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THE ROOTS OF BIM

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Abstract

Today's architectural and civil engineering design is almost inconceivable without collaborative tools. Building Information Modeling supports this with a set of collaboratively usable data. The roots of this concept go back in the past, thus the present paper attempts to depict some of the milestones in its evolution.

Keywords*: building, information, modeling, history.*

1. Introduction

In most simple terms, *BIM* (Building Information Modeling) is a digital representation of the physical and functional characteristics of a building [1] in a unified model which can be applied, managed and used in collaboration by all the actors in the construction industry. Its practical application is through computer-aided software packages, be it planning, construction management, valuation, operation and maintenance, or other building-related activities. By incorporating all the physical and functional characteristics of a building into a manageable model, there are many benefits. Perhaps the most important of these is the accuracy of the model's design, as it avoids constraints and shortcomings in construction that require intervention at the expense of quality, cost, and execution time.

The idea of such computer modeling of structures began to materialize in the early 1970s, and in the mid-1980s articles were published in which practical possibilities and relevant examples were discussed [2, 3]. The term "Building Information Models" appeared first in a paper published in 1992 [4], but it has come into the public awareness in 2002 (through a White Paper published by Autodesk [5]) The origination of the BIM abbreviation is attributed to Jerry Laiserin [6].

2. Product data evolution

The first technical drawing book [7] was published in France towards the end of the 18th century, opening the way for technical graphics. Technical drawing has become one of the pillars of engineering design. On the one hand, it was able to show the structures in parts, and on the other hand, it provided a more detailed product description (specifying more accurately the product data). Computer-aided design was also based on graphic design at first. Computer graphics offered more advantages than hand drawing in terms of tracking design changes and storing design data. Although it was easy enough to make additional sketches or write comments and suggestions on hand drawings, interpreting them required more cumbersome work. In engineering companies where technical activities involved not only design but also manufacturing or maintenance, hand drawings did not provide sufficient productivity. The situation was similar in the technical production chains, where several companies were involved in the design, implementation and maintenance of a product. When different CAD / CAM tools were used, data conversions hampered effective collaboration. Thus, the need arose to develop a neutral intermediate format that would facilitate data exchange between multiple computer sys-tems.

The *AICMA* was founded in Paris in 1950, and was renamed *AECMA (Association européenne*

des constructeurs de matériel aérospatial) in 1973. In 1977, a data exchange format was proposed by this association to allow cooperating companies to communicate surface geometries. Although applied in some cases, it has been forgotten over time **[8]**.

In the 1970s, the ANSI (American National Standards Institute) "X3 / SPARC" committee began exploring how data could be described, regardless of the application or computer technology used. This committee proposed a three-schema methodology whereby different views (conceptual, internal and external) of the same information could be applied using a variety of filters by users on different computer technologies **[8]**.

Based on the ANSI / X3 / SPARC methodology, the US Air Force has developed an information modeling process as a result of the "Integrated Computer Aided Manufacturing" (ICAM) pro-gram. ICAM's goal was to develop new manufacturing automation technologies that could reduce overall procurement costs. ICAM and sub-sequent projects, including the "Product Definition Data Interface" (PDDI) and the "Geometric Modeling Application" (GMAP) projects, have greatly contributed to the development of tools and procedures that have been incorporated into later standards.

The CAM-I (Computer-Aided Manufacturing - International Inc.) organization contributed significantly to the development of B-REP (Boundary Representation) data structures through a geometric modeling project started in the early 1970s. The result of the work funded by CAM-I, which was basically a mathematical representation of standard geometry and topology, was well ahead of its time because it clearly contained more information than the CAD systems of that time could interpret. The CAM-I specification focused on the essential description of interchangeable data, disregarding the exchange mechanism. This description has been submitted to the "ANSI Y 14.26" (Computer Aided Preparation of Product Definition Data) committee [8]. In 1980, NBS (National Bureau of Standards) published the "NBSIR 80-1978" standard for digital representation of product data specification for communications, which was approved as the first version of ANSI IGES (Initial Graphics Exchange Specification), as a neutral data block format that controls digital data exchange between different CAD systems.

In the late 1970s, a group was formed in the United States under the joint control of the industry, government and universities. Its objective was to develop standards and technologies that would enable product data to be controlled and exchanged across various computing systems. This group focused on two main projects, which resulted in IGES and PDES (Product Data Exchange Specification) **[9]**.

In Germany, in 1982, the Automobile Manu-facturers Association developed the *VDA-FS (Verband der Automobilindustrie – Flachenschnittstelle)* format for curves and surfaces of any shape to increase the efficiency and applicability of CAD / CAM systems in design processes **[8]**. Thus, Germany has also contributed to the standardization of international product data models.

Also in 1982, ideas for the development of computer-aided construction tools were launched in Finland, as such, in 1983 RACAD (Finnish abbreviation of the "Computer Aided Design Construction Council") and VTT (Finnish abbreviation of the "Technical Research Center") published a study on integrated computer aided design **[10]**. As a result of the somewhat parallel activities of these two organizations, the RATAS (Finnish abbreviation of "Computer Assisted Design of Buildings") project was conducted between 1985 and 1991. Its proposals were related to the data transfer format structures, according to which there could be used any data structures within the applications provided that suitable filtering programs are given for digital data exchange. A rule-based knowledge description language and a generic data model framework have also been developed. The proposal for a standard concerning product data transfer assumed one-by-one handling of the objects and suggested the use of a programming language with syntax similar to LISP **[10]**.

The French *SET (Standard d'Echange et de Transfer)* project was launched in 1983 within Aérospatial **[8]**. It has been developed to address IGES application problems, primarily for the automotive and aerospace production industries. *SET* reflected the requirements for data exchange between different CAD and CAM systems and the demands for digital data storage.

By 1984, all these international efforts had yielded so many comparable results that the possibility of developing a common solution for CAD data exchange emerged. The main driving forces for this common international standard were**[8]**:

– global trade and data exchange;
– increasingly complex products;
– multipurpose software (for example, design or engineering software systems that could be

used across multiple industries and various activities);
– trust in suppliers at all stages of product development;
– the need for product life-cycle support.

Many felt that IGES could not meet these needs. As a result of international results, the first “Product Data Exchange Specification” (PDES) was released in the United States in July 1984, followed by a second version in November. These were later merged with the STEP (STandard for the Exchange of Product model data) specification developed by the “ISO TC184 / SC4” Committee, which was launched in 1988 and marked as "ISO 10303" [9].

The BPM (Building Product Model) was released in 1989 to handle not only design but also cost estimation and construction, covering the entire phases of building construction processes. Although this specification was more focused on product modeling, it was not yet integrating all the information needed for planning and construction management. CIC (Computer-Integrated Construction) was a more advanced idea [11].

As a consequence of product data standards progression and of the technical software market evolution, in 1994 an industry consortium of 12 companies, called the “Industry Alliance for Interoperability” (IAI), was formed upon the proposal of Autodesk, in order to develop *C++* classes that would support integrated software development. As a result, a data model frame-work for architectural and construction products and services, called IFC (Industry Foundation Classes), was published in 1995 [12]. This consortium was renamed to "International Alliance for Interoperability" in 1997, and later as "buildingSMART" in 2005.

Also in 1995, the concept of GBM (Generic Building Model) was introduced, providing an opportunity for an integrated and collaborative use of information from the beginning of the design to the end of the life of the building. This gave the main stroke to the appearance of BIM after the turn of the millennium.

The first mark-up language, known as SGML (Standard Generalized Markup Language), was introduced in 1986 in order to describe data as text. With the spread of the World Wide Web, HTML (HyperText Markup Language) has become the most widely used tool for disseminat-ing information. As users demanded not only data communication but also data exchange, the W3C (World Wide Web Consortium) published in 1998 a more advanced mark-up language named XML (eXtensible Markup Language). The spread and use of this new language led to several applications, also in the field of construction, such as *aecXML* (Architecture, Engineering and Construction XML), started by Bentley Systems and then developed by the IAI for the construction industry. The “eConstruct” project (IST-1999-10303) was launched in Europe in the late 1990s. Within this framework, *bcXML* (Building and Construction XML) was developed, which became a taxonomy and lexicon based system [13]. The *bcXML* was the basis for the *ceXML* (Civil Engineering XML) mark-up language developed by Reinout van Rees during his MSc Thesis [14]. As the underlying taxonomy of "eConstruct" proved to be inadequate, the concept was further developed in 2000 as part of another project (IST-2000-28671) called "E-COGNOS", replacing taxonomy with ontology [15].

Data editing based on mark-up languages allowed open, scalable and safe development, since it did not require any special software.

3. Software evolution

According to some people, the basic idea of BIM may be attributed to Douglas C. Engelbart, who wrote about the combined architectural use of object-based design with parametric handling and relational database, in pages 4 to 6 of the introductory chapter of his work published in 1962 [16] Sketchpad was launched in 1962, followed by the DAC-1 in 1964, paving the way for computer-aided design.

Most people, however, consider Charles Eastman to be the "father" of BIM because he introduced a pioneering software application he developed in 1975, called BDS (Building De-scription System) [17]. This included thousands of architectural elements that could be graphically combined to create different building drawings. According to Eastman, the architectural drawings did not meet the requirements in terms of efficiency, as different sections of different dimensions were repeated in several places on them. In his view, the use of BDS would have reduced design costs in favour of efficiency. BDS failed to be successful, since its library with architectural and structural components was limited. In 1977 Eastman introduced a new software called GLIDE (Graphical Language for Interactive Design) [18], an improved version of its first software, which allowed for more

accurate editing and design control, and even cost estimation.

GMW Computers began selling the RUCAPS (Really Universal Computer Aided Production System) software in 1977, which was used in 1986 for the expansion plans of Heathrow Air-port Terminal 3 [3], although other software packages (GDS, EdCAAD, Cedar, Sonata, Reflex, etc.) were already also available in England at that time.

The progression of the mechanical industry gave a huge impulse to software development and, in the early 1980s several software were made with three-dimensional graphical modeling capabilities. The emergence of personal computers has further stimulated this.

At the Hanover Fair in 1980, the architectural engineering office founded by Georg Nemetschek in 1963, unveiled an integrated design and computing program for structural design, opening the way for computer-aided engineering on microcomputers. This program became known as AllPlan in 1984 [19]. The company has been developing spectacularly since the 1990s and in 1997 presented the database-based “O.P.E.N.” package, today’s predecessor to OpenBIM. In the following years the company will be transformed into one of the largest groups through successive company takeovers and acquisitions [19].

In the early 1980s, Bentley Systems began developing MicroStation, introducing the DGN (DesiGN) format. This suite was later marketed by Intergraph as MicroStation Triforma. It was originally conceived to be an IDGN (Interactive Graphics Design System) data array editor on PCs, and by 1992 it had a proprietary programming language, called MDL (MicroStation Development Language), which was extended to include Java by the end of the decade [20]. The procedure embedded in the software pack-age was called *"integrated project modeling"* by Bentley Systems [21], and the company was one of the co-founders of the ODA (Open Design Alliance) in 1998. The main purpose of the ODA is to create technical software development tools and filters to facilitate the free data exchange between different applications and platforms [22]. Originally called “OpenDWG Alliance”, it was renamed in 2002 to the current name.

The best known software is probably AutoCAD, the first version of which was written for the CP/M operating system and released in 1982, introducing the DXF (Drawing Exchange File) format. Within one year, it had almost a 1000 users [23]. This Autodesk software was developed based on a previous program written by Michael Riddle (a co-founder of Autodesk, later the developer of EasyCAD and FastCAD) in 1979, called Interact [24], aintroducing the first version of the DWG format. AutoCAD Release 2.1 was introduced in 1986, including the integrated AutoLISP language as a novelty (developed upon the XLISP programming language). By the 1990s, Autodesk had grown to become a major CAD software developer and AutoCAD was one of the most well-known pro-grams. Autodesk began developing targeted software packages for architects and civil engi-neers only later, after some company takeovers and acquisitions (Micro Engineering Solution, Softdesk, Discreet Logic, Revit Technology Cor-poration, etc.), and after some software tech-nology purchases also packages which were not based on AutoCAD (like Revit, RoboBat, Graitec, etc.).

Gábor Bojár and István Gábor Tari founded the Graphisoft software company in Budapest in 1982 [25], their main product was released in 1984 under the name Radar CH and was later successfully developed under the name ArchiCAD. This software is based on a concept similar to BDS and is considered to be the first BIM application running on personal computers (although Graphisoft describes this library-based parametric editing mode as *"virtual building"* [21]). With the help of the embedded GDL (Geometric Description Language), it offers also the possibility to expand the library of architectural elements. The company joined the IAI in 1996 and launched ArchiCAD for TeamWork and ArchiFM in the following years [25]. In 2002, ArchiCAD received the “IFC 2x” certifi-cation. The success and popularity of ArchiCAD was confirmed also by the acquisition of Gra-phisoft's software development business in 2006 by the Nemetschek group.

The Data Design System AS was founded in 1984 in Norway and its software, DDS-CAD, was primarily aimed at the building equipment industry [26]. As a result of their development the company became a part of the Nemetschek group in 2013, after which software versions conceived for architects and civil engineers were also released by them.

PTC (Parametric Technology Corporation) was started in 1985 in Boston, and in 1988 it launched the first version of the Pro/ENGINEER software for mechanical engineering. PTC acquired and continued to develop the Reflex package, offering it for architectural design, but without much success. In 1997, Irwin Jungreis and Leonid Raiz left the company in order to start developing para-

metric software that could be used to create more complex models. Their success did not materialize until 2000, when the first version of Revit was launched, describing their process as *"parametric building modeling"*. The development of this package progressed rapidly over the next 2 years until it was acquired by Autodesk in 2002. It is perhaps no coincidence that Autodesk published its White Paper on BIM that year **[5]**.

Robot Diffusion (later known as RoboBAT) in France began distributing the ROBOT CONCEPTION software in Toulouse in 1985, which became quite successful as ROBOT Structures in 1988 **[27]**. In 1999 RoboBAT became an official Autodesk partner and after one year their software was further developed based on AutoCAD, under the name ROBOT Millennium. The company has also developed other software packages (CAO, RCAD, CBS Pro, etc.) through several partnerships after 2000, and in 2014 they merged with the GRAITEC group **[27]**.

The development of TurboCAD on IBM PCs began in South Africa in the first half of the 1980s. It began to be marketed in the UK and USA in 1986. Starting from 1990 it was distributed by IMSI (International Microcomputer Software). Like Generic CADD, which appeared almost simultaneously, it became well-known as one of the cheaper alternatives to AutoCAD.

Although SCIA (Scientific Applications) was established in Belgium in 1974, their first soft-ware was launched in 1987 (for the modeling of connections in steel structures). Their SteelFab software for modeling steel frame structures was released in 1990. It started as a UNICAD-based CAD package and was later upgraded and further developed based on AutoCAD. From 2006, Nemetschek became the owner of the company and their most popular product, SCIA Engineer, was the first structural analysis software to receive the "IFC 2x3" certificate in 2013 **[28]**.

GRAITEC was founded in 1986 by Francis Guillemard, who, three years later, offered the *Effel* software package for the finite element modeling and analysis of reinforced concrete, steel and wood frame structures. In 1992, he introduced the Arche software for building simulation and automated concrete reinforcement design, and two years later the Melody program for the automatic design and modeling of connections in 2D steel frames. It started working with Autodesk as an official developer partner in 1997 and then established a subsidiary in Romania in 1999. Since 2001, the company has been offering new products (Advance Concrete, Advance Steel, etc.) as an Autodesk partner **[29]**.

In Romania, the *Polied* software **[30]** was developed by the C.T.C.E. Cluj (Cluj Territorial Electronic Computing Center) for 3D wireframe modeling of bodies in CAD models. It was finished in 1984 and in 1986 I attended a demonstrative testing where it proved faster than AutoCAD release 2.1 at the time, but had no market chance.

The Swiss *Cadwork Informatik AG* was estab-lished in 1988, continuing the development of the software started by CSEM (*Centre Suisse d'Electronique et de Microtechnique*) and EPFL (*École Polytechnique Fédérale de Lausanne*) in 1980 **[31]**. Originally designed for watch design, it has since become one of the most renowned software for computer aided design and manufacturing of wood structures. BIM-based software such as *Cadwork Ingénieur*, a road network design component, and Lexocad **[32]** started to be developed in 2004, but nowadays their best-known product is still Cadworks Wood.

Tekla X-Steel (predecessor of Tekla Structures) was released in 1993. The Finnish *"Teknallinen Laskenta Oy"* (Technical Computing Ltd.) was founded in 1966 with the aim of providing a unified computer programming office for various technical activities. In 2011, Trimble Navigation acquired Tekla **[33]**, and then Tekla BIMsight was released, an open software application based on building infor-mation models, aimed at collaborative work on construction projects. This allowed models to be imported from other BIM applications through the IFC format.

In the early 1990s, the IntelliCADD software development company was launched in Cali-fornia. One of their products was AutoCAD Data Extension, which allowed multiple users to ac-cess the same AutoCAD drawing at the same time. In 1994, Softdesk acquired the software and tried to develop it (somewhat secretly) as an AutoCAD clone. Autodesk first tried to sue Softdesk, but then acquired it in 1996, while some of its original employees migrated to Visio **[34]**. Visio IntelliCAD was launched in 1998 at a much cheaper price than AutoCAD. Besides not being as successful as expected, Visio was also not able to provide its support and development alone, thus the ITC (IntelliCAD Technology Consortium) was formed, which took over the full rights of the 2000 version. ITC is also one of the co-founders of ODA, and over time the software has evolved into a general development platform **[35]**. The Belgian-originated BricsCAD was also started from it, as well as

the FINE MEP (Mechanical Electrical and Plumbing) series.

In the late 1980s, AutoDesSys (Automated Design Systems) introduced its first three-dimensional modeling and animation software for personal computers, released in 1991 under the name *Form·Z*. It has been a huge success not only in architectural modeling but also in the game and movie industries **[36]**.

The firm of Frank Gehry, a world-renowned architect, began collaborating with *Dassault Systemes* in 2005. As a result, the Digital Project CAD package based on CATIA (Computer-Aided Three-Dimensional Interactive Application) and GTeam software for project coordination were released. CATIA is a multi-platform software package for Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Engineering (CAE), Product Lifecycle Management (PLM) and Three-dimensional Modeling (3D), the development of which began in 1977 **[37]**. After Trimble acquired SketchUp from Google in 2012, it also purchased the Gteam software of Gehry Technologies in 2014, alongside Tekla (BIM modeling) and Vico Office (BIM data management) **[33]**.

As a result of these initiatives, a large number of BIM-based software is now available in the construction industry, including many neighbouring fields (GIS, PIF, etc.). In addition to BIM, OpenBIM has also become popular, gaining ground due to the software creators who are supporting the open-access development of the “buildingSMART” type data model.

4. Conclusions

In addition to discussing the concept and sig-nificance of BIM, the purpose of this research is to provide a brief historical overview of the technology and software developments leading to it, as information on the World Wide Web is contradictory or inaccurate in many places. Not all of the software was described, only those that were considered more important by the author were mentioned. Knowing this history will give a more accurate picture of the meaning and evolution of BIM.

From the 18th century to the middle of the 20th century technical drawing represented the most used tool, barely changing over the two centuries. The emergence of electronic comput-ers, followed by the faster and faster develop-ment of product data technologies (PDTs) and computing, has led to today's building information modeling that allows not only more accurate structural detailing and cost estimation, but also significantly better quality records, maintenance and tracking of buildings over their lifetime.

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