Processing of Geographic Data for CAAD supported Analysis and Design of Urban Development Areas

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Introduction

The interdisciplinary research project aims at the development of a hard- and software environment to support the representation, analysis, manipulation and design of urban development areas for architects and city planners. It was started in 1990 and involves three groups at the ETH Zürich:

Architecture/Urban design

Processing of Geographic Data/Photogrammetry

Computer Sciences/CAAD

The first part of this paper will give an introduction to the goals and implications of the project by comparing it with a similar project one of the authors took part in as a student. Then the paper gives a brief description of the work of the three groups involved, an overview of the methods they employed and the results that were achieved. The main focus will be on the work of the CAAD group. Finally some conclusions are drawn and problems are discussed. The future work includes the testing of the tool by students during the winter term 1993/94.

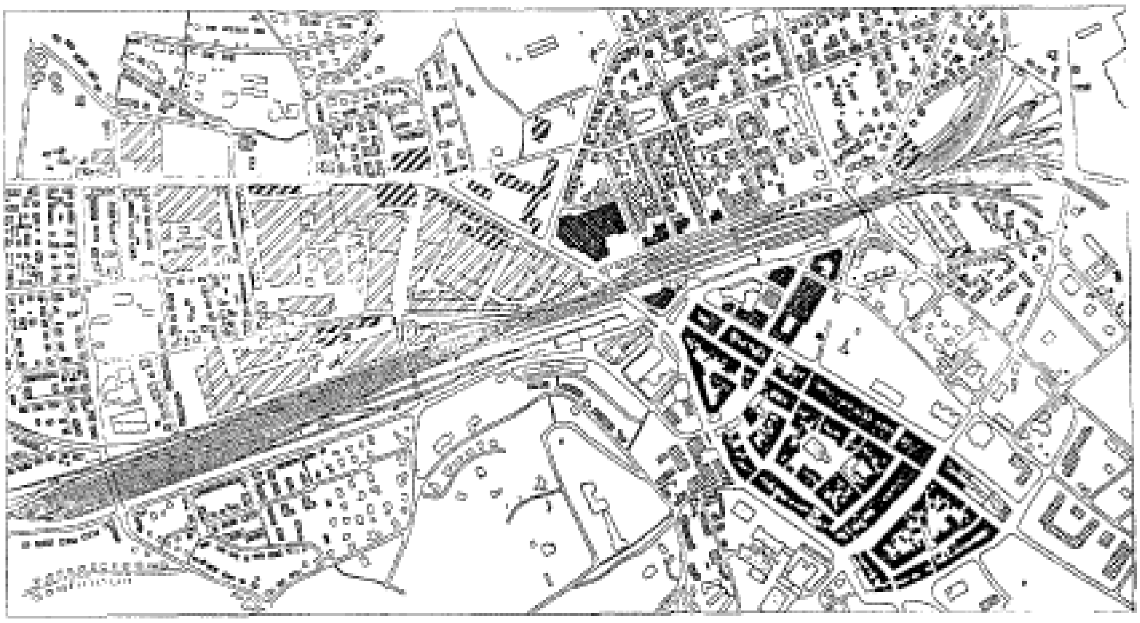
Project description

Complexity of urban planning

The planning and development of complex urban projects require the consideration of many factors. The historical development of the area, its topography, vegetation, usage patterns, transportation networks, buildings etc. as well as its political, social, economic and legal conditions and regulations all must be taken into account. The basic idea of the project is to make as much of this information as possible available in a prototype computer environment that will

a) rationalize the time-consuming process of analysis,

b) allow efficient testing and visualizing of design propositions based on the analysis by providing CAAD functionality in the same environment.



Winterthur - town model: Buildings were placed on different layers according to their type of use.

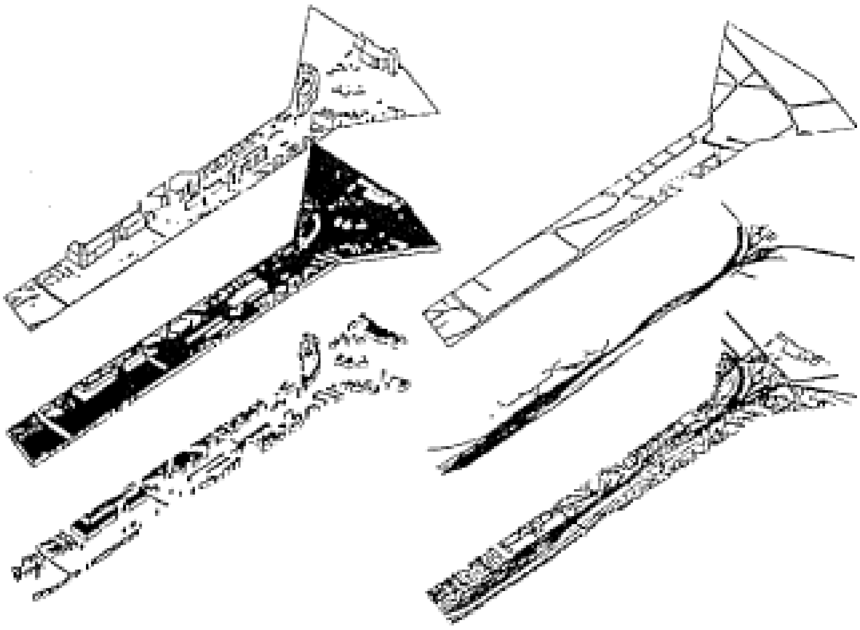
Winterthur - similarities and differences

To make the implications of this basic idea a bit more clear we will now point out the differences and similarities with another project mentioned earlier. It was a design studio about a large industrial site in the very center of Winterthur, a city in the canton of Zürich, for which the students were to envision and plan a new use. The studio was held in the winter semester 1990/91 by Professor Mario Campi in collaboration with the chair of architecture and CAAD of Professor Dr. Gerhard Schmitt. For the first time at the ETH Zürich, this studio introduced the computer as a design tool in urban planning as part of a regular semester course.

The prime motivation for using the computer in the Winterthur project was as follows: The computer model was supposed to help in the analysis and the design process by providing certain additional information and capabilities a traditional model does not offer.

Technically the Winterthur model was very simple. All the spatial information was digitized from plans. The buildings were for the most part simple boxes and stood on one flat surface (as if Winterthur were in Holland ...). In addition to that, the buildings were placed on different layers according to their use and - in some cases - the time when they were built.

Both aspects of the model - the spatial information and the layer structure - proved to be very powerful:



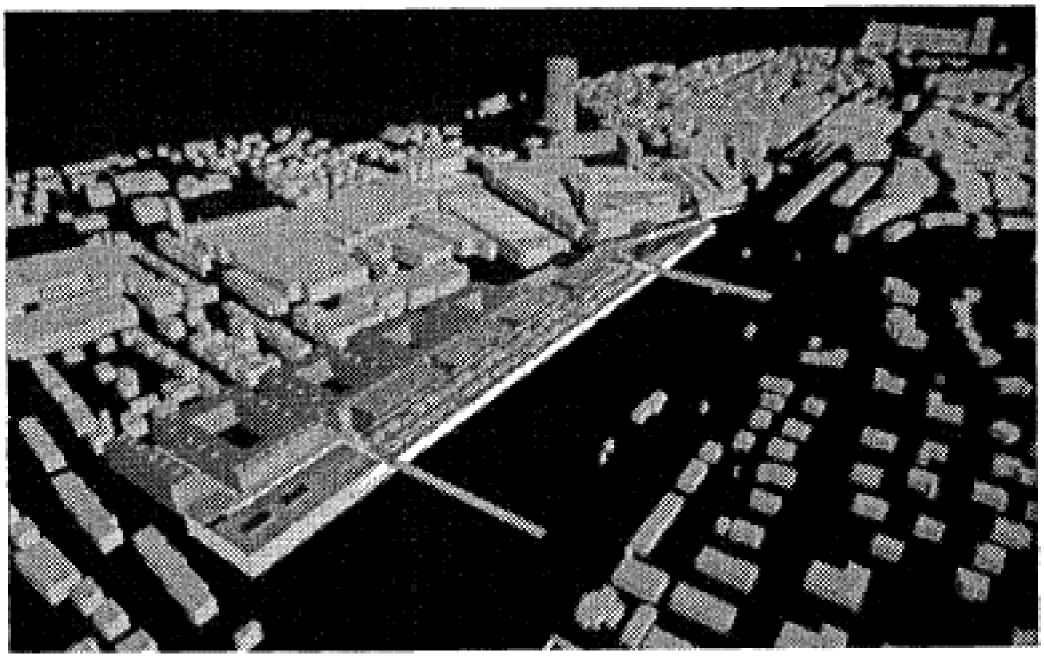
Winterthur - analysis: Investigation of different aspects of the train corridor using axonometric representation

Since the layers can be turned on and off individually, the buildings could be viewed separately or in any desirable combination according to their use or construction time. This proved to be very effective in the analysis phase. It allowed to create very interesting graphic representations - graphic representations that would have been virtually impossible to produce with traditional means and therefore really gave a new understanding of the city.

In the design phase the computer model served as a background to test design propositions, get feedback on them with renderings, realtime animations and the like. While traditional models offer only the bird's-eye view, the computer model can be viewed from any point within or outside of it. It was therefore possible to see a project in its surroundings, test its visibility and appearance from different points of view at a very early stage of design. To make these visualizations we used the program Stalker [Shih], which was then being developed at the chair for architecture and CAAD at the ETH Zürich. It also allowed to investigate urban design questions in terms of motion: How does one perceive a project driving by in the train or approaching it on the sidewalk?

The scope of this new approach was very limited, though, both for the analysis and for the design:

Since the computer model only featured so little information about the buildings in addition to the spatial information, the ways to view it were quite predetermined. To be able to analyse the site the students still had to largely rely on traditional sources, like photographs, maps, manuscripts, historic material and the like. There was no way to link information gained from these sources with the information in the computer.



Winterthur - design (1): Visualization of a design in birds eye view

Additionally, because it did not reflect the topography correctly and all the houses were of one height and did not have roofs, the 3-D model as a reference for the student projects was actually a bit misleading.

The deficiencies of the Winterthur project can be listed as follows:

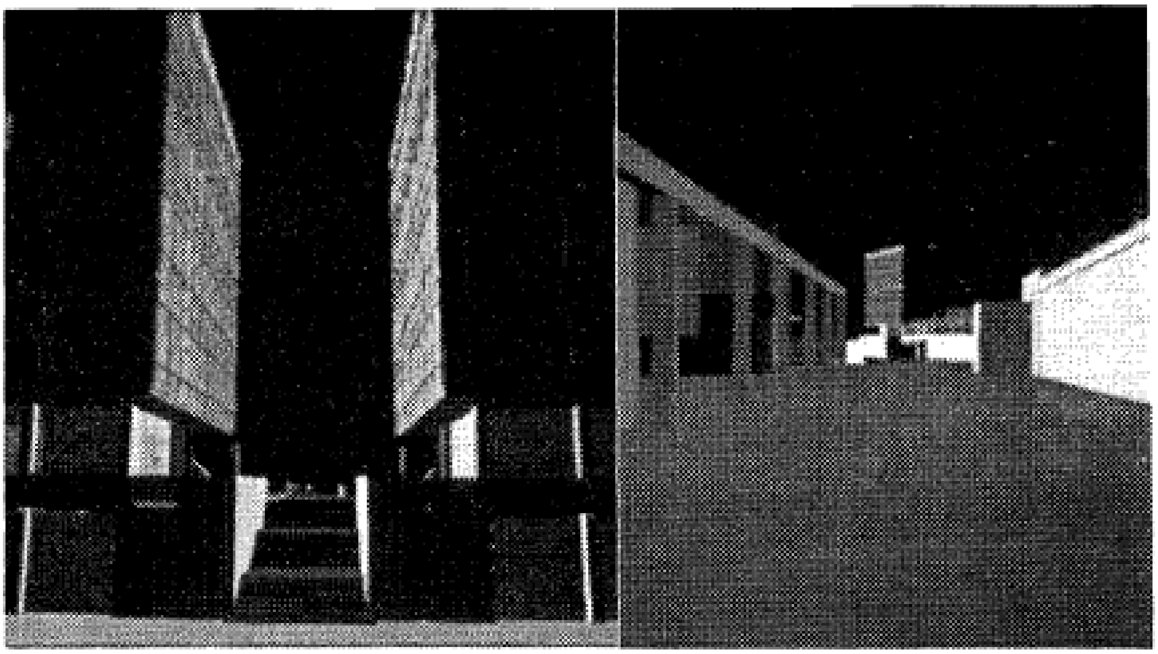
- The model is inaccurate

- The model does not include a digital topography model (DTM)

- There is no possibility to work with raster images (photographs, maps, historic material)

- The computers capacity to effectively handle large amounts of textual information - a key issue in planning - is not taken advantage of, because there is no possibility to link more detailed textual information with the model

Dating back three years, the Winterthur project essentially still represents the way traditional CAD packages can be used in urban planning at the present. Although the value of 3-D computer models to view design propositions in their surroundings is undisputed, and the analysis graphics are interesting, this in itself would not in many cases justify building such a model for a whole city.



Winterthur - design (2): Testing visibility and spatial aspects of a design from eye level views within the model

So the Winterthur project gave just a glimpse of how important computers could be in urban planning. Our current project is trying to keep and enhance the successful aspects of the Winterthur project. The main goal though is to address and overcome the listed deficiencies.

Background

One of the problems of the Winterthur project is, as mentioned above, the inaccuracy of the data. At the same time the acquisition of that data was already very time consuming and would definitely not have been worthwhile for an individual firm. The planning techniques we are investigating can therefore only become general practice when the data will be provided by government institutions.

A new federal regulation that went into effect in January of '93 requires all government institutions of Switzerland to acquire their planning data in digital form. Similar efforts are being made in other European countries. Although the geographic information systems (GIS) used for this purpose do not use a common standard format yet and the plan data is only in 2-D, it should be noted that much of the data in question is already or will soon be available in digital form [Bill]. So there is a very real background to our investigations even though so far architects have not been among the first users of these systems. To point out that this could and should change in the future is another objective of the project.

Methods and Results

Organisation of the project

The project aims to create and test a prototype software environment in which the user is provided with the following:

(1) a complete and accurate 3-D model of a large urban development area
(2) detailed information about it in a database linked with the model
(3) computer tools to visualize analysis and design propositions easily

The interdisciplinary collaboration between the three groups involved works as follows:
The architecture and urban planning group defines requirements and expectations for the system.

The photogrammetry group acquires and processes the 3-D data and converts it into a suitable form.

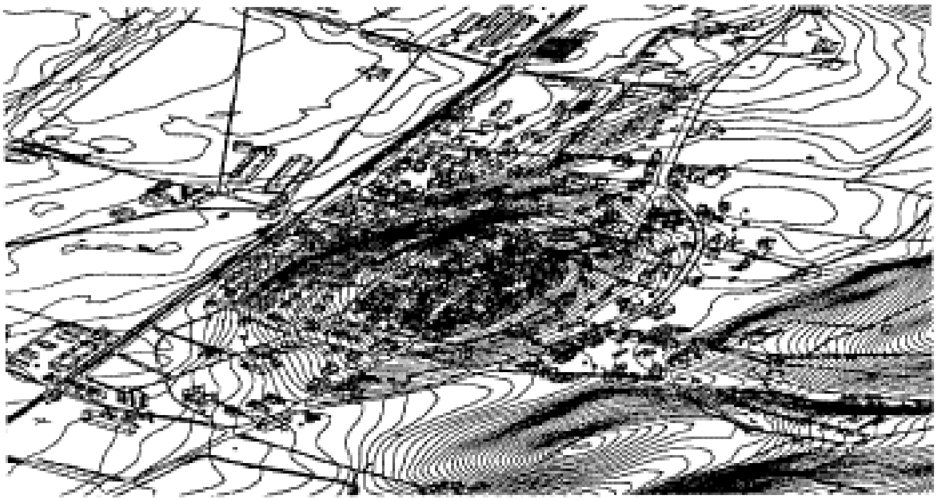
The CAAD group brings the two together, i.e. it incorporates the data it receives from the photogrammetry group into a CAD program to which it adds database functionality and tries to provide a computer environment that meets the requirements of the architecture and urban planning group.

Avenches

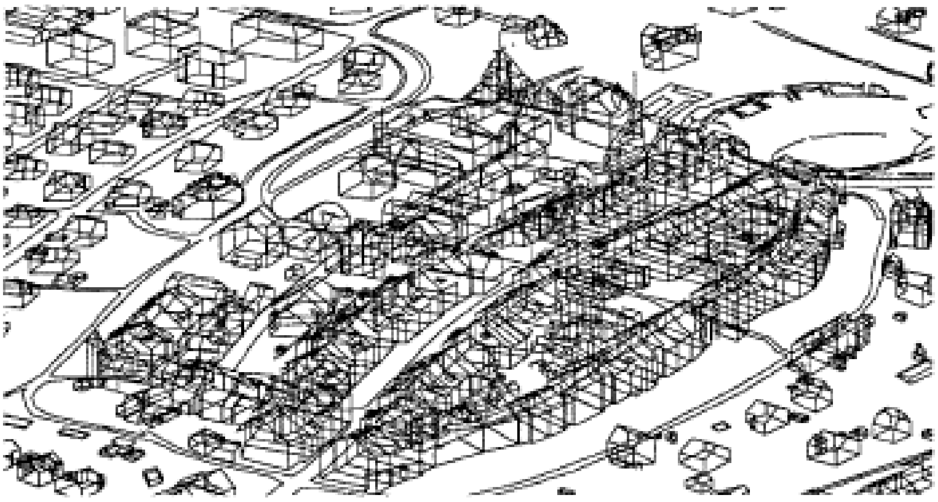
In the first stage, the project focused on a test area of about 16 square kilometres around the town of Avenches, in the West of Switzerland.

A complete photogrammetric evaluation and interpretation was done on an analytical plotter. The vector data acquisition includes the digital topography model (DTM), the water and traffic network, the vegetation and the three-dimensional roofs and buildings. Parcels were digitized from plans. The whole 3-D vector data set was transferred on a CAD system (AutoCAD). The line models of the buildings were edited and partly converted into surface models. Furthermore, orthophotos and 3D perspective views of scanned aerial images, draped onto the DTM were generated.

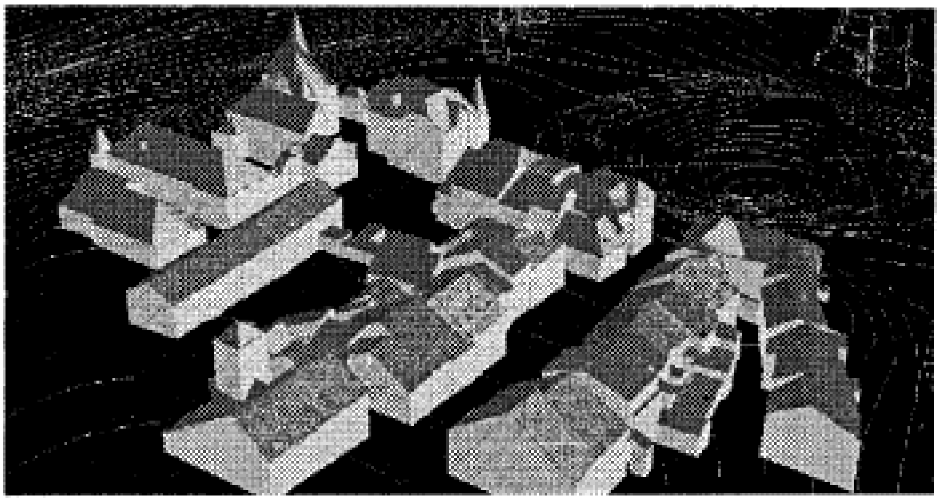
Within the whole test area the accuracy of the acquired data is about ± 10 cm. To achieve this precision is still a very time consuming task, only possible with state of the art photogrammetric instruments operated by highly trained specialists. The research of the photogrammetry group concentrates on rationalizing this process. The main problem at this point is to generate houses with complicated roof forms out of "clouds of points". The time when digital three-dimensional models are available for all of Switzerland (just as maps are available now) is still some years in the future, because to acquire and update this data is much too expensive with today's technology. How soon this will become feasible will depend on how this research progresses.



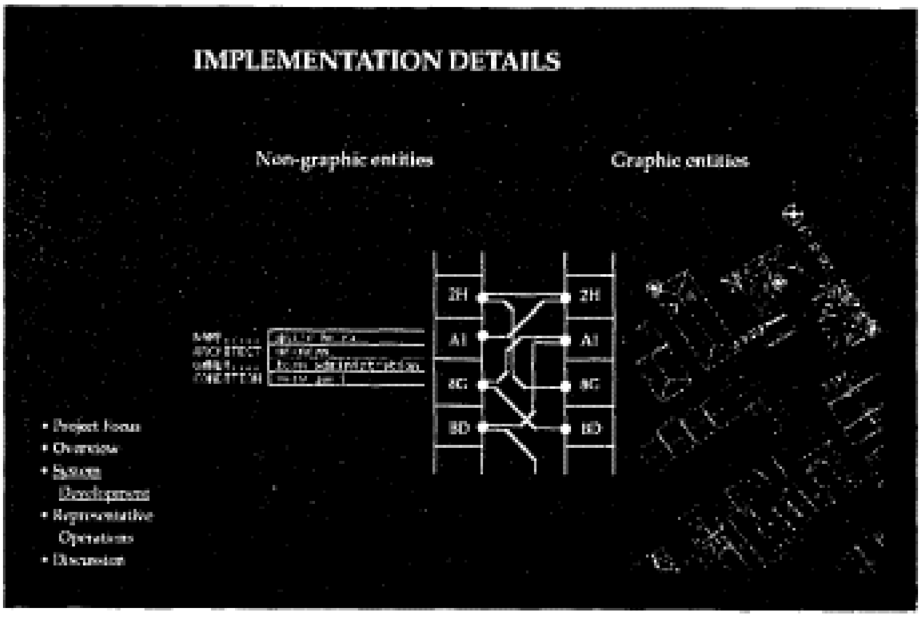
Avenches (1): The 3-D Vector model includes accurate topography and roof forms



Avenches (2): Zoom into the 3-D vector model



Avenches (3): Zoom into the 3-D vector model

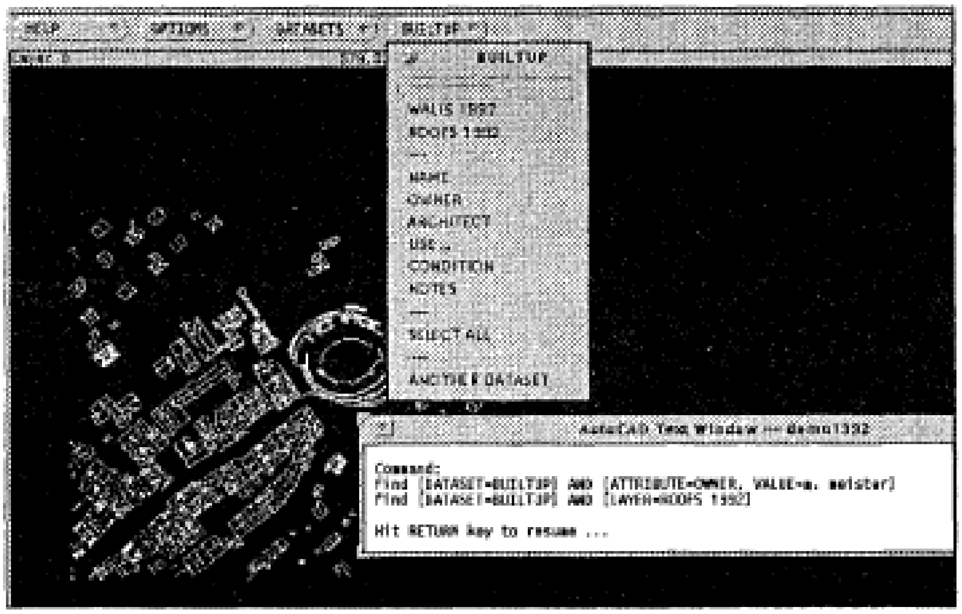


GIS-functionality (1): Linking of textual and graphic information

Integration of GIS functionality and design tool

The work of the CAAD group concentrates on integrating GIS functionality and design tool. There is a conflict: the functionality of most GIS systems on the market is already overwhelming, but they lack 3-D design tools. CAD systems on the other hand have 3-D modelling capabilities, but as the Winterthur project demonstrates, do not offer sufficient means to combine this graphic information with the other necessary planning information. Different GIS systems as well as new CAD systems were tested. The result of the evaluations was that there is no program that offers all the desired functionalities in one and that it is more feasible to implement GIS-functionality on top of a standard CAD program (AutoCAD) than to add design tools to a GIS system.

When the project was started the database functions were programmed within AutoCAD, using AutoCAD's extended entity data [Dave]. It was possible to provide SQL-like query functions. The layer structure - the only kind of textual information the Winterthur model featured - is used to differentiate between different categories of data. To every category any number of attributes can be associated. In the case of buildings, for example, attributes are: the owner, the type of use, the architect, the time of construction and the condition. An additional attribute is provided for special notes about the building, for example whether it comes under any monument protection regulations. It is possible to either select a building in order to view this list or to define attributes for a selection to be displayed. For example one could highlight all residential buildings in bad condition in a certain area.



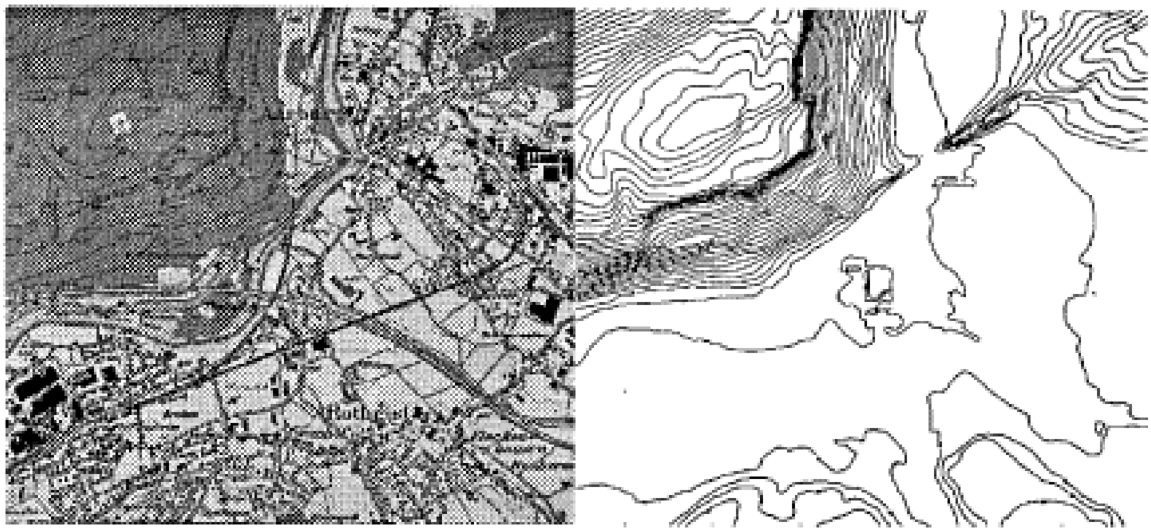
GIS-functionality (2): On-line query of textual information from within AutoCAD

These functions are available in the modelling environment, integrated in the AutoCAD menu. So a very differentiated analysis of the site can thus directly be obtained as part of the design process [Schmitt].

The possibilities to provide database functionality using extended entity data is of course limited. With the SQL interface of AutoCAD 12 we are presently implementing these functions into a commercial database. The amount of information that can be linked with any graphic entity is now virtually unlimited and the data does not impair AutoCAD's performance. It also allows to add more features. For example we are trying to develop means to link building codes to parcels in a way that any new design for a parcel can be automatically tested if it is in accordance with the code.

Olten

The experiences and results obtained with the test area were transferred to a larger area around Olten, a city in the Swiss Midlands (ca. 200 square kilometres). The area is in the "center of gravity" of Zürich, Basel, Bern and Luzern and therefore holds a large potential for future developments. The Architecture and Urban Planning group did extensive research on various aspects of the area. It also included meetings with politicians and planning officials. The tool we developed therefore also got feedback and input from the practical side.



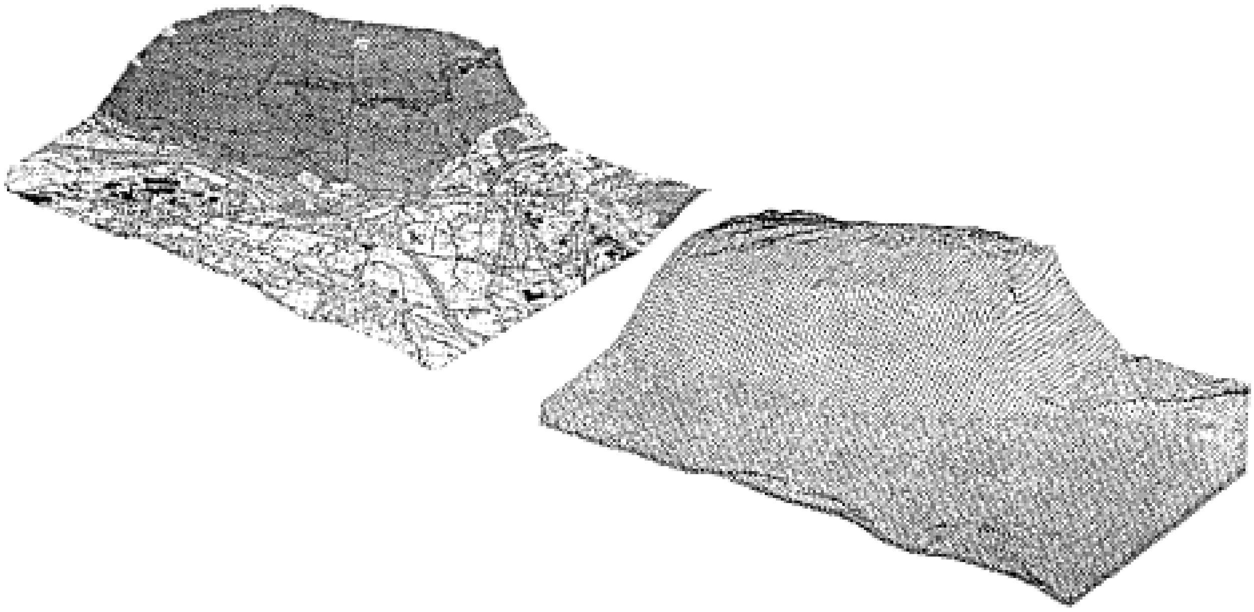
Olten (1): 2-D pixel map and contour lines of Aarburg, near Olten

The result for the area around Olten is a computer environment (a combination of data, software and hardware) which features:

1. **Digital topography model** : The data from the photogrammetry group can be turned into a 3-dimensional surface by triangulation or draping a web of squares over it. This allows the representation of landscape as well as the extraction of section profiles.

2. **Layer structure** : The most important aspects of the area are grouped on different layers. Examples are: streets (subdivided in local, cantonal and national streets), parcels, buildings, Vegetation, water, contour lines.

3. **Database functionality** : This constitutes the main improvement over the Winterthur setup. For every item in the model additional information can be stored. This linking of textual and graphic information basically means two things: On the one hand it is possible to display textual information about any selected graphic element in a window while working with the model. On the other hand this textual information can be explored graphically by defining attribute queries (for example: highlight all public buildings built before 1950). As an analysis tool it is almost as easy to use as the layer structure. But it allows much more differentiated investigations.

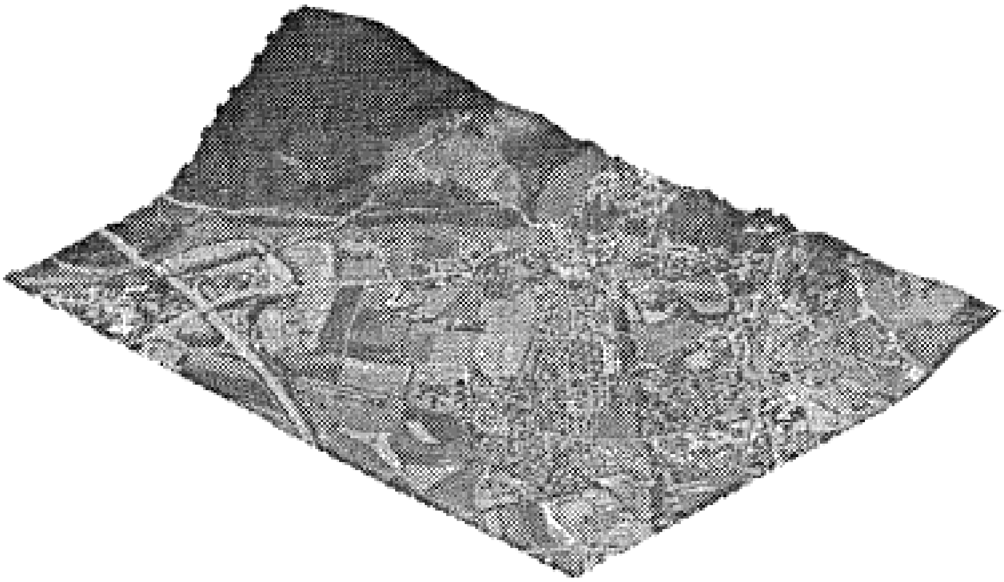


Olten (2): Digital topography model (DTM) with pixel map draped over it and as mesh representation

4. **3-D design tools:** All the 3-D modelling tools of AutoCAD are available, plus additional functions that were developed at the chair for CAAD, for example the types and instances method that allows to develop designs with a vocabulary of interchangeable elements for which different levels of detail can be defined.

5. **real-time visualization:** The program Polytrim [Danahy] which was developed at the University of Toronto, is used for real-time visualizations of the computer model. It allows the mapping of textures onto three-dimensional elements and therefore the direct combination of vector- and pixel data. It also features scripting: animation paths, lighting settings, titles and much more can be defined in a script to facilitate the production of videos.

6. **multimedia presentation:** The program Showcase allows to combine virtually any data of interest: graphic charts, pixel data (scanned in sketches or photographs as well as historic or present day maps), videos of the site or of computer animations, sounds. It is easy to go back and forth between these different topics by providing on screen buttons that call up related matters. It is also possible to start other programs from Showcase in this fashion, so all other parts of the setup can be used interactively in a presentation.



Olten (3): Digital topography model (DTM) with orthophoto draped over it

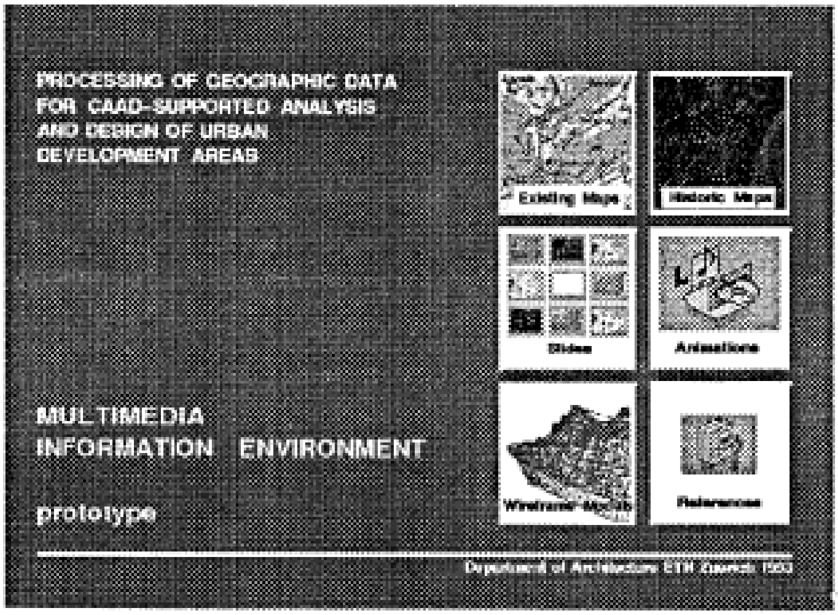
The strategy reflected in this setup can be described as follows:

We did not try to reinvent the wheel: Wherever there were programs on the market that offered the functions we needed and could be easily integrated into our setup we did not try to program them ourselves.

At the same time we tried to keep the number of programs small, because a simple and easy to use setup is in our experience often more important to the designer than many specialized functions he may never use.

We tried to develop a very general tool which offers a high degree of flexibility to the users. The database can be added onto and customized by the user and the functionality of the CAD program is not hindered by it.

By working with a CAD program that runs on a variety of platforms we also ensured openness in terms of independence from any single hardware platform.



Multimedia design environment: Students will be testing the tools in the winter semester 93/94.

Conclusions, problems, future work

Large amounts of data

So far we have only mentioned the things we have been able to improve in our approach, as compared with the Winterthur project. To give a more realistic picture of our work we should also add some remarks about the problems this approach bears. Some parents say about their children that the bigger they get the bigger the troubles and worries get which they cause them. Compared with the Winterthur project you could say similar things about this project.

The main problem we encountered was the difficulty to work with the enormous amount of data that constitutes the digital model. The conflict between the desirable accuracy of the data and the need to handle it easily became a key issue, the longer the project was going on. Performance was not our primary concern since the ongoing improvements in hardware technology make it seem more appropriate to concentrate on other issues. However at this point the problem is severe. Long regeneration times make the work with the model very tedious. We have found a way around the problem by providing special functions that allow us to cut special areas of interest out of the whole model. But we have not developed a strategy to display simplified versions of the whole data set according to the level of detail adequate to the task.

Testing by students

The setup for Olten will be tested by students in a design studio held by professor Franz Oswald. The students will be working with a cluster of Silicon Graphics Indy Workstations that were sponsored for the project. This means that the software environment with all the programs we developed will actually be running on a single hardware platform. The changing of computers depending on the task (Sun Sparcstations for AutoCAD, Silicon Graphics Workstations for visualizations) as it is presently done in the courses taught at the chair for Architecture and CAAD will not be necessary. So the testing conditions will be quite ideal.

The architecture and CAAD group will, as mentioned, work on linking a commercial database with AutoCAD. Because of problems with the delivery of the software the new tools are not yet part of the setup for the students, but will most likely be added at a later stage.

The students are required to have previous experience in CAAD to participate in the program. Still, in the first phase the main problem for the students will be to get acquainted with the tools they will be using. To help in this a set of tutorials was prepared. Whether the setup is really as easy to use and powerful as we think will only be answered in this design studio.

The three groups of research collaborators from the ETH Zürich, involved in the project are:

Architecture/Urban design:
Chair for Architecture and Design, Prof. Franz Oswald (coordinator),
Frank Neumann, Theresia Gürtler

Processing of Geographic Data/Photogrammetry:
Institute for Geodesy and Photogrammetry, Prof. Armin Grün,
Martina Meister, Hanbin Dan

Computer Sciences/CAAD:
Chair for Architecture and CAAD, Prof. Dr. Gerhard Schmitt,
Dr. Bharat Dave, Urs Hirschberg

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