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STUDY OF DIGITAL ARCHITECTURE TECHNOLOGY: THEORY AND DEVELOPMENT

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Abstract - In the beginning of the 20th century, computerization has developed rapidly affected in all aspects of human life. Computer is not only simplified everything, but it has become an instrument which turned into something that is never thought before. In architecture, digital technology is not only impacted on the architectural planning and design aspects but also on the manufactured finished product. This is the study of literature along with interpretation of the author discussing about the phenomenon of the digital architecture development related to the theory, philosophical study, its evolution and development, as well as a deeper analysis to a few studies on the digital technology especially in the realm of architecture.

Keywords: architecture, digital architecture

Introduction

Indicators that strengthening the role of technology in the postmodern life society is characterized by the occurrence of the increased frequency of computer usage along with a lot of software application that they are using, change on the society life style that are utilizing electronics device entirely, the individual boost with higher education background to master the skill of computer technology, as well as the number of institutions that operates based on e-commerce and virtual community.

Architect has been affected by digital technology and experiencing the significant development of using digital technology, where this digital technology allows architects to make an innovative complicated architecture design against the desired final form, the structure system usage, the function of the building, the material that is used and the affected environment.

Starting from that, a study in-depth about this digital architecture technology should be done mainly related to the theory, philosophical concept, evolution, research, fabrication, challenge, work and architectural work practice.

2. Research Methodology

This research uses literature study method. The data is completely obtained from the literature reference related to the digital architecture technology with the author interpretation followed by several research examples on the digital architecture technology and its discussion.

3. Results and Discussions

3.1. Digital Architecture Theories

These below are several theories which stated by some experts associated with digital architecture that underlie the development of thinking about technology and computerization in the field of architecture.

The first theory is digital technology theory related to the practice of digital technology in architecture stated by (Koerniawan, 2012). He is said that “Some areas of digital technology performance that can be developed in architecture are: (1) data-based research, (2) modelling and simulation, (3) computer programming, (4) multi-media presentation, (5) knowledge and information management” (Koerniawan, 2012). From the previous statement, it can be concluded that the whole aspect of architecture is able to be sub-ordinated with digital technology, not only the designing and planning stage, but also until the stage of implementation or the product manufacture.

Furthermore, the theory of digital architecture discourse by Deleuze and Guattari in Koerniawan, (2012) revealed that “Digital media only contribute to the innovation of discovery of meaning, generic de-placements and unlimited input-output design.” (Koerniawan, 2012). Koerniawan also stated that “We will see a bias movement from the work of art to art-event, from simulation of the reproduction into the simulation itself, from mimesis to the virtuality direction, from interpretation to the interactivity, from the image to the interface, and from the system to the Rhizome” (Koerniawan, 2012). These theories explain that digital technology can simplifies and provides the aesthetic in architecture though the devices and computerized systems with the pattern formation that is more variative than the contemporary architecture.

Associated with the consequences of the architecture behaviour, Koerniawan, (2012) stated that “The position of computer technology as a paradigm indeed has typical consequences and will prosecute the subject to behave individually, socially, culturally and also institutionally” (Koerniawan, 2012). Moreover, Koerniawan also explained that “in addition to the preparation of the infrastructure that determines its survival and mastery over the hardware and network software, the development of digital architecture must be followed by implanting a special internal technology logic awareness, demand of the personal-intrapersonal user capacity, and formal institution that will shelter it.” (Koerniawan, 2012). This shows that the change from manual procedure towards something that is technological will bring the consequences which architect needs to be addressed and circumvented.

In terms of an increasing working speed, Colin Lankshear and Michele Knobel in Koerniawan (2012) stated that “A new norm trend that follows naturalization of computer usage of the educational and professional practice construction, namely Timeliness. By computer, job is not only could be done faster and more, but also the subject will practice in a longer matter of time, decision making and evaluation could be done faster. In a situation like this, scientific barriers and discourses will actually “delay” the proper performance speed on a computer usage (Lankshear and Knobel in Koerniawan, 2012). It shows that there are some sectors that affected by the speed in completing something, but beside that it allows other sectors turned into something more complex and takes a long time, such as the preparation program stage that requires a long time, compared to the field execution stage.

Mark Poster in Koerniawan (2012) in correlation of the second media age stated that “boundaries between producers, distributors and blurred information consumers and social relation of communications turns into interactive communications” (Poster in Koerniawan, 2012). That series of knowledge in formulating an issue or architecture product topics are obtained from various multidisciplinary inputs and feedback from the previous architecture product.

Regarding performativity, “The Game of Language” became the base for Lankshear and Knobel to propose a term that puts the information packaging as something that is more or equal importance to the matter of content, which is performance epistemology (Lankshear and Knobel in Koerniawan, 2012). This packaging discourse is important for the formation of meaning from the knowledge gained.

3.2. The Philosophical Concept of Digital Architecture

That digital technology works to simplify jobs in the field of architecture, so the final thing that is expected with this system is efficiency. As stated by RIBA architecture that “Digital technologies are making projects more efficient: over three quarters of respondents recognize this.” (Architecture, 2018). Architecture works to utilize the communication and information technology products in architectural designing process and being an extended brain for architecture, part of thinking, evaluation and decision-making system. That the reason of using digital technology in architecture is the architecture’s desire to develop themselves in accordance with the development of the computer

technology, analogue system is considered less flexible than the digital technology, the level of multifunctional digital technology is quite high, the result of digital technology has better accuracy, and the results of digital technology is more precise.

3.3. Evolution of Digital Architecture

The development of digital technology started since the year of 1784, which this is the first revolution in a digital world that is marked by the discovery of the first loom mechanic engine. Mechanization in industrial section started to grow by using the steam power within this year. Later, the second digital revolution started by 1870, marked by the establishment of the slaughterhouse production in Cincinnati. In this era, the industry develops rapidly marked with the number of mass production or fabrication system, the growth of the network assembly system and use of the electric energy. The third digital technology revolutionary started since 1969 which was marked by the discovery of computer programming system based on PLC (Programmable Logic Controller). In this era, automation between computers and electronics has been formed. The fourth digital technology revolutionary started at the beginning of the 21th century marked with the cyber-physical system development, IoT and network. This timeline of digital revolution which illustrates the journey of the digital technology can be seen in the figure below:

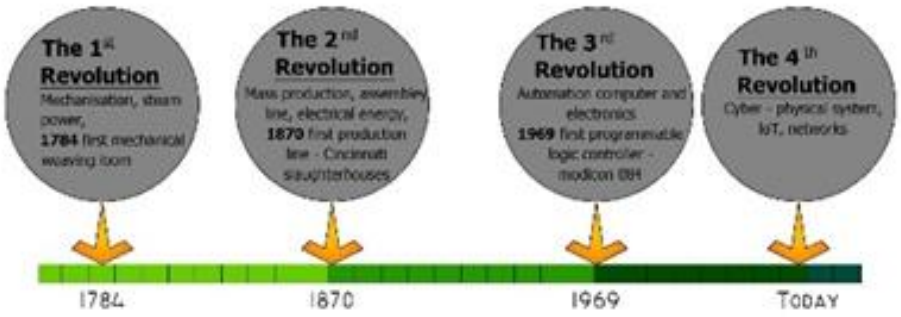

Figure 1. Time Line of Digital Technology Revolution
Source: Compiled from various sources, 2020

Specifically, the development of the software system is divided into 5 periodization. The first one was happened about 1980s, where software is monolithic in which the system is built into a single entity. Furthermore, in 1990s software system experienced new growth namely the phase of distributed monoliths, which multiple computers in one network communicates, coordinates and works together mutually by exchanging messages. Here appears that computers are mutually independent and connected with a computer network namely LAN or WAN, as if turned into an integrated entity. Moreover, around the 2000s, the software system experienced a phase which is called the phase of internet connected, where the integration between computers not only happened through LAN or WAN but its already through the internet. In the 2010s, the software system started to enter the new phase which is called internet is the system phase, where every works can be connected with the compiled system. The last phase is called intelligent connected phase, where even though software made by another source for cross-disciplinary needs, it still can be directly connected and used for one need.

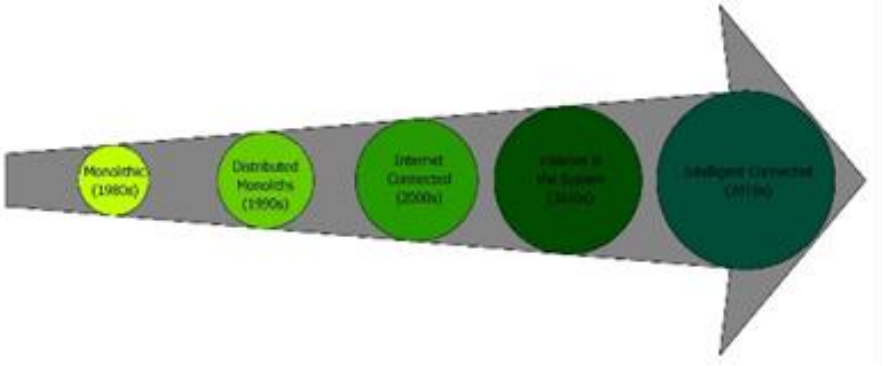

Figure 2. Software System Development
Source: Compiled from various sources, 2020

3.4. Research in Architecture

Satwiko defines “digital architecture as the short term to describe the use of communication and information technology in the process of planning and designing complete architecture.” (Satwiko in Darmawan & Purwanto, 2009)

RIBA architecture defines “Digital transformation is not just the adoption of a set of technologies. Rather, it is a fundamental shift in culture, supported and facilitated by technology” (Architecture, 2018).

The field of digital architecture is quite extensive, not only concerning the planning and designing the design stage, but including at the product manufacture stage until the research stage related the architecture itself. Generally, it includes communication, data research, earlier sketch producing, counting (data processing and simulation), design development, presentation (2D, 3D, animated), working drawing creation, design work archive, virtual world creation and many more. Below is the illustration of the digital technology scope that can be collaborated with architecture problems.

Table 1. Technology Scope of Digital Architecture

DIGITALIZED ITEMS	SUB ITEM	
Research Topic	Digital architecture education	
	Software design	
	Utilization of software	
Software	Building science	Acoustic
		Lighting
		Ventilation
	Graphic	
	Animation	
	VR	
	City environment	
Hardware	Building science	Acoustic
		Lighting
		Ventilation
	Graphic	
	VR	

Source: Compiled from various sources, 2020

3.5. Digital Fabrication in Architecture

The digital fabrication definition as quoted by Putro and Wirasmoyo is “a process that starts with digital design and ends with the output of the fabrication machine. Digital fabrication is the education and activities paradigm applying the multidisciplinary knowledge to combine the 2D design, 3D design, the use of tools and machine.” (Putro et al., 2019). Formlabs in Putro, explains the stages of digital fabrication works which are digital design phase that created virtual model using a software, then the fabrication preparation phase by controlling manufacture parameters and then for the fabrication process, it creates certain file formats to machinery and fabrication process, where fabrication tools produced components based on data (Formlabs in Putro et al., 2019).

In the building sector, industrialized building is a building system such as walls, plates, beams, columns and stairs are produced in bulk by fabrication under the strict quality control. Type of building system engineering includes civil/construction works, electrical works, energy works, mechanical works, plumbing works, structural and technology works.

Fabrication classification in digital architecture includes sectioning, tessellating, folding, contouring and forming. Sectioning is the surface building arrangement from horizontal and vertical profile cut out. Tessellating is the merge of building component pieces into one surface, it usually uses generative components software and CATIA. Folding covers the folds designing in the form of 2 dimensions and 3 dimensions. Contouring is the sculpting process to form the surface texture. Forming is a system of making a mold to create certain formation desired.

The condition of digital fabrication nowadays is not entirely perfect, there are still some constraints in order based on its own level which are partial building process, partial building computing, semi-fabrication connecting computing and digitalizing network-embedded. Partial building process that is referred to is not entire sector of work that use technology so it is not being integrated

into one and standing independently. Partial building computing that is referred to is that all the sector of work is using technology but it is not integrated yet within each sector and still not connected yet. Semi-fabrication connected computing that is referred to means that all sector of work already integrated with technology but the implementation stage is still using manual system. Network-digitalizing embedded that is referred to means that the formation of system technology in the whole sector of work from the designing stage until the implementation stage.

3.6. Challenges in Developing Digital Architecture Research

RIBA Architecture explains the development of digital architecture as follows *"Transformation isn't easy: it takes significant effort and investment to become, and remain, digital-first. In architectural practice, margins are often tight, workloads heavy and the need to continually develop new business ever-present. Staying afloat today while investing in the future is a balancing act."* (Architecture, 2018).

In the field of architecture in Indonesia, there is a common obstacle in technology digitalization which is, no basic enough knowledge that architect have such as advanced mathematic, aerodynamics, heat transfer, fluid, etc. Moreover, digitalization of architecture in Indonesia does not financially guarantee a profit and there is an incompatibility between the software mechanism made by foreigner and condition in Indonesia that is troublesome from using it.

In the architecture branch, the thing that have the best probability in prototype processing of architectural work is by product simulation using technology. It needs to be done with this simulation system is because there are some triggering factors which are the expensive physical simulation and the need for a wide area for doing a physical simulation. Other than that, computer is a multifunction and cross-study tool so that we can simulate various things in one product.

Digital simulation is more superior than the physical simulation because its lower cost, saving more time, the needs for smaller room, lower cost of workers, easier and faster model modification, not depend on a scale, and the availability of cheap illegal software and its generation.

There are three main challenge to a new software formation for digital technology in the world of architecture nowadays. Software that designed for architectural work has already exist in many kinds, it needs to be upgraded so that a software plagiarism did not exist. Other than that, it needs a novelty to new software so that it can be accepted in the market with user-friendly features. The last challenge is that the needs of software that connected and integrated with another existed software.

3.7. Technological Works in Architecture

Currently, there are many existing and widely used drawing tools that support architectural works such as AutoCAD, ArchiCAD, REVIT, SketchUp, Blender, FreeCAD, LibreCAD, OpenSCAD, My Virtual Home, SmartDraw, Sweet Home 3D, BRL-CAD, Sculptris, Meshmixer, etc.

While software product to support for rendering in architecture field that is familiar nowadays are 3DMax, Blender, Maxwell, Octane Render, Autodesk Revit, Cinema 4D, Lumion 3D, Viz Render, Punch Home Design Studio, Vray, Corona and there are many more.

Application software that can be used for the physical building needs are Therm & Window, Psi-Therm, WUFI, Physibel, HT Flux, WINISO, GLASGLOBAL, WINSLT, Dämmwerk, Comsol, Archipak, AGI 32, CalcuLuX, DIALux, Radiance, Microlux, LightCalc, Visual 3D, etc.

Whereas application software that can be used which associated to research methodology with a quantitative research paradigm are SPSS, MATLAB, Tableau, AMOS, SEM, LISREL, Meshmixer. While the application software that can be used for the qualitative research paradigm are Nvivo, Dovetail, Expertchoice, Quip, Confluence, Jira, Typeform, CDC, EZ.

Regarding urban design, application software that can be used are City Engine, Lumion, ArcGIS Urban, Bentley OpenCities, CityCad, Modelur, Simwalk, Urban Canvas, Modeler, Urban Foot Print, Urban ROI Designer and UrbanSim.

Digital architecture already become a necessity in this era, in accordance to the digital development, thus, related to discourse of digital mapping and architecture, Ekomadyo stated that "Mapping had been tested (slightly structuralist) pulling two poles (which derived from two phenomenon earlier), namely "from Digital to Architecture" means how digital technology affects the field of architecture, and "from Architecture to Digital", means how an architect way of thinking can also be affects the digital technology." (Ekomadyo, 2001). "The scope includes 1. Design Approach and Method 2. Design Management 3. Modelling and Simulation 4. Digital Communication 5. IT Design" (Ekomadyo, 2001).

Related to it, software which are specifically helps architect works has developed rapidly, both for the design purpose and research purpose, and it will continue to develop. There are principles of software that are good from some aspects which are efficiency, dependency, treatment and operation.

Efficiency associated with the source of electric power usage for the computer, memory, CPU, cycle period, and storage system of the products. Software dependency is related to reliability, security both from virus invasion and legality and also safety that related with the existence of online/offline or help features mechanism. Treatment includes periodical update level and maintenance automation. While the operation must be easily recognizable to users with a familiar performance even if it used by an ordinary people and availability of a user guide to simplify its user.

3.8. Application of Digital Architecture Case

Below are several journals related to digital architecture as an example of the research development in architecture field that has been grown rapidly. This will be discussed three journals about digital architecture that discuss the digital architecture evolution topic, digital architecture fabrication and the work result in digital architecture.

The first journal related to digital architecture evolution topic that will be discussed titled “Plectic Architecture: Towards a Theory of the Post-Digital in Architecture” (Spiller, 2009) written by Neil Spiller and published by Technoetic Arts, A Journal of Speculative Research Volume 7 Number 2, 2009. There are three main points that discussed in this journal which are the definition of plectic architecture, history and the development of architecture design until plectic architecture and its products example.

An important figure who defines plectic architecture in a clear way is Gell-Mann in Spiller, as quoted in the journal, which is:

“… The study of simplicity and complexity. It includes the various attempts to define complexity; the study of roles of simplicity and complexity and of classical and quantum information in the history of the universe, the physics of information.” (Spiller, 2009). Still quoted from Spiller that mentioned the definition of plectic as follows " the study of non-linear dynamics, Including chaos theory, strange attractors, and self-similarity in complex non-adaptive systems in the physical sciences and the study of complex adaptive systems, Including prebiotic chemical evolution, biological evolution, the behaviour of individual organisms, the functioning of ecosystems, the operation of mammalian immune systems, learning and thinking, the evolution of human languages, the rise and fall of human cultures, the behaviour of markets, and the operation of computers that are designed or programmed to evolve strategies - say, for playing chess, or solving problems ” (Gell-Mann in Spiller, 2009)

From the explanation above, it is clear that plectic architecture is a study which emphasize the role of simplicity and complexity, classic information and quantum in the history of the universe, the physics of information. It is also explained that plectic architecture is a study about non-linear dynamics, including the chaos theory, and the similarity of non-adaptive complex system in the science of physics. The point is that an architect should involves multidisciplinary science by prioritizing the simplest thing in designing a building, but done in detail with complex complexity (Spiller, 2009).

From its history, Spiller explains that post digital architecture starts in the middle of 1980 where Spiller illustrate architecture product at the beginning of 20th century in three substantial line (Spiller, 2009), which are:

- The impersonal way in documenting and describing science refutes the pre-applied self (Spiller, 2009).
- Design is the second order of cybernetic system and Gordon Pask is the first person who emphasize the cybernetics relevance with architecture design. Pask also introduced the idea that architect might start using computers as a substitute architectural assistant (Spiller, 2009).
- Post-digital design is relativistic, global, scalar and built from a genius locus that not only includes anthropomorphic site conditions but also includes deep ecological, mnemonic, psychogeography, and narrative pathways (Spiller, 2009).

While spiller illustrate architecture product at the beginning of 21th century in concept as follows: space, technology, narrative, cyborgian geography, the scopic regime, sensitivity and time (Spiller, 2009).

Recently, Spiller gave some Plectic Architecture product example, which are about rebooting natural ecologies, utilize the imperative growth, mnemonics and interference in the machine, nanotechnology creation, anamorphism and hypertext, common and usual biotechnology, and literature space (Spiller, 2009).

The conclusion that can be obtained from this journals is that we have entered the era of plectic architecture that requires architects to not only be oriented to the architecture science discipline but they also have to consider about many aspects of other science disciplines such as physics, applied mathematics, ecological etc. that architecture design is not just about form and space but also how about the simple themes in everyday life from non-architecture point of view that can be lifted as

something more, so it could be beneficial globally, not only in the field of architecture science discipline.

The second journal that is going to be review is related to digital architecture fabrication topic titled “Aplikasi Fabrikasi Digital Arsitektur Studi Desain Parametrik Diagram Voronoi” (Putro et al., 2019) written by Hendro Trieddiantoro Putro and Wiliarto Wirasmoyo, published by NALARs Journal of Architecture Volume 19 Number 1 in 2020.

There are two important things that became the main subject discussion in this journal which are about the definition of fabrication, the understanding parametric, laser cutting meaning and Voronoi definition, and also phases of fabrication with parametric design of Voronoi diagrams for architectural products (Putro et al., 2019).

Regarding the beginning of the general fabrication technology, Hutama in Putro explains that “The history of fabrication technology begins with the bulk production that are introduced and developed by Henry Ford, founder of Ford Motor Company in the early of 19th century (Hutama in Putro et al., 2019). This method works by producing a replicated model. Therefore, the correlation between quantity, time, and accurate predictive quality, and the lower cost of operation (Putro et al., 2019).

While in the definition of digital architecture technology itself by Blikstein in Putro is “Technology of digital fabrication becomes better and easier to access, and the possibility of intellectuals activity made by new technology became more respected and important. Industry of designer can make the prototype in days, not months” (Putro et al., 2019).

Jabi in Putro explains the definition of parametric by explaining that “Parametric design is a designing process based on algorithm ideas that shows the details parameters, where parameters strengthen and clarity the relationship between the design purpose and how design will respond to the problem.” (Putro et al., 2019).

Related to the understanding about laser cutter, Putro explains that “Laser cutter is a machine that uses laser to cut materials such as chip board, matte board, felt, wood and acrylics up to 3/8 inch (1 cm) of thickness. Laser cutter are often bundled with a software that interprets the image vectors which generated by a number of CAD platforms. Laser cutter is able to modulate the speed of the laser head, along with intensity and laser beam resolution, thus it can cut and print the material, as well as approximating raster graphics. Objects cut from materials can be used in a physical model creation which only requires the parts assembly (Putro et al., 2019).

To understand about Voronoi diagram, Putro stated that “In mathematics, the Voronoi diagram is the division of an area into several parts based on the centre point. Each point becomes correlation that merge an area, this area called Voronoi cells (Putro et al., 2019).

Moreover, in his journal, Putro explained that the fabrication stage of parametric design divided into three stages which are digital design stage, preparation and fabrication process stage, and assembly line stage. In the digital design stage, the process begins with making a box in a desired place with Rhino Grasshopper software with a certain specified size. After that, raises the points in the box so that the required number of points will appears. If points and box are raised, then it will be adjusted with the number and 3 dimensions position expected. At the preparation and fabrication process stage, it will change the surface orientation, from the 3 dimensions image to the X and Y area, and will be executed by machine. Furthermore, at the assembly line stage, the output of the laser cutter machine with the same code is partially assembled into one to be assembled again as a whole into an object according to the initial design (Putro et al., 2019).

From this journal, it can be concluded that fabrication technology in general can be done from the designing stage until the product formation, with a shorter period time of processing, but in the designing process, it requires an accuracy and relatively longer and precise time as well as the necessity of the ability to master the software.

The third journal is related to digital architecture work topic that will be discussed which titled “Arsitektur DVD (Digital Virtual Design)” (Mintorogo, 2000) written by Danny Santoro Mintorogo, published in Journal of Architectural Engineering Dimensions vol. 28 issued on July 2000.

In this journal, Mintorogo explains two things which about understanding of the CAD Architecture, DVD Architecture and factors associated with it. According to Mintorogo, “First CAD Architecture developed from two dimensional graphic and expected to assist designers in improving their architecture working drawing quality as well as shorten the completion their architecture working drawing both by its guidelines and field work.” (Mintorogo, 2000). The three basic CAD categories were originally created by including mechanical engineering, electrical engineering and architectural. Mintorogo explains the details that “The CAD Architecture capabilities in general is 2D drafting for working drawing or details, 3D modelling for mass/geometry/shapes studies, rendering for presentation/lighting studies/architecture material, animation for sequential study of space on a human

walking/hovering scale and virtual for the study of the perfection of a work or room or architectural mass." (Mintorogo, 2000).

Additionally for the DVD architecture, Mintorogo explains that "Digital Architecture Virtual Design is still a part of Architectural CAD System, which depends on the sophistication and capabilities of a CAD program in order to create/design a 3D architectural models in a digital virtual, both exterior (massing) or interior (space/light quality) which can be said as The Virtual Space or The Virtual Building." (Mintorogo, 2000). Mintorogo also explains that architecture DVD is related to virtual reality factor, movement/animation, Information Technology and environment. Regarding virtual reality, Mintorogo explains "DVD presenting simulated space/building in imitation reality, real design but imitation/virtual digital" (Mintogoro, 2000). Regarding with movement/animation, Mintogoro explains that "The movement control related with appropriate free interactive communication between computer tools and designers to create sequential motion effects." (Mintorogo, 2000). While regarding with information technology, Mintogoro explains that "With DVD architecture (always displays the form of "shading perspective digital" in three dimensions), various communication information technology will be obtained continuously and interactively; which are: sense of material, sense of scale and sense of geometry of the space." (Mintorogo, 2000). While associated with environment, Mintorogo explains that "Factors of environment that affects a room is light (daylighting, ambient light, artificial light), colour (walls, ceiling and furniture), texture (rough surface, smooth, lustrous), material (granite, marble, wood, glass, mirrors, water, etc.), humans (giving a sense of scale) and background (strengthening the sense of outdoor or indoor)." (Mintorogo, 2000).

From these journals, it is obvious that one of the digital architecture work result which is familiar up until now that used by architects is CAD software. This software has undergone many improvements and has triggered the growth of other complementary software in its development.

4. Conclusion

From the explanation above, it can be seen that the development of digital architecture technology has developed extremely rapid, so it requires architect to innovate not only related to architectural planning and design but also related to new software inventions that can support architect performance.

That the digital architecture technology aiming for growing the architect work efficiency, both at the planning stage and product manufacture stage, the synergy of multidisciplinary science is required especially in the creation of a new technology.

That the study of digital architecture technology continues to evolve, so that formed an opinion about how the future of architect associated with technology, which later will change the system and the architect's operational way gradually. Thus, this attitude should be observed and needs to be conceptualized of how the future of architecture and architect with technology will be.

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