AItect : Can AI make designs ? Architectural Intelligence/Artificial Intelligence

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Has there ever been a Science in Architecture?
The concept of Architectural Intelligence

The purpose of architecture (design) is to create. To make things better. The purpose of science is to know. The aim of science is to know, more widely and more deeply, how all things work. The area between knowing and making is called engineering. Design tells us what to make, engineering tells us how to make it, and science guarantees the basis for judging how to make it. Since architecture is the work of creating physical entities, it is inevitable that it involves engineering. Stone is strong enough to be stacked vertically, but it is prone to splitting when it is passed horizontally to form a beam. Wood, on the other hand, cannot be stacked like stone, but it can be laid horizontally to form a long span beam. Such knowledge and ingenuity are the engineering that has been used since humans first came out of the caves and started building their homes. Engineering is different from science. Engineering uses science as a basis for its decisions, but it does not necessarily require a logical explanation of why its criteria are appropriate. If you were to ask an ancient carpenter why he judged that a timber of this cross-section was appropriate for a span of this size, all you would get would be, "That's just the way it is". And the architecture made with that answer will live up to expectations. For engineering, if it fulfils the required function, that is enough. Intuition and experience are also engineering. Of course, it would be even better if the logic behind the empirical values could be discovered using scientific methods, but this is not a necessary condition for engineering to work.

However, this distinction also becomes ambiguous if we continue to ask why and how. The engineering reference value for how much load steel can withstand is not a theoretical one, but an experimental one. It is not clear why this value is used. The acceleration values in the seismic standards are arbitrary and can change according to country and time. So, if we say that science derives everything from theory, then even in that science, the fact that water boils at 100 °C is not a theoretical value, but a measured one. In the realm of the so-called social sciences, theories are obtained from the statistical treatment of observations. On the other hand, the definitions by humans, such as 1X1=1, the chains of symbolic logic derived from these definitions, and mathematics, are not based on experiments or observations. Some areas of science have logical foundations that cannot be broken down further. In some domains, science and engineering are clearly distinct, while in others they are difficult to distinguish. The relationship between why and how is something that comes and goes. Structural mechanics and environmental engineer ing run side by side in today's architectural design. In structural de

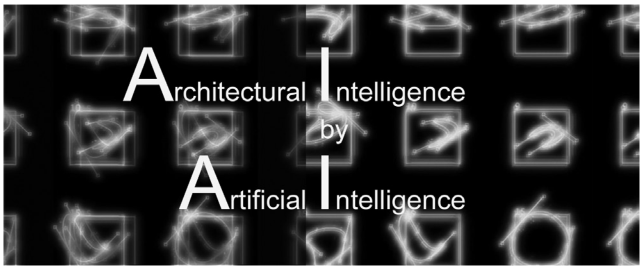

Figure 1. AI by AI

-sign, the required conditions and physical data lead to a logical solution. The same applies to heat loads, airflow models, etc. Patterns of elevator use and evacuation simulations provide rational planning. Such engineering design assistance can be reproduced and verified as long as the same programs and settings are used. However, in the narrower sense of the design field, not including structural design, equipment design, etc., such engineering assistance is less common, although the use of programs is increasing. As ever, the old methods of design are still the norm. There have been research areas in architectural planning for a long time, but most of them are (or seem to be) concerned with guidelines for the quantity and layout of necessary facilities and functions. In the end, architects (including me) still make and destroy a lot of sketches, models and computer graphics, trying to find the ideal solution that must exist somewhere. Eventually, deadlines loom, and around this point, it is time to give up and make a design decision. Hopefully, before then, the solution will appear in front of him/her. It is a blissful moment of descent. In anticipation of this almost miraculous encounter, the architect continues to try and hesitate until the very last minute. Along the way he uses various simulations, calculations and sometimes genetic algorithms, but in the final moment neither science nor engineering can intervene. There is no logic in the coming of the light. It is the same as the absence of the question of why in faith. What there is the inspiration of a talent that calls it forth.

Apart from "inspiration", which cannot be measured or predicted, the engineering/scientific activities related to architecture (which can be calculated), such as structural mechanics, environmental engineering, architectural planning research and various simulations, have been separated into each field and have not been treated in a comprehensive manner. These methods, especially the recent ones using computer programs, have a higher affinity with the IT field than with the traditional " studies " of architecture. In biology, for example, the mainstream method of classifying and systematizing fossil evidence has been replaced by the phylogenetic analysis of DNA, which has led to the discovery of different evolutionary lineages using the same fossil material. In contrast to the established theory of evolutionary phylogeny, by reconnecting the same material with the DNA perspective and method, a different sequence emerged and a new evolutionary path was proposed. The main difference between this hypothesis and the old one is that it can be experimented with and verified.

Rather than competing over whether method A or B is better, a concept and attitude that can deal with different methods and different paradigms from a bird's eye view would be required. Thus, the "totality" of the "multifaceted intellectual endeavors to improve architecture using science as a reference base" is called Architectural Intelligence - AI (AQS International Symposium 2015). "Architectural Intelligence" is a way of looking at all of the methods and research involved in architectural design in terms of "intelligent actions that use logic, algorithms and programs as effective tools". The hope is that by changing the way we look at things, a new system will emerge from the same set of materials. In modern times, science, engineering and design have become increasingly specialized and fragmented. (Incidentally, the world's first engineering faculty in a university was established in Japan in 1877. In the pre-modern Renaissance, they were not as fragmented as they are today. Leonardo da Vinci, the all-round genius, was an artist/architect, a military and civil engineer, a researcher of optics, fluid mechanics and anatomy. The world of design/engineering/science, which has diverged like an evolutionary phylogenetic tree, may be gaining a different form of integration with the new tools of technology. The following are some examples of what I have done so far in this area of Architectural Intelligence, and where I see it going in the future.

Figure 2.“Architecture comes closer to a soft/flex science”/(Kentiku wa yawarakai kagaku ni tikazuku) published 2002

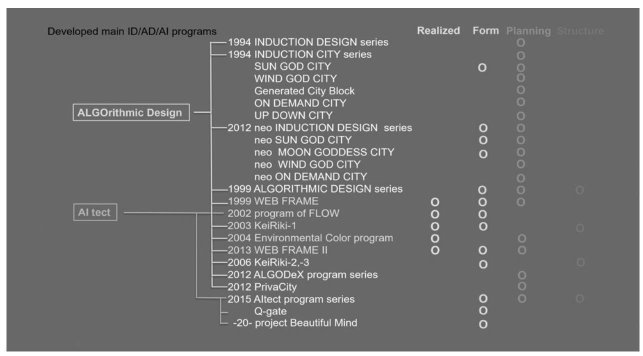

Figure 3. List of major programs researched/developed to date. Sections marked "Realized" in blue = used to design and complete the actual architecture.

ID 1994 – Instead of design, generation

Can architecture and cities be generated according to required conditions instead of designed with traditional methods? In 1994, struck by that concept, I created the first programs to enable it – the series of programs called INDUCTION DESIGN (ID). Here, “conditions” means the various elements of the plans that make good cities and architecture possible. To begin, I selected sufficient light, pleasant breezes, and efficiency, together with streets that are a pleasure to walk on, an appropriately rising and falling topography, and various functions laid out in optimum relationships. Then I began working on computer programs to generate cities that would better fulfill these conditions. Rather than specifying forms and layouts through direct operations, these programs obtained their results by operating on the conditions. This resembles the electromagnetic induction of physics, so I called the series Induction Design. A key point is the diference between ID and using the computer to create forms and plans. The aim of ID is to obtain the plan, environment, and structure required of architecture by obtaining a configuration, layout, and form that solve the project's various conditions. Rather than human

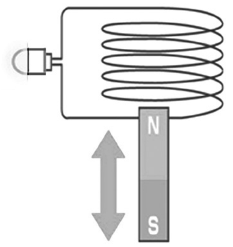

Figure 4. Electro Magnetic Induction

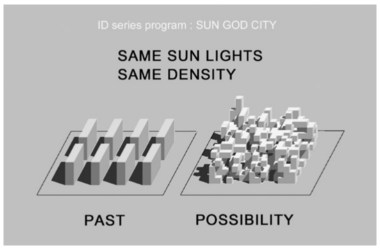

Figure 5. Sun God City < INDUCTION DESIGN (ID) 1994

creations, these are solutions that best meet the conditions. They are "better" solutions. Therefore, although creating variations by adjusting parameters is important, the variations are not the objective. ID seeks correct solutions, not a large number of candidates. In 2001, WEB FRAME (Subway Station IIDABASHI on the Oedo line) became the first work of architecture in the world to be generated with this method–

Figure 6. AI by AI WEB FRAME (Subway Station IIDABASHI) 2000

solving required conditions by program–and actually built. This was followed by the KeiRiki series, which took structural mechanical conditions and, while maintaining the architect's intended form, generated the light est structure. In 2004, the KeiRiki-1 program was used to complete the Shin Minamata MON project 2005. Nowadays, similar functions of the KeiRiki series, called generative design, etc., are becoming standard equipment in commercial CAD software. The KeiRiki series is a much earlier pioneer of such "structural aptimization" software. (The term "optimal" is inappropriate here as there is more than one solution. The answer obtained is a solution that fits the specific parameters of the task to a "high degree", and it may not be the only "best" solution to the task) These series of attempts, including other instances, are called "ALGOrithmic Design (AD)"

Figure 7. Shin Minamata MON by KeiRiki-2 2005

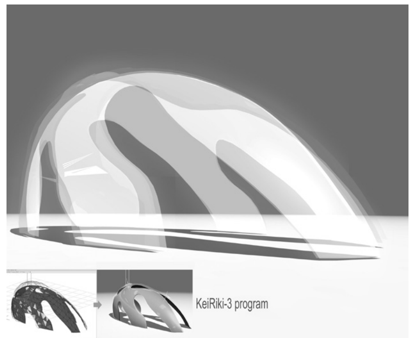

Figure 8. KeiRiki-3 for Shell structure

AD 2001 – Externalize what occurs in the architect's mind

Both ID and AD take judgments that are made in the architect's mind, externalize them, and write them down. Architects are normally not conscious of the mental processes they use to arrive at judgments and selections. After conducting various studies, they make these decisions intuitively. However, there are some challenges that the head, or human brain, cannot solve. When there are interrelationships between elements, it is difficult to picture in our minds the best relationship between them.

ID and AD are attempts to write down the judgment and selection processes as algorithms. If these processes can be written as algorithms, they can be translated into computer programs. And if programs can be written, they can be used to generate architecture. Therefore, the core of this method is externalization of algorithms.

To externalize algorithms, standards of judgment need to be set. It is necessary to define what is good and what is bad. It is essential to decide what makes a good street, what makes a good disposition of functions, what makes a goodXXX. It is not hard to define "good" for physical phenom ena like temperature or the amount of sunlight or wind. It is also possible to determine good and bad for function dispositions and volumes. But conditions related to humanfeelings and preferences are difficult to define in this way. Good and bad can be defined when an underlying framework is accepted. But preferences cannot be defined. Everyone is different from others, and different from themselves from day to day. Even if expressions were read and brain waves me sured with a Brain-Machine Interface, tomorrow might bring a dif-

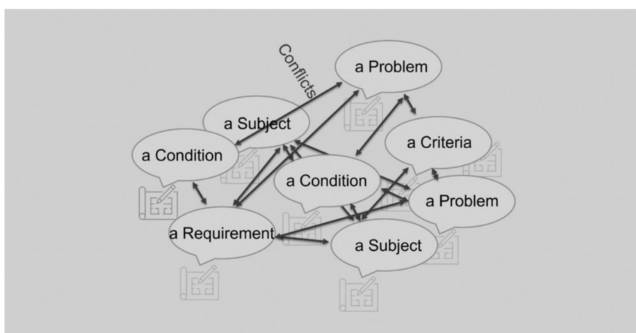

Figure 9. Multiple, interacting requirements - cannot be solved by the human brain

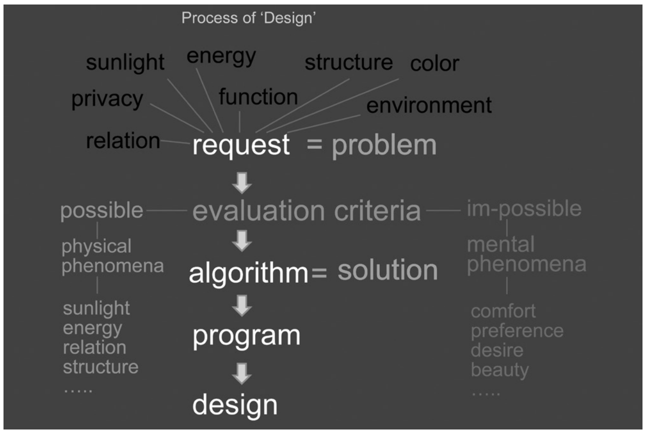

Figure 10. Process of making design

ferent result. Standard values cannot be defined in the realm of preferences. Algorithms cannot be obtained without defined values, and programs cannot be written without algorithms AD becomes impossible. So what should be done?

AIdesign 2001 – Algorithms of preferences

This challenge was taken up in 2001 by the Program of Flow. This was developed to allow forms thought to be good by the architect to be obtained without writing down algorithms. Architect aims are achieved through a dialogue with the program. The architect makes multiple sketches, scores them, and passes them to the program. The program reads the drawings and produces what it thinks is a good form. This is scored by the architect and returned to the program. The idea is that the architect's desired form will be display after a certain number of repetitions of this process. It might be said, correctly, that this could be done by hand. Every architect worthy of the name can draw good forms by hand. It might also be said that the form of architecture is decided by making overall judgments of various requirements, and not by drawing good lines. That is also true. Before deciding on a form, studies are needed of functions, the environment, structure, and history. But while conceding all of that, "good form" was still selected as a theme, because I think that this is the realm least suited to computer programs. If it is the most difficult, then there is value in taking up the challenge. Let's try it. Another reason for isolating the work of drawing forms from the integrated work of design is that this would allow other conditions to be incorporated. This is because values can be defined for many other conditions. If a value can be decided, then an algorithm to achieve it can be created, meaning that it can be programmed. The idea is that if it were possible to develop algorithms for this impossible theme – good forms – then it should be possible to develop them for other conditions.

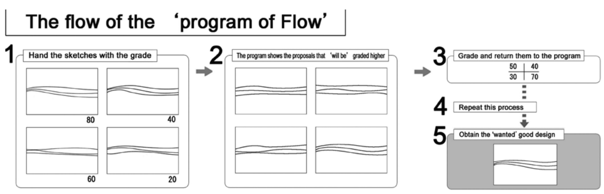

Figure 11. Program of FLOW - Application procedure

Here, "good forms" has a number of different meanings. To one architect, it may mean simply beautiful forms. Another architect may require that designs be astonishing, or even disturbing. In the same way that bad scents need to be mixed into certain good scents. "Good" means different things to different architects. There is no such thing as an absolutely good form. There are as many good forms as there are architects and users. What kind of method could generate such individually different "good forms" without algorithms? The 2001 Program of Flow was an attempt to realize such a method. Combining a neural network with genetic algorithms, it could be called AI.

In 2004, this program was used to complete the Tsukuba Express Kashiwanoha Campus Station, which is configured from 3D curved-surface unit panels. It can be called the first work of architecture in the world to have used AI to generate architecture by solving required conditions.

AItect 2015 – 2021-Will a super architect emerge? / pBM – project Beautiful Mind

The Tsukuba Express Kashiwanoha-Campus Station was completed as the world's first AI-generated architecture. But the performance of the Program of Flow that was developed for this project did not reach the expected level. In the actual design, the program's results were finally adjusted manually. In the end, the AI program was no match for human hands. Then,

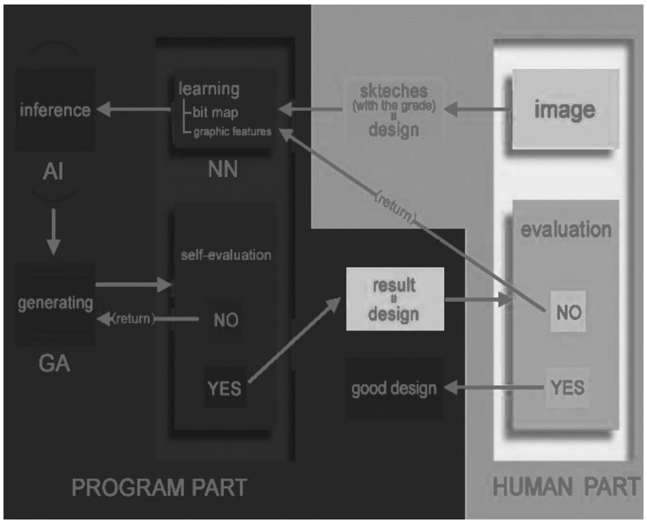

Figure 12. Multiple, interacting requirements - cannot be solved by the human brain

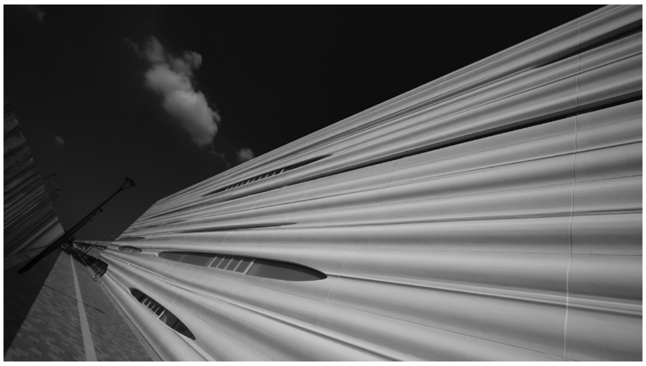

Figure 13. Kashiwanoha Campus Station 2004

in 2015, a new project was begun to inherit this concept – pBM: project Beautiful Mind.pBM aims at the emergence of the architect through AI, or in other words AI architect → AI-tect. pBM can also be called a project of collaboration between intuition and AI. This series of conceptual perspectives – ID, AD, AItect – is an intellectual experiment in the realm of architecture. It could be called AI, for Architectural Intelligence. The word AItect encompasses two meanings: Architectural Intelligence and Artificial Intelligence.

Objectives and targets

The pBM is an ongoing project as of 2020.

The pBM as of this section provides effective solutions to some extent, but it is not yet sufficiently satisfactory. We are working on trials and improvements (and in some cases innovations) in the following areas: development of the original AI, improvement of the UI, and a system for linking with CG software.

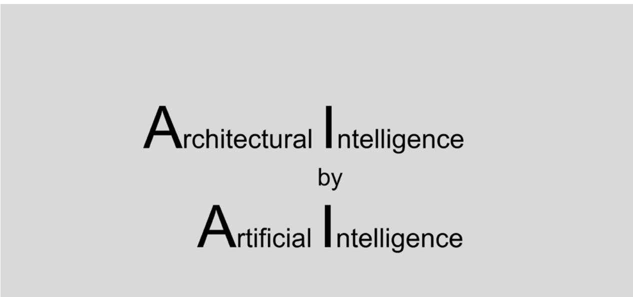

Figure 14. Double meaning

The goal of pBM is for the program to present the form (potentially) desired by the designer (i.e., beautiful form) in three-dimensional geometry. Of course, there are many other conditions in architectural design besides the form. The objective at this stage is to prove that the desired answer can be obtained when only the condition of form is selected from among the various conditions. The reason why only one condition is selected among the various conditions is because the program cannot satisfy multiple conditions if it cannot meet even a single requirement. If the program can solve the single condition called "morphology", then it can be expanded to deal with many different conditions. “To achieve many things, start from one thing”

Features pBM_AI has the following features:

- Does not require teacher data.
- Proceeding in an interactive way with humans.
- Gradually (to some extent) grow.

Many AIs require a huge amount of teacher data.

However, when trying to do a specific design, it is not practical to prepare a large number of teacher data in advance. Even if the images and data of all the works of that designer are read and used as teacher data, the amount of teacher data will not be sufficient. Besides, it is impossible to create new designs if they are pulled by past trends. An AI that does not use teacher data is required. In moreover, since the user does not know himself/herself what he/she is seeking, the process of operation must be a dialogue between the user and the AI. Therefore, the operation process has to be interactive. And because we start without any teacher data, it is essential to have a system that enables the AI to gradually learn and increase its effectiveness.

There is another feature:

No evaluation criteria are defined

This is a big difference from the ALGOrithmic Design. In ALGOrithmic Design, the evaluation criteria need to be determined in advance. Otherwise, the algorithm cannot be composed. We need to determine what is good and where the boundaries are. Even for an AI to distinguish between, say, a human face and a stain on a wall, it would need a consistent criterion that could distinguish between the two. It may be a criterion that humans can understand, such as the ratio of eyes/nose/mouth, or may be a criterion that the AI has learned on its own and is not recognizable to humans. But with pBM, we do not decide if it's good or bad. It is the users themselves who decide/choose it. The user determines the value each time. In the process of interacting with the user, the AI "learns" what is good or bad. ("Learning" in this context is a figurative term) It is you, on every trial, who decides whether it is good or bad. The criteria for judging is different for each person, and the same person often changes his/her mind. The beauty for you may change from yesterday to today. Even under such circumstances, pBM should be able to provide answers. And trying to do exactly that is what makes the development of pBM not an easy thing to do.

Difficulties in AD/AItect Monkey jump effect

If the design conditions can be written down, the process of solving the problem can be made into an algorithm, so " ALGOrithmic Design" is possible. If the conditions cannot be written down, algorithms are not available, so "ALGOrithmic Design" is not possible. This is where AItect comes in, as it uses AI that is (poten-

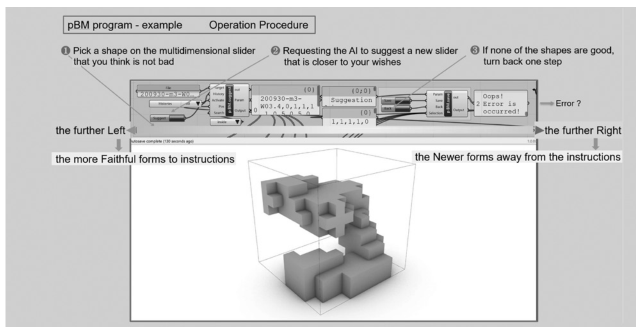

Figure 15. Current pBM - Execution process

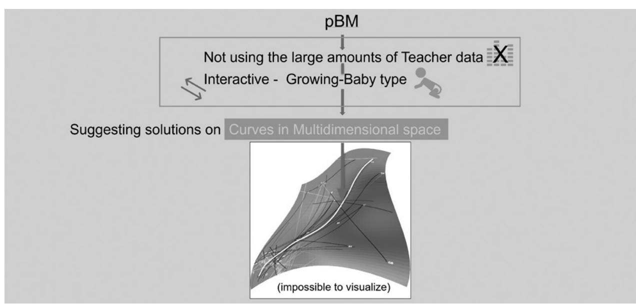

Figure 16. The AI presents a different slider (=a multidimensional curve in a multidimensional space) each time.

tially) capable of solving problems without writing them down. Even that AItect also has its difficulties. To solve a task that cannot be written down, it still needs to be evaluated. Even if the evaluation criteria cannot be written down, the evaluation itself can be done. Although we cannot explain what "like" means, we can tell whether we like it or not. Using this mechanism, the AI can operate. However, there must be a consistency in liking/disliking. If every time it continues to dislike something previously liked, AI will not know what to make a decision on. That AI becomes dysfunctional (...possibly like that HAL). And this is what often happens. The human mind is fickle. Love is transposable. This is an obstacle for AI.

It is OK if inning/losing or the degree of conformity is consistent, such as achieving victory in a game or reproducing the touch of a Van Gogh painting. But when the subject is dependent on human emotions and moods, such as likes and dislikes, there is a great deal of fluctuation in evaluation. And design is just that area. Even if you reach the end of the branch, the top of the decision tree, the branch from which you are advancing through a series of yes/no bifurcations, your "favorite" can suddenly jump in a flash to the next non-contiguous branch. A leap that jumps over the path of logic, a leap that cannot be followed by logic. Action without context. I call this" Monkey jump effect".

The Monkey jump effect buries the accumulated efforts of decisions at each juncture in an instant. It turns the decision tree into a useless dead tree. Monkey jump effect is the first of the many difficulties of design AI. AItect's difficulties do not stop there. It is not the same as chess, shogi, or video games where the only answer=a winner exists. Unlike distinguishing human faces, animals, and cars, there is no clear typology of forms to classify, either. Nor are there any common rules or language, like musical notation or chords. In this vague universe of design, where there are few clues and where anything is possible, it is necessary to find what is "good". Will we ever be able to catch the monkeys flitting from branch to branch ?

Science + Art Paths in the opposite direction actually lead to the same place

ID and AD tried to obtain better architecture by bringing architecture closer to science. They could be called white boxes, because they tried to answer “why” questions with rigorous logic. The brain of the architect and AItect are the

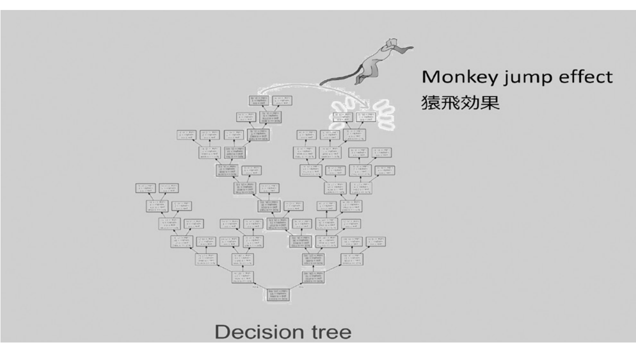

Figure 17. Monkey jump effect

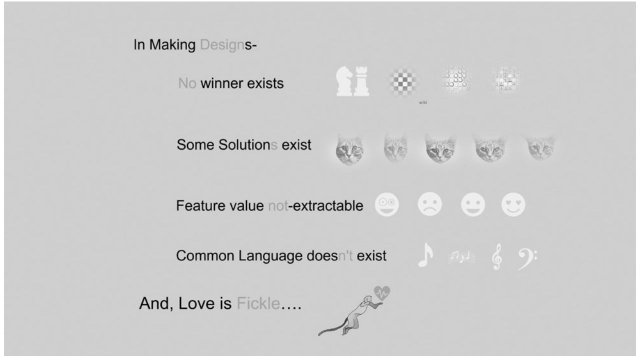

Figure 18. Difficulties in AD/AItect

Figure 19. pBM_credit

rigorous logic. The brain of the architect and AItect are the exact opposite. They are black boxes. Instead of answering “why” questions, they suddenly produce excellent architecture (assuming that they are good at what they do).

The attempt to obtain better architecture by bringing chitecture closer to science. They could be called white boxes, because they tried to answer “why” questions with rigorous logic. The brain of the architect and AItect are the exact opposite. They are black boxes. Instead of answering “why” questions, they suddenly produce excellent architecture (assuming that they are good at what they do).

The attempt to obtain better architecture by bringing architecture closer to science involved the pursuit white boxes. It is interesting to see how this attempt ended up with black boxes. Further, although science, with its principles of verification, and art, which is produced through intuition, appear to be going in opposite directions, in fact they may be describing a loop, so that they are connected at their destinations. That is also interesting. The challenge of ID, AD, and AItect will probably help clarify this uncharted trajectory.

It is not necessarily true that AI will remain a black box forever. With the advent of Explainable AI (XAI), which is capable of providing a rationale for its decisions, AI may once again be transformed into a white box.

AD + AItect When machines have dreams, what will humans see?

As a result of pursuing (soft) science in the realm of design, arriving not at science but art. As a result of seeking to acquire the logic (algorithms) required by science from the act of design, which depends on experience and intuition, arriving at AI without algorithms (at least not algorithms that can be understood).

While pursuing the extraction of white box algorithms from the black box of intuition, arriving at AI, a new black box. This is a paradox. A strange but interesting paradox. Is collaboration possible between the primordial black box (brain: intuition) and the new black box (AI: learning type)? During lectures on algorithmic design, there is a FAQ that comes up often: if programs generate architecture, what will architects do? I always answer as follows. Machines are better than people at solving complex problems with many intertwined conditions. In that realm, people are no match for machines. But people are the only ones who can create an image that does not yet exist. Machines do not have dreams. Will this answer always be true? Will the day come when machines have dreams? Getting ready for that day will involve exploring that path of fortunate cooperation between the brain and machines.

This will require work in both areas: that of white boxes = the scientific approach = ALGOrithmic design, and that of the two black boxes, toward collaborative methodologies = +AItect. In the same way that our left brains and right brains handle different functions and collaborate to deliver outstanding performance.

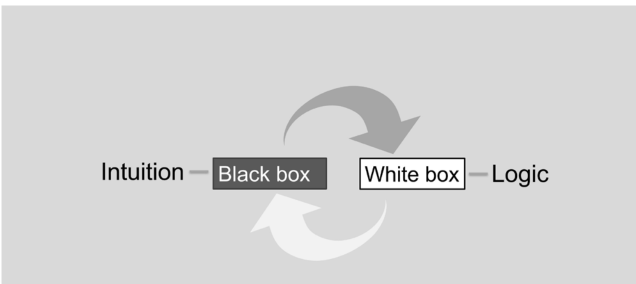

Figure 20. Color of the box

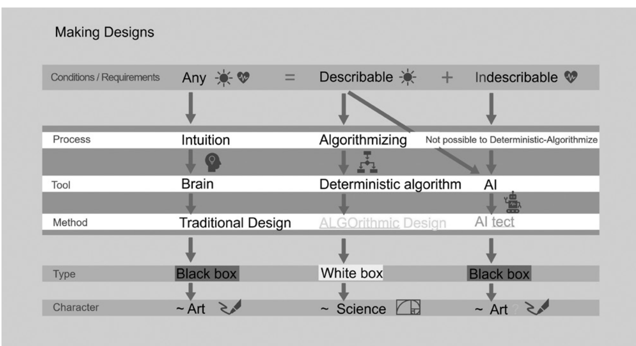

Figure 21. Process of making design

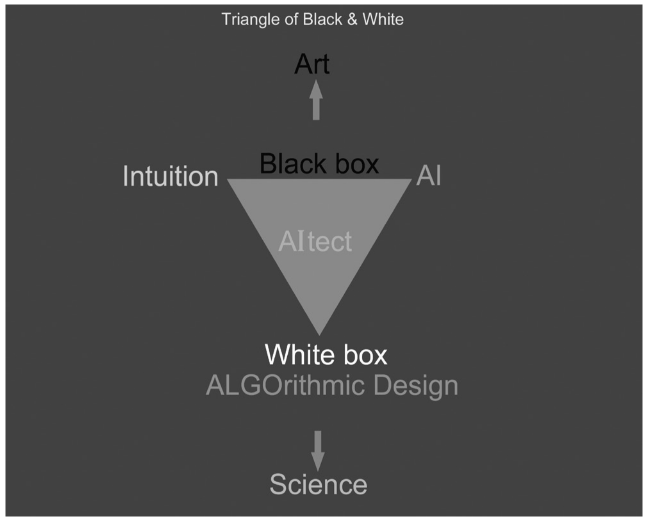

Figure 22. What color is the box?