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GOD, SEX AND PROSTHESES OR THE MYTH OF THE MACHINE IN THE PROCESS OF ARCHITECTURAL DESIGN

BÓG, SEKS I PROTEZY ALBO MIT MASZYNY W PROCESIE PROJEKTOWANIA ARCHITEKTONICZNEGO

Abstract

Architecture, as well as the process of architectural design, has always been linked to the spiritual, emotional and political transformation of society and closely related to technological development. This interdependence (technology/architecture – architecture/technology) is reflected not only in form, but also in language and terminology – particularly pronounced and clearly visible is the technical and technological development in the design process during the last 50 years. During the continuous development of digitalisation, this paper deals with the myth of the machine and the problems related to its impact on architecture, especially in the context of new intersections as well as the new threats to the design process.

Keywords: design process, fabrication process, digital architectural tools, digital matters, automated design

Streszczenie

Architektura, jak również proces projektowania architektonicznego, zawsze były związane z duchową, emocjonalną i polityczną transformacją społeczeństwa oraz ściśle powiązane z rozwojem technologicznym. Ta współzależność (technologia/architektura – architektura/technologia) znajduje odzwierciedlenie nie tylko w formie, ale także w języku i terminologii – szczególnie wyraźny i dobrze widoczny jest rozwój techniczny i technologiczny w procesie projektowania w ciągu ostatnich 50 lat. W kontekście ciągłego rozwoju cyfryzacji niniejszy artykuł dotyczy mitu maszyny i problemów związanych z jej wpływem na architekturę, szczególnie przez pryzmat nowych powiązań, jak również zagrożeń dla procesu projektowania.

Słowa kluczowe: proces projektowania, proces fabrykacji, cyfrowe narzędzia architektoniczne, digital matters, projektowanie zautomatyzowane

1. INTRODUCTION

The digital revolution is widely believed to be the cause of the greatest changes in social and cultural behaviour as well as in the world of work, mobility, religion, tradition, language, education and aesthetics since the industrial revolution. Important early achievements towards the digital revolution include the development of the first digital computer Zuse Z3 (1941),

the first transistor (1947) and the first microprocessor (early 1970s), but the most important point and the beginning of the Digital Revolution is the introduction of the World Wide Web by Tim Berners-Lee in 1989.¹

2. STAGES OF DIGITAL ARCHITECTURAL TOOLS

The changes and innovations (digitalisation, new media, communication behaviour as well as accessibility, language culture, etc.) caused by the technological development have influenced architecture as well as the architectural process and have solidified as digital tools in different stages and at a different speed. The development of digital tools in architecture can be divided into three stages (generations).

The first stage of digital architectural tools is Computer-Aided Design (CAD). In the 1980s, this design tool was first offered to many companies as an application programme called AutoCAD. The first prototypes already existed in the 1960s, but the large-scale availability in architectural offices took place in the second half of the 1990s. The reasons for the introduction of CAD are, on one hand, the very clean drawings, the faster production and the much simpler modification, which ultimately resulted in a more cost-effective production of design drawings.

The second stage is Building Information Modelling (BIM), which was introduced in companies at the beginning of the 21st century. The main feature of BIM is that, in contrast to the CAD-system, the design process no longer involves two-dimensional lines, arcs, circles and surfaces, but individual components. In this process, precisely defined properties are assigned to the components, such as wall thickness, type of material, parameters of the insulation, colour tone of the plaster, etc. As a result of those set parameters, exact data on material expenditure and cost calculation can be retrieved directly from the programme. When changes are made in the design, the material expenditure and costs are also changed at the same time, which improves the productivity of the planning process.

The third stage contains Network-based cooperation and artificial intelligence. It is not an exact innovation or a development of a new system, it goes beyond the use in the own company. The third stage includes new ways of cooperation with other companies, different new cooperations of different areas, sectors and industries as well as the direct simultaneous interventions from the design process into the manufacturing process. The key point is considered to be the increasing computing power and better and faster data transmission as a result of the expansion of the data network. There are a number of different terms used to describe these cross-industry and cross-sector collaborations: Digital Matters, Fabrication Design, Automated Design, Generative Design, Robotic Tectonics, Kinetic Systems, Additive Manufacturing, Robotic Fabrication, Extending Design, Digital Fabrication and many more. Among this large selection of terms, a clear line is nevertheless recognisable; the terms Robotic, Design, Fabrication are frequently listed² (Ill.1).

¹ Cf.: C. Eames, R. Eames, *A Computer Perspective. Background to the Computer Age*, Harvard University Press, Cambridge 1990; Explore timelines [in:] Computer History Museum, <https://computerhistory.org/timelines/> (access: 30.06.2021); D. Laws, *Who invented the transistor* [in:] Computer History Museum, 2013. <https://computerhistory.org/blog/who-invented-the-transistor> (access: 30.06.2021); *Transistor* [in:] *Encyclopædia Britannica*, <https://www.britannica.com/technology/transistor> (access: 30.06.2021).

² Cf.: M. Phiri, *Information Technology in Construction Design*, Thomas Telford Publishing, London

A special feature of the third stage is that, depending on the direction, focus, priorities and objectives of the cross-industrial and cross-sectoral collaborations, different types of digital tools can emerge in the design process and even change the architectural process itself. Three examples: simultaneous processing in the design process by different specialist planners; the production of individual complex components and building materials with the support of computer-assisted processes; the automated creation and editing of plans in the design process through computerised systems.³

2.1. SIMULTANEOUS PROCESSING IN THE DESIGN PROCESS BY DIFFERENT SPECIALIST PLANNERS

The existing technical tool BIM but also 2D-supported CAD-systems form the starting point. The project is no longer developed locally (stored on their own computers) by different specialist planners one after another. It is stored on an external secure data storage device and the processing is carried out at the same time by all specialist planners; changes are immediately available to all specialist planners and can be taken into account in the respective planning. Long waiting and processing time are eliminated. This design process requires a prepared structure, a schedule with defined workflows and a high level of control and coordination by BIM managers.

Buzzwords for this design process: BIMcloud.

Technological development required: coordinated and compatible CAD programmes, external secure data storage, extended data transmission network and high data transmission rates.

2.2. THE PRODUCTION OF INDIVIDUAL COMPLEX COMPONENTS AND BUILDING MATERIALS WITH THE SUPPORT OF COMPUTER-ASSISTED PROCESSES

In contrast to traditional manufacturing, computer-aided manufacturing is carried out using mathematical systems (entered by programmers) through technical tools (robots and machines). Particularly on the construction site, traditional manufacturing of components is made by men – simple bricks are laid by a bricklayer to form a wall, wooden beams are screwed or nailed together by a carpenter to form a framework, roof tiles are laid by a roofer, tiles are laid by a tiler, and so on. With computer-aided manufacturing, not only the type of production undergoes a change, with the new types of production, new possibilities and also limits for the design process – form, material, strength of the component – arise at the same time. Reasons for computer-aided manufacturing can be a complex shape, minimal error tolerance, consistent component properties within a series etc.

The simplest form of computer-aided manufacturing in the design process is the 3D printer. Initially, they were used for small models and small items made of thermoplastics for individual use. Today, larger elements can be made from various metal alloys with different properties for high-performance and precision machinery. In 2017, for example, a 1.35 m

1999; J.L. Encarnacao, R. Lindner, E.G. Schlechtendahl, *Computer Aided Design – Fundamentals and System Architectures*, Springer, Berlin 1990.

³ Cf.: A. Menges, B. Sheil, R. Glynn, M. Skavara, *Fabricate 2017*, UCL Press, London 2017.

ship's propeller was printed from a nickel-aluminium-bronze alloy, manufactured in 298 layers.⁴ Furthermore, large components made of carbon fibres are woven with the support of drones and robots, and bricks are built into mathematically shaped walls by robotic arms using logarithmic systems.⁵

Buzzwords for this design process: Digital Matters, Fabrication Design, Robotic Tectonics, Additive Manufacturing, Robotic Fabrication, Digital Fabrication. The multitude of terms mostly referring to the differences within manufacturing.

Technological development required: coordinated and compatible interfaces between individual CAD programs and manufacturing terminals.

2.3. THE AUTOMATED CREATION AND EDITING OF PLANS IN THE DESIGN PROCESS THROUGH COMPUTERISED SYSTEMS

Another major development of the third stage is the Automated Design (Generated Design) of projects. With the help of artificial intelligence, several different designs, in common cases several hundreds or thousands of designs, are generated on the basis of key data and evaluated with key figures. The final step in this design process is the final evaluation of all criteria and the selection of the final design by the designer. In this process, the programmes learn about individual preferences and the importance of individual factors from previous final evaluations of all designers and in this way undergo continuous further development. At present, computer programmes already exist in which only the outline of a building has to be designed, and the floor plan is generated automatically when further key data is entered.

For their own office space for a research centre in Toronto, Autodesk's programmers collected various key data from employees, including: "work style preference, adjacency preference, low distraction, interconnectivity, daylight, and views of the outside."⁶ Based on this collected data and with the power of cloud-based calculations, around 10,000 design variants were generated and the final design was selected in a final evaluation.⁷

Another example is Sidewalk Labs, the real estate development team generates different designs using artificial intelligence (like the Autodesk team), but the generated designs cover

⁴ Cf.: 3D-Druck: Schiffsschraube nähert sich der Vollendung [in:] Autocad Magazin, 13.09.2017, <https://www.autocad-magazin.de/3d-druck-schiffsschraube-naehert-sich-der-vollendung/> (access: 30.06.2021); Ramlab unveils world's first class proved 3d printed ship's propeller [in:] Ramlab, 30.11.2017. <https://www.ramlab.com/updates/ramlab-unveils-worlds-first-class-approved-3d-printed-ships-propeller/> (access: 30.06.2021).

⁵ A. Menges, *Forming machines – Achim Menges in conversation with Philip Beesley* [in:] F. Gramazio, M. Kohler, S. Langenberg (eds.), *Fabricate 2014*, UCL Press, London 2014, pp. 156–166; S. Andreani, M. Bechthold, *[R]evolving Brick: Geometry and Performance innovation in ceramic building systems through design robotics* [in:] *ibidem*, pp. 182–191; A.A. Apolinarska, *digital matters: Entwurfshelfer Computer* [in:] Detail, 30.06.2009, <https://www.detail.de/artikel/digital-matters-entwurfshelfer-computer-1420/> (access: 30.06.2021).

⁶ *Demystifying Generative Design – for Architecture, Engineering, and Construction*, Autodesk, 2018, p 4, <https://damassets.autodesk.net/content/dam/autodesk/www/solutions/generative-design/autodesk-aec-generative-design-ebook.pdf> (access: 30.06.2021).

⁷ A. Hauck, M. Bergin, *The Triumph of the Turnip* [in:] Gramazio F., Kohler M., Langenberg S. (eds.), *op. cit.*, p. 20.

several blocks of houses. In addition to the cost-benefit analysis, the results take into account factors such as open space, daylight and building density.⁸

Buzzwords for this design process: Automated Design, Generative Design, etc.

Technological development required: fast, powerful computers, artificial intelligence.

A characteristic of the technical development in the architectural process is the ever-increasing influence of the fabrication process in the design. Moreover, with the further development of different processes and artificial intelligence, it is no longer sufficient to represent a wall in the plan by two lines, today a lot of different parameters are needed – the selected materials, the direction of the sky, the GPS coordinates, even the reflection parameter of the glass of a window plays a role.

3. HUMAN FACTOR IN THE ARCHITECTURAL PROCESS

The processes described above differ not only in type of technical tools. A much greater and significant difference can be noticed when considering the human factor within the process. The term human factor describes the share of human activity (physical as well as mental) in different processes. It is used in the teaching of human-machine systems and human-machine interaction and is also an important component in ergonomics. By looking at the human factor, the degree of automation in the different architectural processes can be determined. The extent to which the different architectural processes are dependent on the use of humans or the extent to which they can be carried out without the involvement of humans is defined. Special emphasis is placed on the physical activity or support as well as the different cognitive demands. In his treatise *Supervisory Control* (1987), Thomas B. Sheridan describes in detail the different classifications of interaction in human-machine systems. He calls these:

- Manual control – the human operates a device, which only reacts to his operation.
- Supervisory control – as with manual control, the human operates an element. However, in the technical process an apparatus (e.g. a computer) is interposed. This has an influence on the criteria for the process task. A human being monitors this process and can intervene in it.
- Automatic control – a self-contained, autonomous system that can perform the process task without human involvement. The human merely serves as an observer.
- Direct Control – the difference to the previously mentioned is the absence of an apparatus or a machine within the process task. In this case, a human operates an element, tool, etc. The process task is carried out directly by a human.⁹

With regard to the classification of interaction in human-machine systems by Thomas B. Sheridan, a classification can be established on the basis of the human factor in the architectural process. A distinction must be made between the human factor in the design process and the human factor in the manufacturing process.

⁸ A. Novak, *An update from the Sidewalk Labs real estate development team* [in:] Sidewalk Labs, 22.06.2021, <https://www.sidewalklabs.com/insights/an-update-from-the-sidewalk-labs-real-estate-development-team> (access: 30.06.2021).

⁹ Cf.: T.B. Sheridan, *Supervisory Control* [in:] G. Salvendy (ed.), *Handbook of Human Factors*, Wiley, New York 1987; G. Johannsen, *Mensch-Maschine-Systeme*, Springer, Berlin 1993, p. 284.

Classification based on different degrees of automation in the design process:

- Direct control – full project control by the designer; no restrictions by technical tools, the designer uses drawing board and various drawing instruments.
- Manual control – full project control of the designer (for the most part); limitations due to insufficient computer power or lack of knowledge, the designer creates the design using simple CAD and BIM systems.
- Supervisory control – partial project control by the designer; constraints due to shape and scale of the computer-generated components, artificial intelligence systems design individual components (or entire designs), input of initial parameters and final evaluation and corrections are made by the designer.
- Automatic control – no project control; computer-generated design by mathematical formulas, artificial intelligence systems design entire projects based on previous experience, no more corrections necessary, no designer needed (future).

Classification based on different levels of automation in the manufacturing process:

- Direct control – full project control of the contractor; manufacturing by humans, craftsmen use simple tools (e.g. hammers) in the manufacturing process, low degree of precision.
- Manual control – full project control of the contractor (for the most part); fabrication by humans, craftsmen use machines (e.g. crane, excavator) in the manufacturing process, low precision level.
- Supervisory control – partial project control of the contractor; computer-controlled production of individual components (also entire objects), control and monitoring by humans (e.g. components – series production), final production of prefabricated components by humans, medium to high degree of precision.
- Automatic control – no project control, computer-controlled manufacturing, no human supervision of the manufacturing process, high degree of precision (Ill. 2–4).

4. CONCLUSION: TOWARDS ARCHITECTURE WITHOUT ARCHITECTS

The classification of the individual architectural processes under consideration of used technical tools illustrates the technological development, the learning ability of artificial intelligence and the shift in the scope of tasks as well as the control of humans in the architectural process (new era of the design process / new era of the manufacturing process in architecture). The developments in the architectural process lead not only to a new method of designing in the process, itself, but to a change in the basic principle in the architectural system (design – fabrication),¹⁰ they are a change in the key activity of architecture, a change in the basic intellectual and creative performance, a shift away from human thought and action, creativity and aesthetics. The result is an automated fabrication of designs in the architectural process. Is this change justifiable and acceptable? In this way, the architectural

¹⁰ Boundary or transition between design and fabrication, the combination of design intention, computational abstraction and automated fabrication; the human task in design process and the human task in fabrication process.

process becomes a simplified decision resulting from the selection of proven designs from a vast catalogue, becoming an instruction manual for the architectural process just as the Kamasutra is an instruction manual for pleasure.

In the first example of the third stage (simultaneous processing of the design) is the design described as a common action, based on human experience and discussions between different participants. In the third example of the third stage the design seems to have been wrested from human influence in the architectural process.

In this design process, the question of art (architecture as art) arises. Art as “*techne*” is a human activity. Machines do not create art. According to Heidegger, one can say: lead from the hidden into the unhidden.¹¹ The architect as an artist would become a programmer who enters lines of code into the computer and emotionlessly trusts the results of the programme. If art were to be found in this process, it would only be in the lines of code, the art in the programme code, created by the programmer. Art in architecture as an individual expression would then no longer exist. Accordingly, architectural competitions, for example, would become unnecessary, different architects would present the same design, generated by the same programme.

In addition, the question of criticism must be answered from the perspective of art – how can one question a mathematical formula – how can one criticise the art designed by artificial intelligence? The meaningfulness of such criticism of a work created according to a mathematical formula is open to doubt – how does one want to criticise the Fibonacci sequence? Criticism of the artificially created is artificially created criticism.

A multitude of data and information are entered into a program and it calculates the best result based on a logarithm, usually in a remote data store. Programs usually copy and refer to forms and patterns from nature (e.g. the systematic structure of shells) and thus follow naturally created mathematical examples. If art is a human activity, God-created nature is therefore not art but natural beauty. If programmes refer to nature and are inspired by it, they do not create art, they copy God-created natural beauty.

Thus, in this way, the design process becomes partly God-like. And not only in the previously mentioned example of art; when we pray, we send our prayer (information) to heaven and expect an answer (whether we receive an answer is subject to subjective interpretation). In this example, the person involved in the design (e.g. architect) also sends information but not to heaven but to a cloud and also expects an answer from an abstract construct.

Another aspect of automated design or automated fabrication in the architectural process is the problem of aesthetic originality in the creation process (aesthetics of fabrication). Who is the creator, the originator of a product, designed in Generative Design or manufactured in Automated Fabrication. What is the original, what is a copy? Imagine that in a competition a bricklayer and a programmed robot have the task to build a wall 100 times. Factors such as speed or cost efficiency are not taken into account in the result. Small differences can be detected in the master bricklayer’s produced walls – joints of different widths, perhaps even differences in the wall bond. In contrast, the robot’s walls are all the same, all joints are the same width, made according to a programmed pattern. All walls are copies of a digital original, whereas the walls of the master bricklayer are each unique. The master bricklayer is *causa efficiens* – according to Heidegger, he is the skill (*Geschick*). It is different with the

¹¹ M. Heidegger, *Die Frage der Technik* [in:] *Gesamtausgabe*, Band 7, Klostermann, Frankfurt a. M. 2000.

robot, it is not the robot that is the *causa efficiens* but the programmer. Of course, a robot can be programmed to make different walls but it is still only a result of a logarithmic change in the programme.¹²

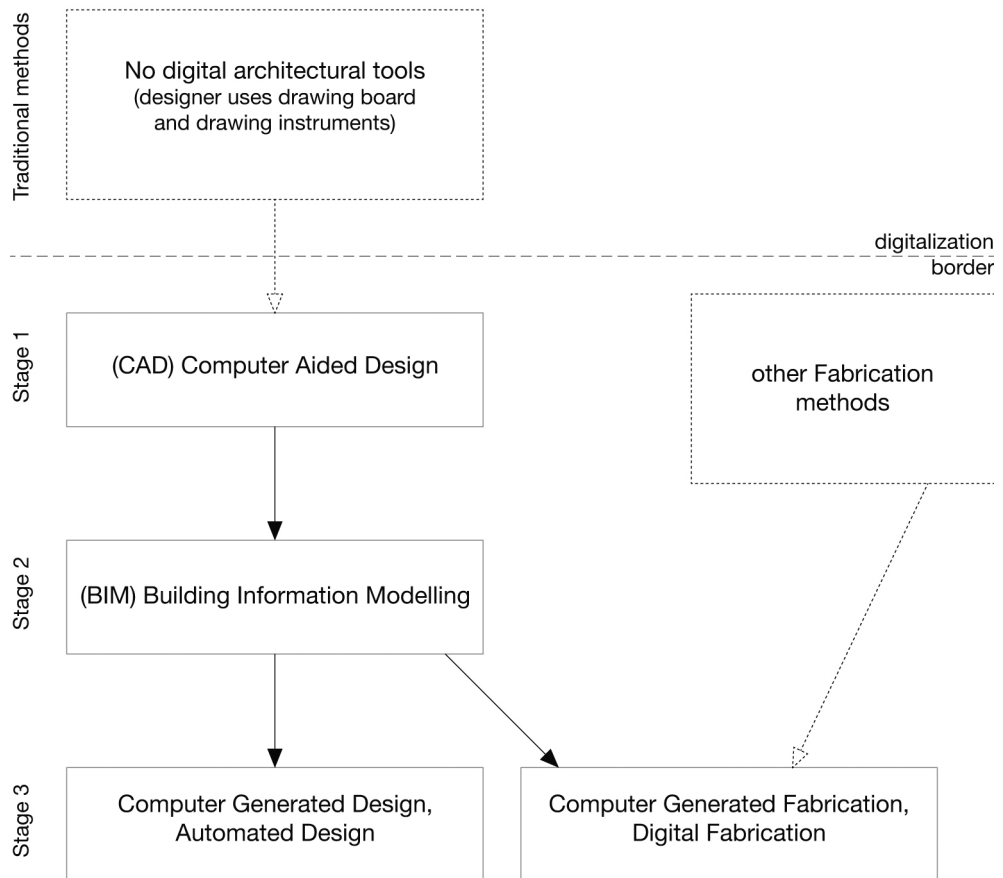
The computer and the monitor become technical tools for the (physical) human to understand and feel the (digital) beauty in the lines of code that create the (physical) architecture – prostheses for understanding the digital beauty through which the physical architecture is presented.

When Michelangelo made his David, he carved the statue out of marble according to his ideas. He did this on the basis of his experience and knowledge (*causa efficiens* / *Geschick*). He did it this way, not any other, and not because the hammer and chisel told him “if you do it this way you are 5% more efficient”.

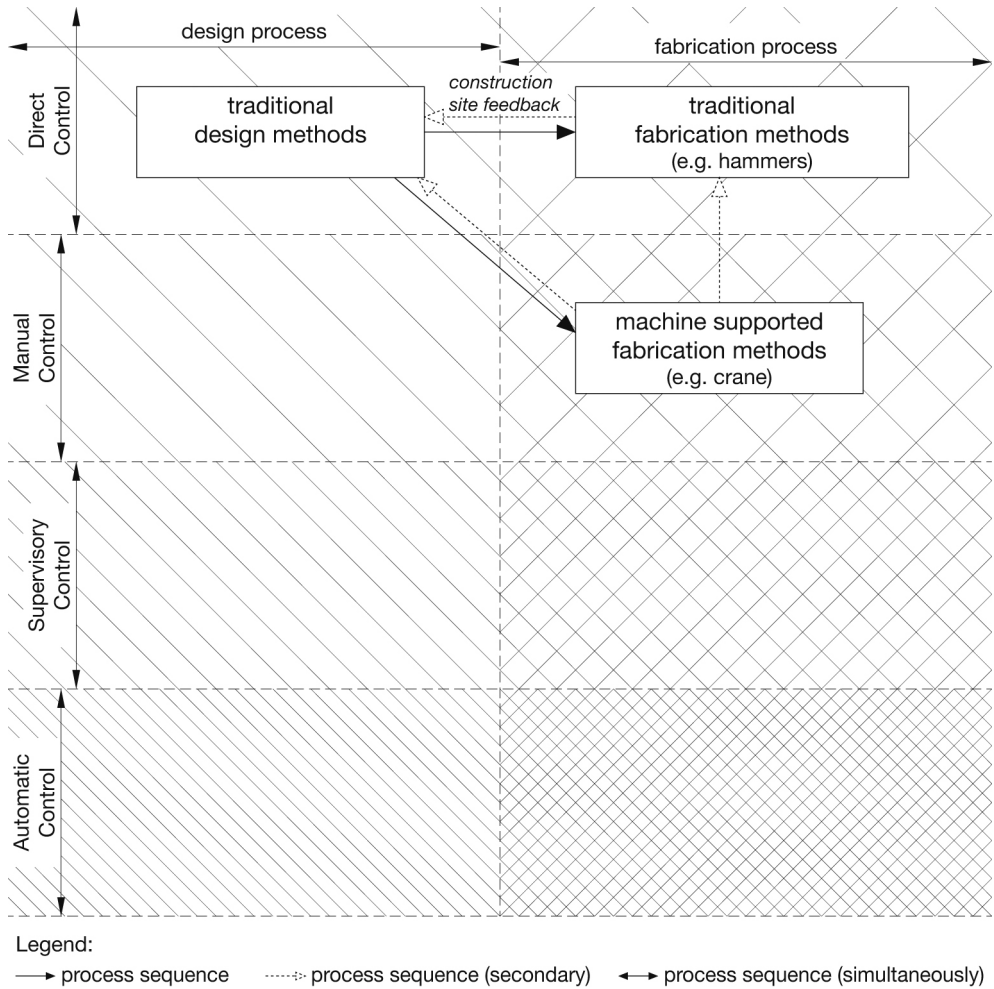
The designer in the design process, as well as the executor in the production process, must allow the computer-aided systems to influence their intellectual and creative performance, they must not be forced upon them, only then can it still be guaranteed that the final project corresponds to their ideas.

It remains to be seen to what extent the different types of design and production will prevail and develop in the architectural process. It is possible that the scope of the architectural profession will split up with the further development of technical progress, as has often happened in the past. In Vitruvius’ ten books on architecture we can see the scope of the architect’s tasks at that time; in addition to housing, public buildings, material science and others (still relevant today), an architect also had to know about canal and water infrastructure, war and siege machines, clock making and astronomy. According to Bertrand Gilles, Leonardo da Vinci was the first master builder in the Renaissance to specialise in hydraulic engineering. In the following, new professions tailored to technical progress emerged: mechanical engineer, bridge engineer, aeronautical engineer, etc. Perhaps the architectural profession will split again; to an architect who deals with architecture as art and to an engineer who writes architectural programme codes and enters them into a computer.

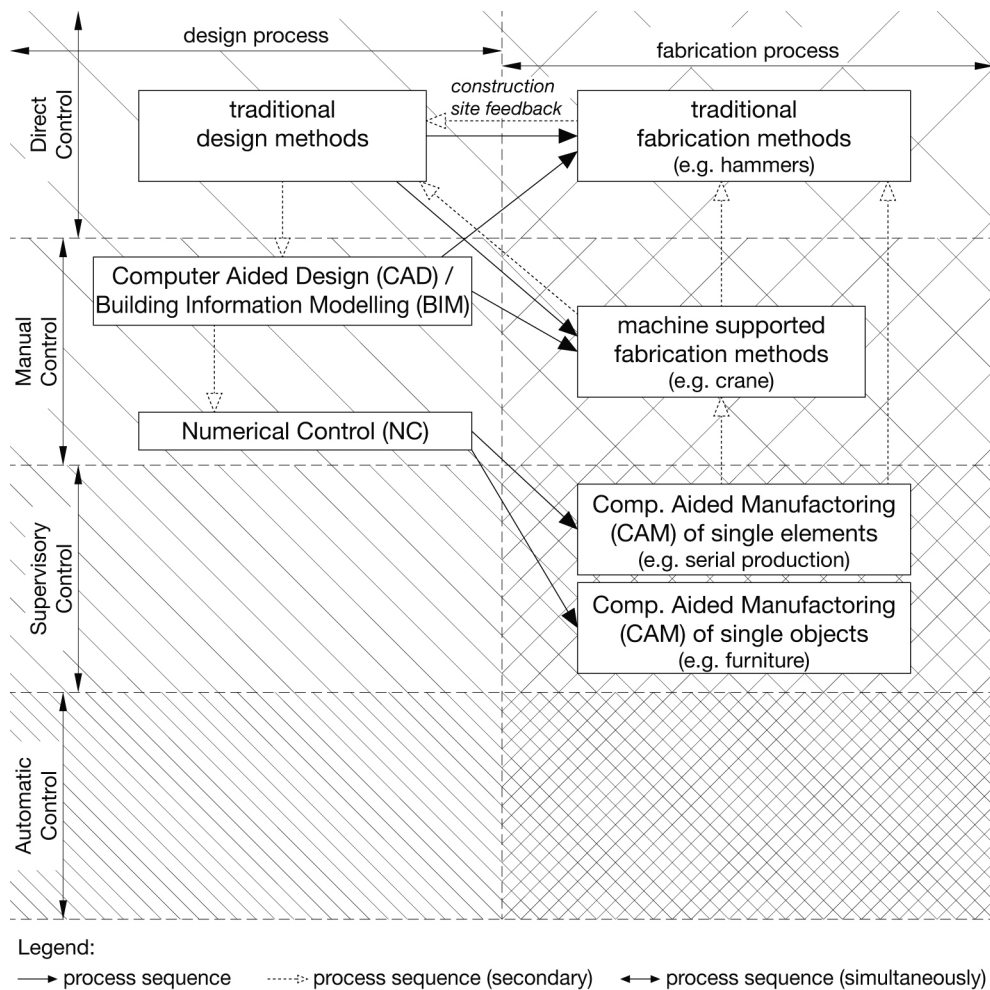
¹² *Ibidem*.



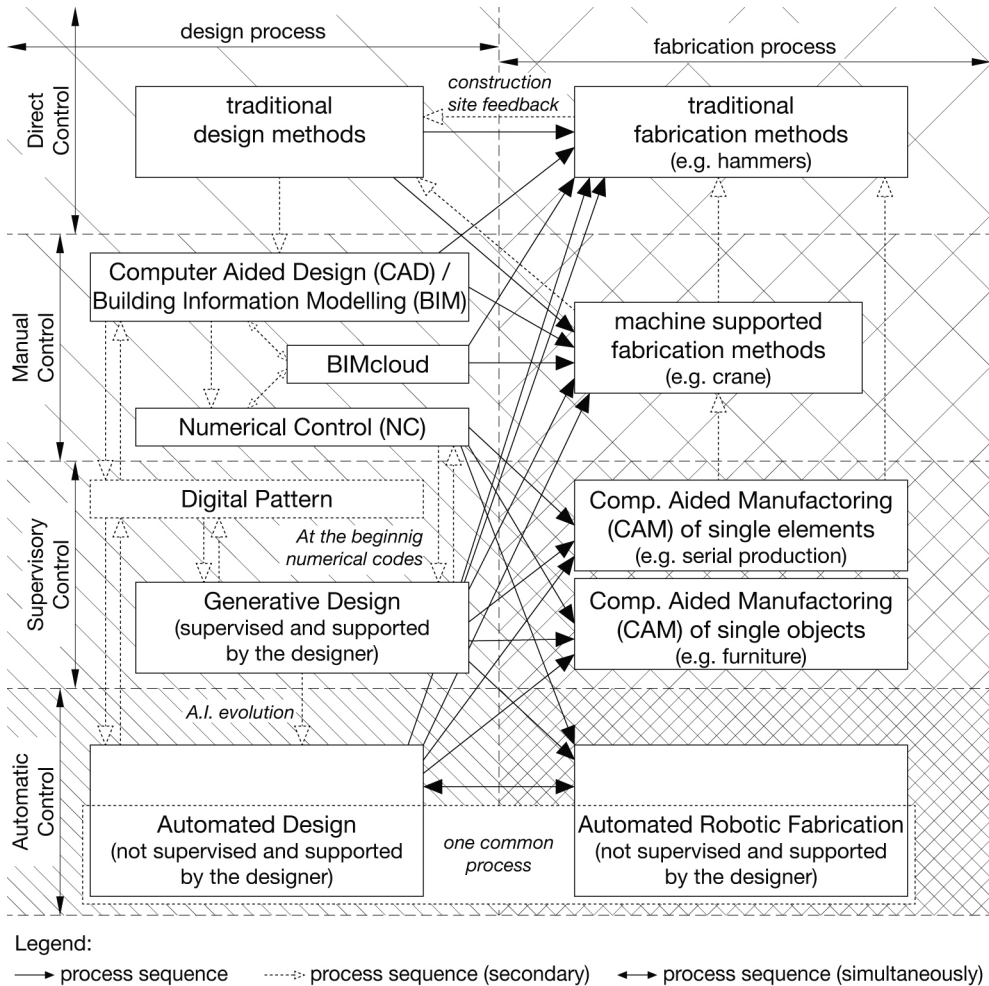
III. 1. Development of the different stages of the digital architectural tools.



III. 2. Design and fabrication methods and the human factor in the architectural process before introducing the computer aided design system in the 1960s.



III. 3. Design and fabrication methods and the human factor in the architectural process at the end of the 20th century and at the beginning of the 21st century (first and second stage).



III. 4. Design and fabrication methods and the human factor in the architectural process after introducing the third stage of the digital architectural tools. The future full automated design and fabrication method are included.

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