in time, time intervals and time series. Time lines may e.g. be longitudinal, like for the era, orcyclic, like for a calendar. Points in time may be represented in a time dimension e.g. with the aid of time-coordinates. Time intervals are comparable to certain periods and timeseries to a range that has points in time. [Benthem, 1983], [Nauta, 1974], [Whitrow, 1965], [Whitrow, 1975]. In the domain of Informatics 'time stamping', 'version control', 'event schedules' and 'time management' with 'time increments' are already used for the registration of a time property while datarecording.[Hee, 1985]. For the reproduction of a design process you may use time intervals or time series for a representation it he form of e.g. an animation.

To be able to analyze and evaluate temporal aspects of design information, design stages and design processes, knowledge should be gathered about how calculations should be done with temporal properties. For the purpose of time calculation you can e.g. make use of time arithmetic or, as it is also called, chronology. For the determination of a unit of measure and a unit of account, also called time dimension may be used. A time dimension is a longitudinal chain of time units. It may be employed to denote a time line and also points in time, time intervals and time series in time-coordinates. To represent time-coordinates the Julian calendar, with a time indication in days and fractions of days, may be used e.g. [Ernst, 1988], [Gumbert, 1987], [Whitrow, 1972].

All this should lead to a better analysis and evaluation of design stages and to a possible analysis and evaluation of the followed procedures.

Temporal aspects of design information as the research problem

The formulation of the research problem is determined by the central issue, which is: how to record temporal aspects of design information in an architectural data system. With temporal aspects of design information is meant here the aspects of these data that are temporary or restricted to a specific time.

Information may e.g.:

- have the shape of a specific state ('frame') or a transition ('tween),
- be valid for a specific moment (point in time), or in a period (time interval) or periodically (time serie),
- be a representation of a case ('instance') or 'event',
- be related to the past (retrospective), the present (current) or the future (prospective).

Time indications may e.g. be:

- absolute (clock, calendar, era) or relative (stopwatch, age),
- cosmos-dependent (sundial, location-dependent) or mechanism-dependent (clock, regional).

When recording design data the 'infinity' of the volume of such information and the 'finiteness' of the capacity of recording media should be taken into account. Therefore processing is necessary to be able to makeworthwhile or the reduction of the amount of data. The infinity of design information is caused by the fact that the building process is not cyclic. It is a process that proceeds longitudinally. Design data for a specific site may be added continually to an information system. The finiteness of the registration media is caused by functional and technical limitations attached to several media. Books should be manageable and archives controllable. And although there is a constant refinement of possibilities, the capacity of the memory of computer systems is still limited too. Processing possibilities to reduce the volume of are e.g.:

- choosing a general type of design stage,
- making a more specific selection from design versions,design variants or design studies,
- making an aggregation of specific design stages.

Choices and selections may e.g. be made on the basis of relevancy, age or currency. Aggregations may e.g. yield a intersection of, or a subtraction between, numerous stages. You can also think of other processing possibilities. A transformation resulting from a possibly automated procedure may be registered without intermediate stages. The available procedure can be used again and again for any reproduction of this transformation. Through development and maybe automation of procedures, the size of the design system may be limited considerably. There will be much information in a data

- Objects in design information for the comparison of different stages. This subject has been put within the intersection of Informatics and Architecture.
- Space in CAAD-systems to record size and location of objects. This subject has been placed within the intersection of Informatics and Logic.
- Time in temporal aspects for a discrete recording of processes. This subject has been put within the intersection of Logic and Architecture.
(Figure 4)

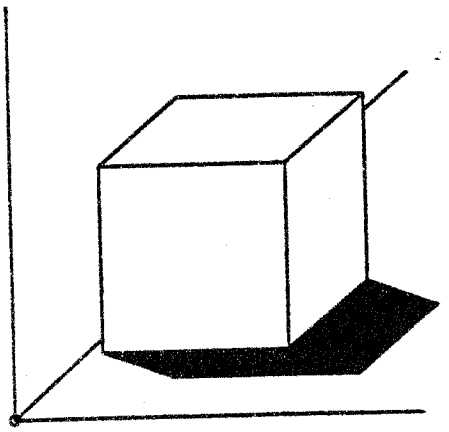

Figure 4: A representation for the relation between object, space and time

The heart of the investigation is not formed by the intersection of the different research domains, which corresponds with the intersection of the three different subjects. The fact is that this would indicate an effort to achieve complete integration of objects, space and time or an integral linkin gof the so-called 4th dimension to the three spatial dimensions in CAAD-systems. This would mean e.g. that concrete 'hardens', trees 'grow' and that buildings 'get older' in the CAAD-system. Since only specific conditions of such processes can be stored in CAAD-systems, there will be no such thing as a 4D CAAD-system for some time.

The research is part of our main subject of research 'Design Systems', as done at the faculty of Architecture at the Eindhoven University of Technology. Research in the field of Architectural Information Technology, among other things, has been classified under this main subject. The following sub-research from this research are of interest for the research proposed here:

- Research into presentation techniques with, among other things, attention for animation techniques (representation of changes according to a certain time serie) and 'virtual reality' (real-time animation for the purpose of evaluation and adaptation of virtual objects).

- Research into simulation techniques with, among other things, attention for (slowed down) simulations of the behaviour of light (DIM) and sound (SAX) in a virtual space.

- Investigation into methods and techniques for system development with, among other things, attention for methods and techniques to also analyze and design procedures or routines (IDEF2, for the modelling of dynamic, time-dependent models, State transition diagrams, Grafen theory) and also with attention for methods and techniques to set down and evaluate information plans.

Within this main subject of investigation, research is done, among other things, into Design methods. Starting-point here is a dependence of design levels, design domains and design processes. The Domains theory and the so-called GOM-model are used. [Bax, 1991], [Bax, 1992], [Trum, 1992]. In this research the need is felt for an empirical examination of the theory and the corresponding model. An adequate CAAD-system, in which also design processes can be stored, will be capable to support such an examination as one of the instruments of investigation.

Research elsewhere in the field of IT in Architecture is done especially in the domain of standardization, integration and communication of architectural data for all phases of the building process and, in general, aims at multi-functional product models. You can only expect to find any attention for temporal aspects, design stages and processes in Project Group P8, which, within the framework of ISO/STEP, Study Group 'WG3 ProductModelling', is going to pay attention to 'Product Life Cycle support'. [Bjork, 1991]

Informatics research which is relevant for the investigation proposed here, deals with the Object-oriented approach because of the object-related data. More specifically, we think we should try to join in with informatics research into 'Time management' and into the possibilities of 'Log-files' and 'Version control'. 'Log-files' store the processing 'history' during work on a data file. Version control in a data file enables the user to record different (sometimes up to 250) representations of entities.

For the purpose of joining in with the already mentioned research into 'Design systems', and taking knowledge and experience of the researc hteam into account, the following changes have been made in relation to our research elements. Research will restrict itself to design information. Data for the benefit of the construction and for management of architectural objects will be left aside during this research as much as possible. Design information will be confined to functional aspects of buildings or parts of buildings. Building-physical and/or structural aspects and urban development situations will not be considered for the time being. As far as the questions are concerned that may be asked concerning design stages, the research will only go into questions that have to do with the realization of these stages. Attention will be paid in

particular to 'What' and 'When' questions. Other types of questions, like 'How' and 'Why', having to do with knowledge and rules, can or should be examined separately at a later stage.

With respect to the choice of investigation methods to be used and the chosen ways of processing the data that are found, it seems important to state explicitly, and it is inherent in technological scientific research, that the research questions cannot be answered with the help of any empirical research yet, and that research data will have a predominantly qualitative character. This investigation too can be characterized as 'Goal-driven', where design of a prototype through probin and the development of hypotheses starting from a theory, are emphasized.

Research questions of a descriptive, exploring and testing character

As posed before, the main research issue for the investigation which is submitted here, is the question how temporal aspects of design information can be set down in an architectural information system. Next to this central issue the following main questions have been formulated.

- In what way can temporal aspects be recorded technically (within the domain of Informatics)
- In what way can relations between objects, space and time be described logically?
- In what way can design data develop during the architectural design process?

Based upon these main questions, several sub-questions will be dealt with during the investigation. The order of these questions shows a shift of the research emphasis during the investigation.When it is carried out, the following, for the most part descriptive, sub-questions will be emphasized:

- What time indications are possible?
- What development has taken place in recent history concerning the description of the relation between objects, space and time?
- What temporal aspects are relevant to the description of architectural objects and to the recording of design data in information systems?

Next, the following, for the most part 'exploring' sub-questions will determine the main lines of the investigation:

- How can different design stages be registered and reproduced in a data system with the aid of informatics techniques?
- How can logic time-indications be used to compare differing design stages and to compute time data?
- How can the architectural design processes also be registered and reproduced besides the design stages that originate from them?

Finally, the following, predominantly 'testing' sub-questions will have to yield the necessary know-how for the development of practical computer applications in which temporal aspects have been effectively implemented:

- What is the practicability of representative general computer programs in relation to a temporal coordination of data?
- What is the feasibility of temporal coordination of data in specific architectural computer applications?
- What are the requirements for the development of architectural computer applications in order to achieve a temporal coordination of data in them?

Theory, prototypes and hypotheses as research results

To answer the research questions, knowledge is needed from several disciplines, like Informatics (contents and meaning of temporal information in data systems), [Hee, 1985], [McCullough, 1990], [Rolland, 1988], [Rooney, 1987], [Schmitt, 1992], [Wagter, 1992]. Logic (relation between objects, space and time) [Bentem, 19??], [Bunge, 1977], [Fokker, 1960], [Kramer, 1987], [Nauta, 1974], [Whitrow, 1965], [Whitrow, 1972], [Zwart, 1988] and from Architecture (development of information during the building process) [Bax, 1991], [Bax, 1992], [Giedion, 1967], [Joseph, 1991], [Trum, 1992], [Vermaas, 1990]. As yet, the starting-point is that research in the different domains will for the greater part take place analogously. Architectural questions e.g. will have to be answered from Mathematics and Informatics and any paradigms originating from Philosophy and Logic may possibly serve as metaphors when formulating architectural questions and answers. The investigation consists of the following sub-investigations:

- description of a theory
- development of prototypes
- formulation of hypotheses

Description of a theory

This deals with research into possible indications for temporal qualities, into developments concerning the relation between objects, space and time and research into temporal aspects of architectural objects, design information and data systems.) Through a critical study of literature, a normal survey and the generalization of the findings, the formulated 'descriptive' sub-questions should eventually lead to a specific or an ad hoc theory about the possibility to record all design data in an information system in a temporally coordinated manner.

Development of prototypes

This deals with research into how design stages can be registered and reproduced in data systems, how time indications can be used to compare

stages and to compute time-related data, and research into the way that processes can be registered and reproduced. The 'exploring' sub-questions should lead to a prototype of a data system through a case-study, in the form of research while design and developing, and on the basis of an idea about the temporal coordination of design data in information systems.

Formulation of hypotheses

This deals with research into the utility of general computer programs, the feasibility of temporal coordination in architectural computer applications and research into the requirements for the development of architectural computer applications. Through pre-experimental research in the form of a pilot design-project, on the basis of theory and with the aid of the prototype, the 'testing' sub-questions should lead to hypotheses with respect to how temporal aspects of design information can be recorded in a CAAD-system.

Research workers and system developers as users

Research results will, as has been stated before, consist of a theory, prototypes and hypotheses. The theory will deal with the possibility to record all design data in an information system in a temporally coordinated manner. The prototypes will be data systems that can be used to test and demonstrate theory. The hypotheses will deal with the question how temporal aspects of design information can be set down in a CAAD-system.

It will be possible to have the theory applied by participants in (inter)national research and development projects in the field of 'product modelling'. Well-known projects in this context are: ISO/STEP, EDIBUILD c.q. EDIFACT, NOBI Practical Projects and our own main research issue: Design Systems. It will be possible for the people who carry out the investigation to use the prototypes for their own presentations and demonstrations. Other researchers should be able to use certain prototypes too as investigation instruments in e.g.empirical research concerning architectural design processes. The hypotheses can be used by developers of architectural data systems and/or computer applications in actual practice as well as in institutes for education and research .Writers of manuals for, let us say, the practical usage of CAAD-systems, will also be able to use the hypotheses, as done in e.g. the VCA Fanfare project.

Theory, prototypes and hypotheses will also be at the disposal of researchers for parallel investigation, but then concerning data that have to do e.g. with construction or with building management instead of design information. In the case of temporal coordination of construction data, you may think of applications in the field of graphic planning techniques and logistics. Especially applications in the field of facilitymanagement and building documentation may be important for building-management data.

The researchers are involved in a number of (inter)national collaborations and organizations. Therefore they have an opportunity to put forward theoretical (interim) results in several projects and to draw the attention of people working in the actual practice and of institutions for research and education at many occasions. Concerning the integration of architectural data and the development of CAAD-systems, the research will particularly emphasize a 'stage-oriented' or a 'process-oriented' approach. Because of this the investigation clearly distinguishes itself from research in other places where particularly a data-oriented or object-oriented approach is stressed. As a result of this, participation in specific research and development projects may turn out to be a surplus value for these projects. This surplus value may e.g. be determined by the possibility to register procedural data next to declarative data. Moreover, any temporal ordering of information may also be important beside a topological ordering of components or a hierarchic ordering of objects.

When developing prototypes, existing theories, generally known computer systems and computer programs and data from accepted architectural information systems, will be used as much as possible. This should guarantee an easy connection with the actual practice of informatics, building industry and IT in Architecture.

The research results, eventually the hypotheses in particular, can be used immediately in all the research and development projects regularly done by the Institute of Calibre for several agencies, companies and institutions. This application of research results in actual practice will provide regular test cases.

Final remark

The general interest for a time dimension for CAAD-systems will increase as the third spatial dimension becomes more established.

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