# Advances in Communication between CAE-Systems

Progrès dans la communication entre les systèmes informatiques

Fortschritte in der Kommunikation zwischen CAD-Systemen

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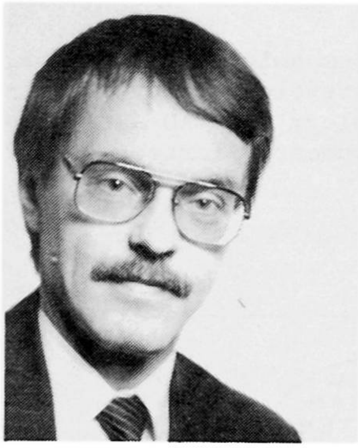

Matti Hannus, born in 1946, received his civil engineering degree from the Helsinki University of Technology. He has 20 years of experience in computer aided engineering, which became his main profession in 1979. He is now managing director of Cadex Oy, a software house specializing in AEC-applications and CAD data exchange.

## SUMMARY
The paper presents a standard for bi-dimensional intelligent CAD data exchange created within a national development effort 1984–87 in Finland. Communication between various CAD-systems in based on an extremely compact transfer file format which is especially feasible for electronic data interchange. Interfaces to various CAD systems have been prepared by CAD-vendors, software houses and users. For the end users of of CAD-data a receiving system software package is provided with functions like graphical viewing and editing, plotting, extracting alphanumeric attributes and interfacing to computer integrated manufacturing. Application program developers are provided with software tools that allow them to interface in-house application software with various CAD systems.

## RÉSUMÉ
Le document présente un standard pour l'échange de données bidimensionnelles de CAO créé dans le cadre d'un effort national de la Finlande entre 1984 et 1987. La communication entre les divers systèmes de CAO repose sur un format de fichier de transfert extrêmement compact, qui est spécialement favorable à l'échange électronique de données. Des interfaces pour divers systèmes de CAO ont été préparés par les vendeurs de CAO, les sociétés de logiciel et les utilisateurs. Pour les utilisaterus finaux de données de CAO, un progiciel système de réception est fourni avec des fonctions comme: vue et édition graphiques, tracé, extraction d'attributs alphanumériques et interface pour fabrication intégrée avec ordinateur. Des programmes d'application permettent l'interface des logiciels d'application maison avec divers systèmes de CAO.

## ZUSAMMENFASSUNG
Dieses Referat stellt einen Standard für den zweidimensionalen, intelligenten CAD-Datenaustausch vor, der in den Jahren 1984–87 in Finnland entwickelt worden ist. Die Kommunikation zwischen verschiedenen CAD-Systemen basiert auf einem höchstkompakten Übertragungsdateiformat, das für den elektronischen Datenaustausch besonders geeignet ist. Schnittstellen mit unterschiedlichen CAD-Systemen sind von CAD-Lieferanten, Software-Häusern und Anwendern vorbereitet worden. Den Endbenutzern von CAD-Daten steht eine Empfangssystem-Software zur Verfügung, und zwar mit u.a. folgenden Funktionen: grafische Abbildung und Aufbereitung, grafische Darstellung, Abfrage alphanumerischer Attribute und Schnittstelle mit computerintegrierter Fertigung. Die Entwickler der Applikationsprogramme werden mit Software-Werkzeugen ausgestattet, die ihnen den Anschluß der betriebseigenen Anwendersoftware an verschiedene CAD-Systeme erlaubt.

## 1. BACKGROUND

By late 1984 integrated computer aided design had been applied in several building projects in Finland. In most cases the involved parties had different CAD-systems and various ad-hoc methods were used to solve communication between various systems. Interfaces based on the well known IGES standard for CAD-data interchange were generally found unusable because of:

- large file size practically prevents electronic data transfer,
- loss of information due to incompatible implementations,
- high translation cost due to heavy processing load,
- lack of well defined subsets leads to high cost of developing new compatible interfaces.

At the same time various companies in the construction industry were accelerating their efforts in the development of computer integrated design and manufacturing. The missing technology for CAD-data interchange was setting limits to the integration and development efforts.

## 2. BEC-PROJECT

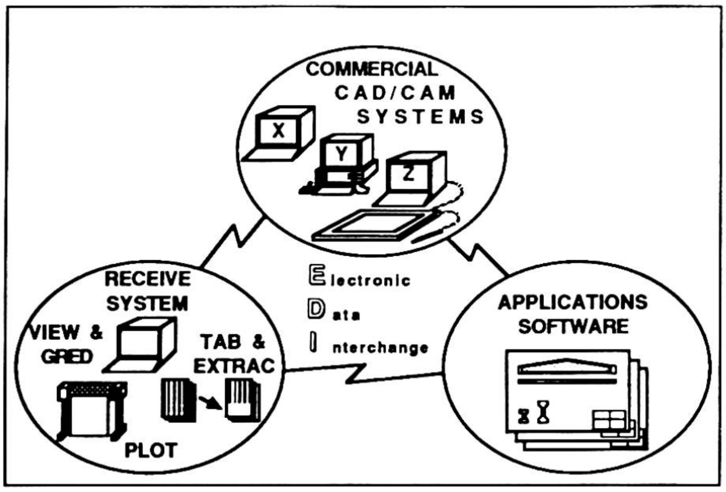


Fig. 1. Scope of BEC transfer system

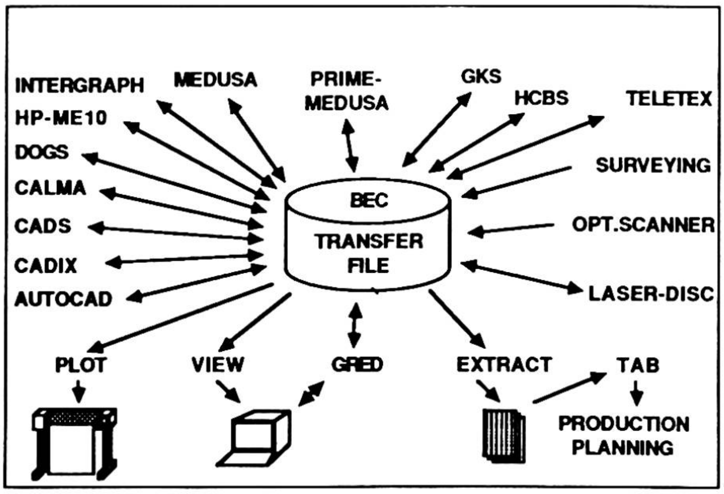


Fig. 2. CAD-systems and various applications supporting BEC data interchange format

In late 1984 the Association of Concrete Industry of Finland initiated a national development project on computer aided design and manufacturing of precast concrete components. Again, it was recognized that the major obstacle to development was the poor communication between various CAE-systems of the numerous companies participating in the design-manufacturing process Although this problem was evidently common to the whole (building) industry a decision was made in early 1985 to solve this problem between the most commonly used CAD-systems (in Finland). During 1985 a neutral transfer file format was specified. Also a common software library was developed to be used in writing all the various system dependent interface programs In January 1986 agreements were made with several CAD-vendors on cooperation to develope interface programs between their systems and the BEC transfer file format. During 1986-7 several interface programs were developed. As the last phase of the project a number of companies developed interfaces to their existing application software. The project was terminated in november 1987. The BEC format remains accepted as a de facto standard and is widely supported by CAD-vendors and users.

It was only natural that the initial development project called "BEC" (Betoni Elementti Cad) became to lend its name to the CAD data interchange system, which was an important but not the only part of the overall BEC-project. Other results of the BEC-project were:
- handbook on computer aided design of precast concrete,
- standardized product definition of precast concrete structures and components.

The purpose of these efforts was to create unified common practices that would allow more automated information processing and data exchange between organizations.

However, it should be noted that the BEC file transfer system described in this paper is based on general purpose computer graphics only and is independent of the technical application area.

## 3. TRANSFER FILE CHARACTERISTICS

The BEC transfer file format has been mainly affected by:
- Limitation to 2D-graphics only with associated alphanumeric information.
- ISO/GKS-standard on computer graphics programming.
- Data compression algorithms used to control some graphical devices.
- Common entities and data structures of modern CAD-systems.

The transfer file contains logical entities of the ISO/GKS-standard enhanced with several commonly used entities of interactive CAD-systems: line, arc, text, dimensioning, fill area, segment, symbol, layer, transformation matrix, alphanumeric attribute etc.

Data values are stored in packed ASCII format. The transfer file is unreadable to a human and "looks" similar to control code of e.g. a graphical terminal. The data is coded into a continuous sequence of ASCII-characters using a binary packing algorithm. As a result, the transfer file size is extremely compressed. Generally a BEC-file is less than 10 % of the corresponding IGES-file. A BEC-file is also typically about 50 % smaller than the original system dependent binary file of a CAD-system.

It should be noted that a BEC-transfer file can be treated as any ordinary text file. Any technology for text file transfer can be directly applied to transfer intelligent CAD-files as well.

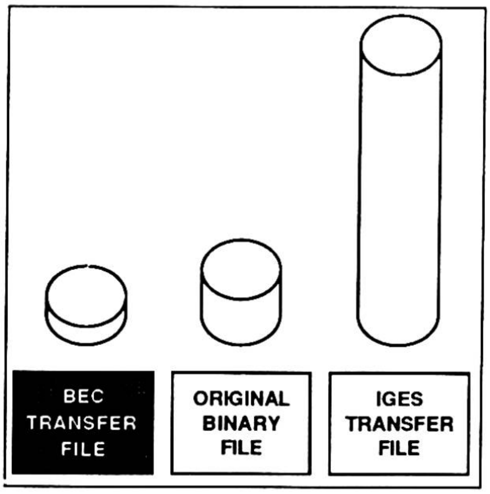


Fig. 3. File size in different formats

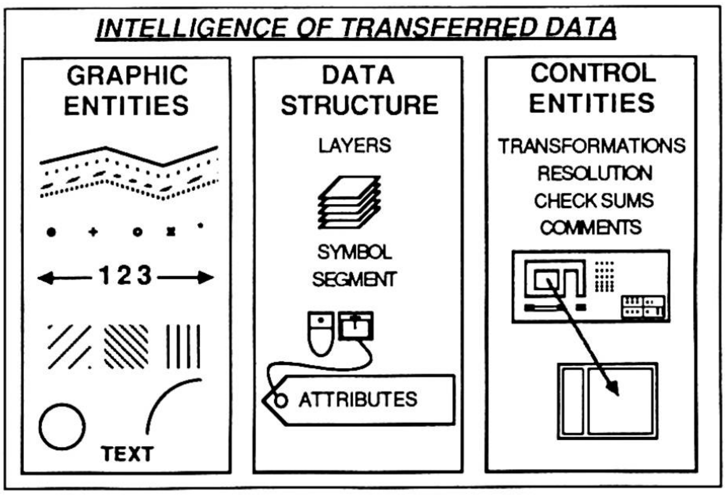


Fig. 4. Logical data structure of BEC transfer file

The core of the system is a common subroutine library which complies with the Fortran77-binding of the ISO/GKS-standard with some enhancements. The purpose of this software library is to assure compatibility of the various programs and to reduce the required development effort. As an internationally accepted computer graphics standard, GKS was a natural choice for the programming interface.

## 4. COMPATIBILITY

Development of compatible data communication software is an extremely sensitive process where the possibilities of something to go wrong are numerous. For this reason several precautions were taken in order to assure compatibility of various interface programs:

Instead of only releasing a written file format definition the authors of interface programs were provided with tested program modules and assistance during development. The common software modules are maintained as one original source code only for all supported different computers.

All interface programs are subjected to a formal validation test. Without approval any delivery of an interface program is prohibited. The vendors are obliged to inform their customers about the approved level.

It is also extremely essential to clearly define the implementation levels at which various conversion programs should operate. Otherwise various subset-implementations automatically lead to incompatibility and corrosion of the whole concept.

Three implementation levels of BEC were defined:

Level 0: All graphics must be transferred but no requirements are imposed on the logical data structure. Various user-developed application programs are allowed to operate at this level.

Level 1. In addition to visual graphics also the logical data structure is concerned (primarily layers, segments, symbols). This is the minimum accepted level for commercial CAD/CAM-systems.

Level 2. Alphanumeric attributes associated with graphical entities must be transferred. This is a voluntary capability.

Graphics can be transferred across implementations at all levels without loss of information.

## 5. RECEIVING SYSTEM

A receiving system was developed for the end-users of CAD-files. Such organizations may be passive users of data and may not need a "real" CAD-system. The included modules are:

- Previewing program VIEW allows viewing of BEC transfer files on a graphics screen with zoom, pan and level selection.
- Interactive modification of BEC-files is provided by the graphical editing program GRED.
- Program PLOT outputs transfer files on a plotter.
- Program EXTRAC separates alphanumeric attributes from the transferred file into formatted text file.
- Program TAB manipulates e.g. quantity information in array formed text files in various ways: sort, sum, re-order etc. Resulting data would typically be further transferred to a production planning or CIM system.

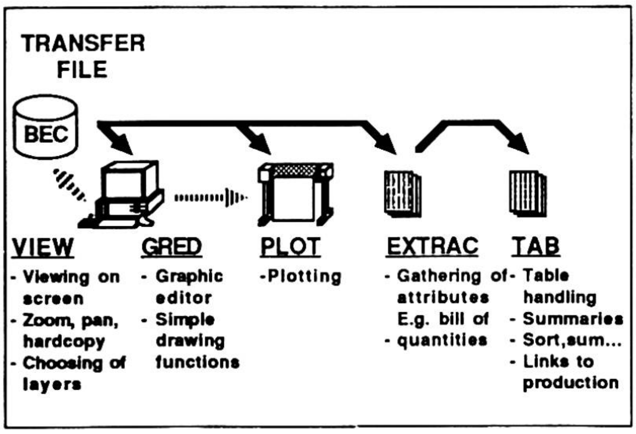


Fig. 5. Receive system modules

For electonic data transfer the public-domain terminal emulation program KERMIT is most commonly used to transmit files between various computers over public telephone network. Resently teletex emulation software like TELETEX-EMU has become available and adopted for BEC file transfer with a high automation level of data communication. Also other means for electronic data exchange are becoming available. If large amounts of information are to be transferred then physical media like magnetic tapes or PC-diskettes may be more appropriate.

## 6. INTERFACES TO APPLICATION SOFTWARE

Inspired by the removal of communication barriers between CAE-systems some innovative software has emerged within related applications.

Existing application software of a number of companies has been interfaced through the GKS/BEC-subroutine library which has been delivered to application developers. An alternative interface based on the well known HCBS subroutine library has also been used. These "conversionware" tools reduce the development effort of new interfaces.

Data transfer and conversion software converts recorded field surveying measurement data from data acquisition terminal connected to a theodolite and distance measurement equipment into CAD-files. Typical applications are: topographic surveying, measurement of old buildings for renovation design etc.

Interface program to an optical scanner transfers manually prepared drawings into various CAD-systems.

The VIEW-program of the BEC-receiving system has been enhanced for menu-controlled viewing and retrieval of CAD-archives stored on optical laser disks. Other spin-offs of VIEW are a graphical user interface to data base management systems and a PC-based maintenance system using CAD-graphics.

## 7. TOWARDS HIGHER LEVEL TRANSFER OF PRODUCT DATA

The focus of the BEC data transfer development was on 2D graphics exchange. However, as part of the overall BEC-project a higher level product model data transfer format was defined. Basically the definition is based on hierarchical assembly of buildings, components and details. The model also supports connections between objects. Experiments were made to define a whole building in this manner. Experimental software was developed to extract from a product model transfer file various kinds of lists and drawings.

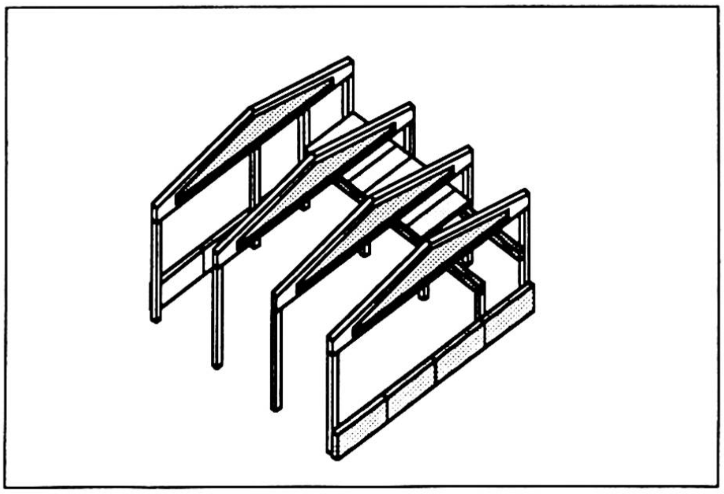

Fig. 6. Product modelling

Similar concepts of product modelling have been adopted in the development of vertical applications and have already resulted in commercial CAE-systems for the design of concrete and steel structures.

In a national research and development project called RATAS more general product modelling concepts of building design are developed. As practical results standardized data transfer formats are being defined for various types of data and combinations of them: text, array, vector graphics (=BEC), raster graphics, product model (of buildings) and knowledge (rules and facts). The aim is to provide guidelines for further development of more integrated utilization of CAE-technology from public data bases to design, construction, maintenance etc.

## 8. CONCLUSIONS

Electronic data interchange (EDI) is emerging as a key technology in the way that organizations operate in the near future. After the initial years of learning to use computers also construction industry and building consultants are entering the era of computer integrated design and manufacturing. In this process electronic CAD-data interchange is a crucial element.

In about three years since the start of first development efforts the BEC file format has been accepted as a de facto standard for 2D-CAD data exchange method in the Finnish building industry and consulting. To some extent BEC has also been adopted in other application areas like mechanical engineering. In the near future electronic data interchange based on the BEC format is expected to be an essential element in the development of computer integrated design and manufacturing of buildings.

The majority of CAD-systems that are used in Finland provide a BEC-interface and new interfaces are continuously developed.

For the (small) CAD-community in Finland it was more important to get the day-to-day problems solved than continue the unsure waiting for something useful to appear from the CAD-vendors as a result of international standardization efforts. With limited resources but realistic goals it has been possible to develope a feasible solution for intelligent 2D-CAD interchange.

Encouraged by the results so far more ambitious developments have been initiated on a higher abstraction level of product modelling.

## 9. ACKNOWLEDGEMENTS

The initial development of the CAD-data transfer system described in this paper was funded by the Association of Concrete Industry in Finland (SBK) and the Technology Development Centre (TEKES). The work has been supported by leading organizations of the Finnish AEC-community, CAD/CAM-vendors and numerous individuals.

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