

The architecture of complex objects: computers, aircraft, buildings, bridges, landscapes, towns

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Abstract:

Architecture seems to be currently torn between two extreme movements: one tending to limit it to buildings only, in a sort of protectionism, the other tending towards widening of its scope. Previously, we referred to the architecture of gardens and to naval architecture. Now, we also speak of software architecture, aeronautical architecture, and molecular architecture. In fact, it seems that these apparently opposed, paradoxical movements are two manifestations of one same process. What is this process? In this article, it is suggested that we are witnessing the emergence of architecture's specificity among the different disciplines that concern complex objects/systems and their design.

The purpose of this article is to provide clarification of this question.

1. Introduction

Nowadays, it is clearly obvious that the range of architectural objects, which some people consider should be limited to buildings, is in the process of being widened. Previously, one spoke of the architecture of gardens and of naval architecture. Now, we also speak of software architecture [Deschaintre,1998], aeronautical architecture [Rechtin,1991], molecular architecture [Mesplède,2000], financial architecture [CAE,1999] and even defence architecture [ADAM,1999].

This widening was recognized and theorized in the early 1990s by H. Rechtin, an engineer and professor of aeronautics. Rechtin showed that the specific nature of the architect's "art" – i.e., the capacity to "architecture" or to "architect" things – was also valid for all complex systems that have to be designed and that, for new fields of engineering, this art was required in order to get beyond the dead ends of their traditional methods [Rechtin,1991&1996]. This need led to the emergence of the first software architects, mechanical architects, etc.

This paper proposes to examine the consequences of this development for the architectural discipline¹. It is accepted that, as a discipline, architecture has at least five characteristic fields.

The first field, its principal subject, is that of "architectural objects and their architecture". Here, the term architecture² is used in the "generic" sense of "*Principle of organization of a set of objects*" [Imbs,1979].

The second is an activity, "architectural practice", which establishes architecture as "an art", i.e., the capacity to "architect" objects in a situation where they are created or modified. The verb "to architect" is taken to mean "*to construct and arrange something as an organized whole; to give an architectural character to something*" [Imbs,1979] - one dictionary definition is as follows: "*to architect: to design (a building) - as architect*" [Oxford,1987].

The third is the branch of knowledge formed by "architectural knowledge" (or "architectural expertise") concerning objects and practice, knowledge that is considered to include the "science of architecture".

The fourth is the activity of "architectural research", which develops, in particular, this science.

¹ Where "discipline" is defined as "a branch of knowledge, a field of activity, a subject of teaching and study" [French Academy,1990].

² One should not be surprised at the use of the word "architecture" in a sense different to that of the classic architectural discipline. This word is polysemic, i.e., it has several meanings. This was shown in a previous work that analyzed definitions given by architects and by dictionaries [Hanrot,1998].

The fifth is also an activity, “teaching“, which passes on this knowledge or expertise to students, leads them to the experience of architectural objects, and initiates them in practice and in research.

Starting from this basis, we shall see that we can classify traditional and new architectural objects in a consistent manner. Among these, buildings, gardens, public spaces, infrastructures, landscape and town form a particular ensemble that determines the living space of man and society. These everyday objects are easy to distinguish from aeronautical, marine or information systems objects, to mention just a few examples.

This classification shall be presented in its principle, and we shall use it to answer the question that we are concerned with, viz.: what are the consequences, in other fields of the discipline, of the widening of the field of architectural objects?

2. The widened field of architectural objects

A building is composed of a large number of parts (storeys, rooms, floors, ceilings, walls, bricks, etc.) that define forms and spaces. It also belongs to a context which may be urban, peri-urban, rural, or natural. It performs several functions: use, comfort, cultural, mechanical, constructional, thermal, etc. Its lifetime starts with its design brief and then its actual design, its construction, and its use up until its destruction. It has an architecture that is recognized in the composition of its different parts and the ordering of its forms and spaces in order to perform its multiple functions, in the urban, peri-urban, rural or natural contexts in which it is located, throughout its lifetime, which may be up to several thousand years.

In a previous work [Hanrot,2000], it was shown that aircraft, software and buildings all have a large number of parts, they all perform a large number of functions, and they all belong to a context. Therefore one may recognize architecture within them.

The architecture of an aeroplane is expressed by the composition of its different parts (fuselage, wings, engines) and sub-parts, and by the coordination of the different functions that it must perform in the air and on land, throughout a lifetime of around twenty years.

The architecture of software may be understood as the composition of its various parts (modules, procedures, etc.) and sub-parts, that enable it to perform its different functions in the domestic or professional contexts in which it could be installed, throughout a lifetime that may be very long.



House of the Australian architect, Peter Stutchburry

All these objects that have an architecture belong to the field of architectural objects. The factor that they all have in common is that they are complex objects that form systems³. This leads us to a generic definition of the architecture of complex objects that is more precise than that of Imbs quoted above: *architecture is a principle of composition of the parts of a complex object/system as a whole, which allows and coordinates the accomplishment of the system's various functions in the context(s) to which it belongs, throughout its lifetime.*

However, buildings, aircraft, and software applications are different objects. A building belongs to the world of things that can be directly perceived by man, as is an aircraft, but not a software application. A building is fixed in its context, while aircraft are mobile. A building has interior or exterior forms and habitable spaces, as has an aircraft, but not a software application. A building plays a part in the daily living conditions of man and society. It has a comprehensive character and a lasting quality that are not envisaged in either aeronautics or information systems. Lastly, buildings are constructed in situ - which is not true for aeronautics or for information systems. Other differences could be pointed out, but these are particularly characteristic. Therefore the question is: are there other complex objects that distinguish themselves from aircraft and computers in the same way as the building does?



The Airbus Beluga, with its astonishing architecture

Affinities and differences:

In previous works [*opus cit.*], I showed that civil engineering structures, roads and public spaces, infrastructures, garden and parks, large-scale landscaping and towns are complex objects which, like buildings, are part of the space and forms of man's living environment. Just like buildings, they distinguish themselves from objects such as aircraft or software applications by their physical materiality and by the fact that they are fixed in their context and setting.

However, there are differences between buildings, civil engineering structures, roads, landscape and towns. A building and a city do not have the same lifetimes. The lasting qualities of a garden and a civil engineering structure are also different: one develops and changes through the growth of the plants that make it up, while the other changes only very slowly.

However, these differences are minor in relation to the links that relate these different objects. In fact, some of these objects may be considered parts of another.

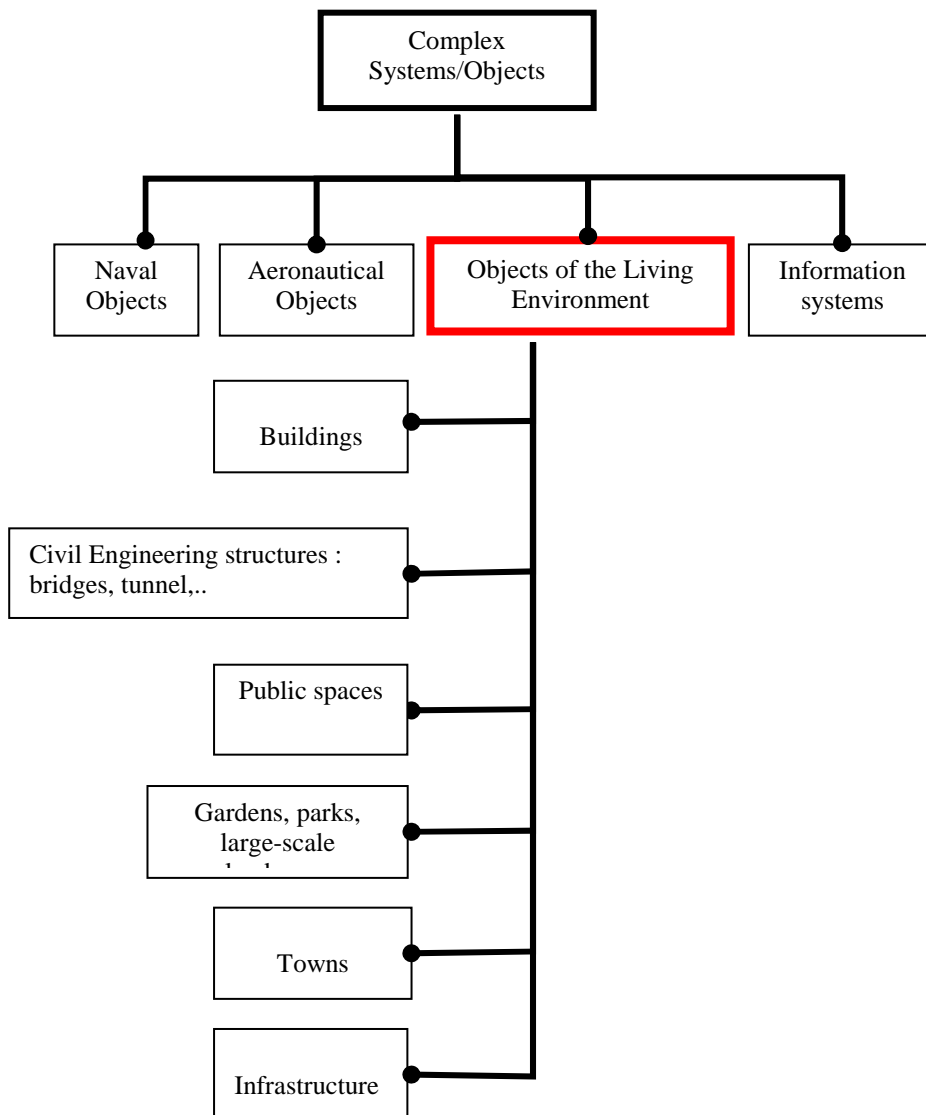
Conversely, this "other" object forms the whole to which the first belongs. Thus, a building can be part of a town. The town is the whole to which it belongs. The town forms a part of the building's

³ A system is composed of an object, or structure, and a function. Here, reference is made to definitions given firstly by Von Bertalanffy ("Théorie générale des systèmes" L. von Bertalanffy, Dunod ed., Paris, ISBN 210 001841 8, 1993) and then by J.L. Lemoigne ("Théorie du système général", J.L. Lemoigne, PUF, 1976).

context, the other parts being the site itself with its climatic factors, its users, etc. A garden (such as an atrium garden) can be placed within a building, and a building (such as a summerhouse, a greenhouse or a café) can be placed in a park. A civil engineering structure or a planted embankment may be parts of a road. A town is a whole composed of buildings, gardens, infrastructures⁴, etc.

Is it possible to find similar relationships between an aircraft and a building, or between a software application and a town? Obviously not. An aircraft may be housed in a hangar, but it is not a part of a hangar. It is a vehicle that is a “user-occupant“. A software application in itself may not be considered a physical part of a town, although it may contribute to a town's functions, e.g. a software application for regulating urban traffic.

Fig-1: Classification of architectural objects.



⁴ Speaking of American roads, F.L.Wright wrote: “Year by year, as new, more and more enormous roads systems are added, they are constructed more and more magnificently. I predict that roads will soon also be architecture – as they fully deserve it: great architecture”. (from French translation of “Autobiography”, Frank Lloyd Wright 1943, Editions de la Passion, Paris, ISBN 2-906229-33-4, 1998).

Objects of the living environment:

These common characters and interrelations define a quite uniform field of objects that make up man's living environment and are built by him. Each of them is ordered by an architecture and contributes to the general architecture of this living environment. Therefore it is appropriate to group them together in one class in order to distinguish them from the others. Let us call this class the constructed things, edifices or "objects of the living environment"⁵. This corresponds to the definition of architecture⁶ proposed by J. Fleming, H. Honour and N. Pevsner in their dictionary of architecture [Penguin,1998].

Taxonomy (systematic classification):

As shown in the attached graph, we may draw up a taxonomy (or systematic classification) of architectural objects in the form of a generalization/specialization tree. The complex object/system forms the generic class of architectural objects.

From there, a first level of specialization can be established in which we distinguish "objects of the living environment" from other objects such as ships, aircraft or computers.

The objects of the living environment themselves have sub-classes. These include: buildings, civil engineering structures, roads, infrastructures, gardens and parks, large-scale landscaping and the town.

3. Architectural practice as activity and as process:

Widening of the field of architectural objects to complex systems in general inevitably leads to questioning on the different practices in architecture and on their correspondences. So what do the architect of a building, the architect of an aircraft and the architect of a software package⁷ have in common? Is it the fact that they "architect"⁸ in the same way in these different fields?

Taking the architecture of buildings as a paradigm, H. Rechtin [*opus cit.*] shows why notions of architecture and architectural practice can be now extended to the different complex systems produced in contemporary engineering.

In order to "architect" or "architecture" complex systems, the architect uses heuristic methods to examine ill-defined problems related to these systems.

According to Rechtin, heuristic methods⁹ are more efficient than purely "prescriptive" standardized methods that consist in copying reference models. For the latter limit creativity and innovation, even if they sometimes make work easier. Heuristic methods are also more efficient than "rational" or "procedural" methods, whose step-by-step development is well-known. Although,

⁵ In this sense, an "object of the living environment" is an object that belongs in a fixed manner to a context or setting and is characterized by forms and spaces that make up the human and social living environment. It thereby performs, to varying degrees of success, several functions (relating to various aspects: social, use, comfort, aesthetics, symbolic, economic, technical, etc.). Any "objects of the living environment", as a complex system, is presumed to have an architecture. This architecture lasts for varying lengths of time throughout the existence of the "objects of the living environment" and places it in a historical continuum.

⁶ Architecture: "The art and science of designing structures and their surroundings in keeping with aesthetic, functional or other criteria. The distinction made between architecture and building, e.g. by Ruskin, is no longer accepted. Architecture is now understood as encompassing the totality of the designed environment, including buildings, urban spaces and landscape." [Penguin Dictionary of Architecture & Landscape Architecture,1998]

⁷ Practically every edition of the French newspaper "Le Monde" contains an advertisement for a position as information systems architect or multimedia architect. It is interesting to note that Bill Gates calls himself Microsoft's "chief software architect"! In information technology, architecture is a reality since the 1970s.

⁸ Rechtin and Maier used the verb "to architect", or more precisely, the form "architecting", which is translated into French as "architecturer".

⁹ An heuristic rule is a rule that guides the designer's action in the resolution of such problems. For example, people often mistakenly believe that a design scheme is devised from the general level to the particular, from the whole to the parts, or from the overall scale to the precise scale. However, in reality, the design scheme is developed and re-adjusted as the designer goes repeatedly back and forth between the two levels/scales. Therefore one must not hesitate to change scale and to reconsider the whole on the basis of the parts.

here again, the latter may be useful for a well-defined sub-problem. Heuristic methods are not only suitable for dealing with the problem in itself. They also take into account the context of political, social and financial decisions in which the design project develops.

In the field of objects of the living environment:

Rechtin's proposal is not without questioning of the architect's skills and area of competence. These are usually specified by adding another word before or after "architect" to designate the architect's particular field of specialization. Thus, one says architect-town planner for the architect who works on urban matters, or landscape architect for one who specializes in gardens, parks and large-scale landscaping. In France, one does not speak of a "building architect", which is a qualification or area of competence by default, although one speaks of the "civil engineering structure architect" or "architect-engineer". Until the early 20th century, the architect who worked on roads design was called an "*architecte-voyer*" [literally "highway architect" or "streets architect"]. This person held an extremely important position in the local municipal administration of cities¹⁰. In any case, the use of the generic term "architect" by building designers in France is rather improper.

There are common threads of practices and knowledge that run between the different classes of objects, and it is not rare for architects or groups of architects to have dual qualifications or areas of competence. One can be an architect-town planner and building architect, or a landscape architect and architect-town planner. However, specialization is very often necessary, since each field of practice requires specific know-how and knowledge.

Taxonomy:

As shown in the attached diagram, the architects of complex systems/objects form the generic class of practitioners. From there, a first level of specialization may be established in which one distinguishes the architects of "objects of the living environment" from other architects such as naval architects, aeronautical architects or information systems architects.

Architects of "objects of the living environment" are themselves divided into fields of specialization: building architect, civil engineering architect, roads architect, infrastructures architect, landscape architect (gardens, parks and large-scale landscaping) and architect-town planner.

4. Architectural knowledge:

The fields of knowledge on objects and practices may be common at a certain level generalization and also specific, according to whether we are concerned with particular objects. The knowledge of an architect who designs civil engineering structures and that of an architect who designs buildings are quite similar. However, such knowledge is much further removed from the software architect's particular knowledge, and the gap of difference to be bridged between one type of knowledge and the other is very wide. However, this difference would be much greater between any given architectural knowledge and the technical knowledge of fluid dynamics or of cancer pathology in medicine.

Taxonomy:

Knowledge concerning architectural practices and objects is composed of branches and sub-branches. Knowledge concerning complex systems/objects and design practices forms the generic knowledge.

¹⁰ Such positions still exist in the municipal departments of the City of Paris.

From there, differentiated branches of knowledge may be established for architecture and the practice of “objects of the living environment“ and for the other types of architecture (naval, aeronautical, information systems).

Knowledge concerning the architecture of such objects and their practices is divided into its own fields of specialization: building, civil engineering structures, roads, infrastructure, landscape architecture (gardens, parks and large-scale landscaping) and town.

5. Research as an activity:

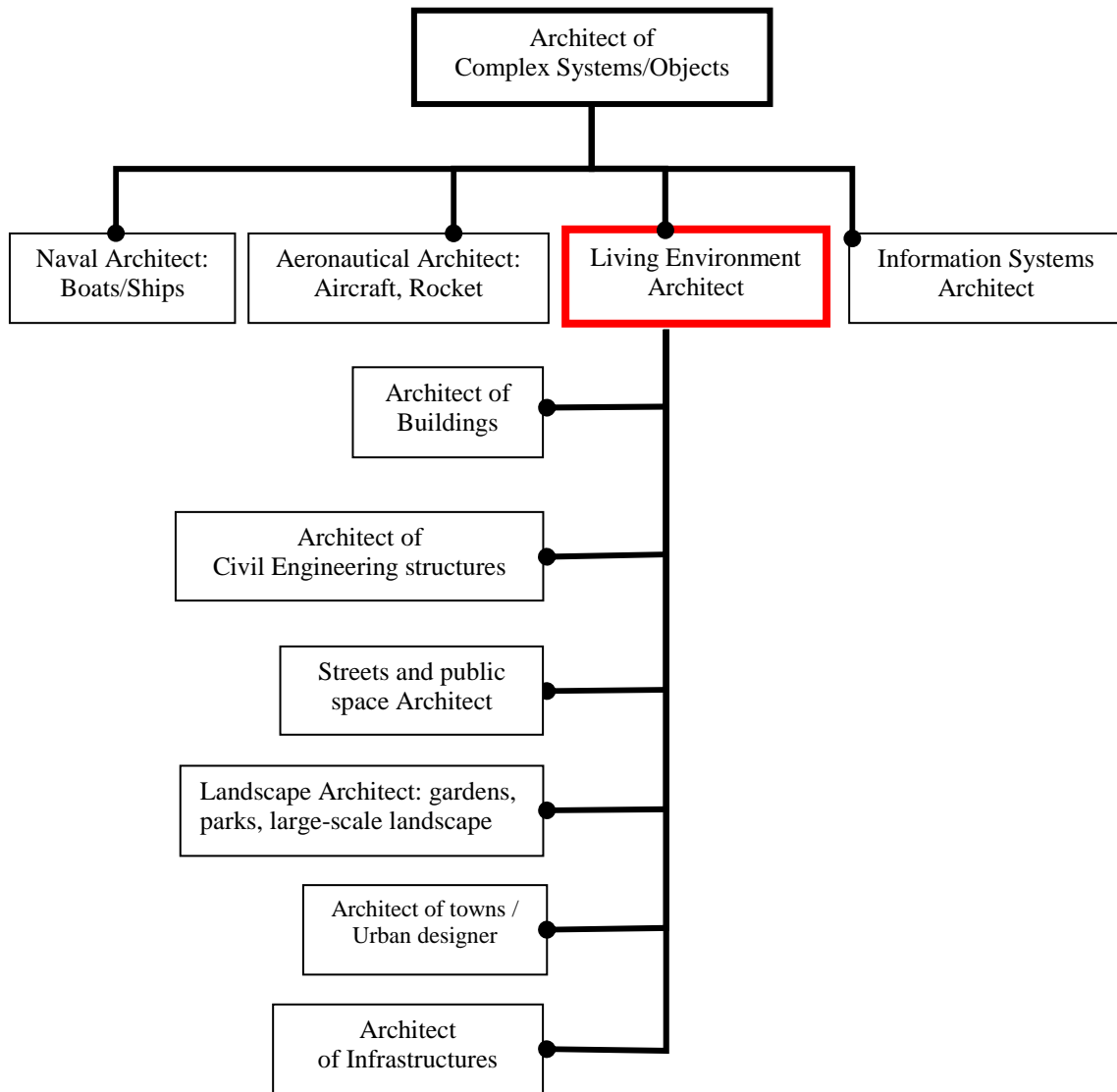
Research is an activity that aims to understand architecture and to form knowledge of architectural objects and practice. Naturally, the prime subject of study of research is the architectural object. How can we describe and understand architectural objects and particularly their architecture? What are the types and how is their great diversity organized? What are their models? How do they interact with the user/occupant and with society? How can the idea of architectural scale or architectural synthesis be conveyed?

Obviously, these questions are asked differently, according to whether one is studying the architecture of computers or the architecture of buildings. And it is obvious that the specialized knowledge identified for some is not relevant to others. However, at a certain level of generalization, certain knowledge is transposable and common to all, as shown by H. Rechtin.

Research also examines the genesis of these objects and the practice that governs them. How can we explain the detailed ways and means of practice? What role does the architect play with respect to the other players involved in the design process? How can we define the idea of the design process and the action of "architecting"?

The answer to all these questions is found in the study of objects and practices, by devising architectural theories and by developing applications that interest architects in their position as practitioners, for all types of complex objects.

Fig-2: Taxonomy of architects and architectural practices.



Taxonomy:

Architectural researchers can place their subjects of study on different levels. They are “fundamental“ researchers and in this case they develop theories of the architecture of complex systems/objects and practices as generic entities.

They can also place their attempted formalization and production of knowledge at a first level of specialization, that of objects and practices of the architects of “objects of the living environment“, naval architects, aeronautical architects or information systems architects. It is then a matter of forming the knowledge specific to a branch and identifying its relation to more general theories of complex systems and their design.

Lastly, researchers can place themselves on a more precise level of specialization, specific to certain classes of objects or of practices of the architects of buildings, civil engineering structures, roads, infrastructures, landscape (gardens and parks, large-scale landscaping), and towns.

6. Teaching:

The fifth field, “teaching“, is intrinsic to the idea of discipline. Teaching is mainly provided in public schools of architecture, and also in universities and schools of engineering¹¹.

Training for architecture and for practice:

According to our taxonomy, training courses in the architecture of objects should have use of a common corpus (or body of knowledge) in order to open up to fields of specialization according to the types of objects chosen. In France, the fragmentation of training courses between the different schools and the university does not facilitate this sort of coordination. Rather, it leads to promoting various interest groups and cliques, starting from the teaching stage.

One could ask whether combined training courses could be provided on the architecture of “objects of the living environment“ and the architectures of other complex objects, such as information systems or aeronautics. Specialization is often necessary, according to the type of built object, and it is all the more necessary from one complex system to another. It is very unlikely that someone could be both a building architect and an information systems architect or aeronautical architect of a high standard. However, a body of fundamental knowledge and skills is shared by them all. Therefore it would be useful and interesting to compare the teaching developed in each field of architecture, particularly as regards the architect's standing in relation to the engineer¹².

Taxonomy:

Teaching, with its curriculum and its concerns, may be considered as analogous to the taxonomy of objects. One may therefore identify teachings that are generic or specific, to varying degrees, with respect to architectural objects and practices:

- Teaching on the architecture of complex systems/objects and on practices, as generic entities, would be far from an operational, hands-on practice. However, it would provide access to the fundamental knowledge of architecture shared by all fields. It would also provide overall understanding of the discipline.
- Teaching on the first level of specialization of objects and practices of the architects of “objects of the living environment“, naval architects, aeronautical architects or information system architects is therefore aimed at a specific branch. The student information systems architect needs to match knowledge on the architecture of computer networks and of software applications. This is part of the student's general training. Similarly, the student architect of the living environment must match the knowledge and interrelations between the architecture of buildings, civil engineering structures, landscape, infrastructures and the town.
- Teaching on the specific objects, practices and knowledges of the operational field at which the student architect aims - i.e. to certain families of objects or practices of architects who design buildings, civil engineering structures, roads, infrastructures, landscaping (gardens and parks, large-scale landscaping) and towns - takes on a specialized form. The other objects of the field of “the living environment“ are then seen as forming the context of the studied object. For the architect who specializes in building, the town and the landscape are seen as forming this context.

¹¹ In France, for example, UTC (Université Technique de Compiègne) awards an "Information Systems Architect" diploma, with a course provided by IMI (Institut du Management de l'Information, created by UTC and located in Paris).

¹² Rechtin establishes architecture as both an art and a science, and he proposes detailed means for validating heuristics, and also teaching curriculae. For, once architectural practice in new fields of engineering is recognized, its knowledge must be structured and teaching courses must be provided that shorten the learning curves that are usually involved in professional experience.

7. Branches of the architectural discipline:

Starting from the reasoned taxonomy (or systematic classification) of architectural objects, it was successively shown above how we can match taxonomies of architectural practices, knowledge, research and teachings. Since the five fields of the discipline can be consistently matched in a single classification tree, we may speak justifiably of different branches and sub-branches of the architectural discipline, which are attached to a common trunk composed of the architecture of complex systems/objects. This classification tree takes the architectural object as a discriminant criterion. It is illustrated in the attached diagram and shall be interpreted as follows:

The architecture of complex systems is the generic class.

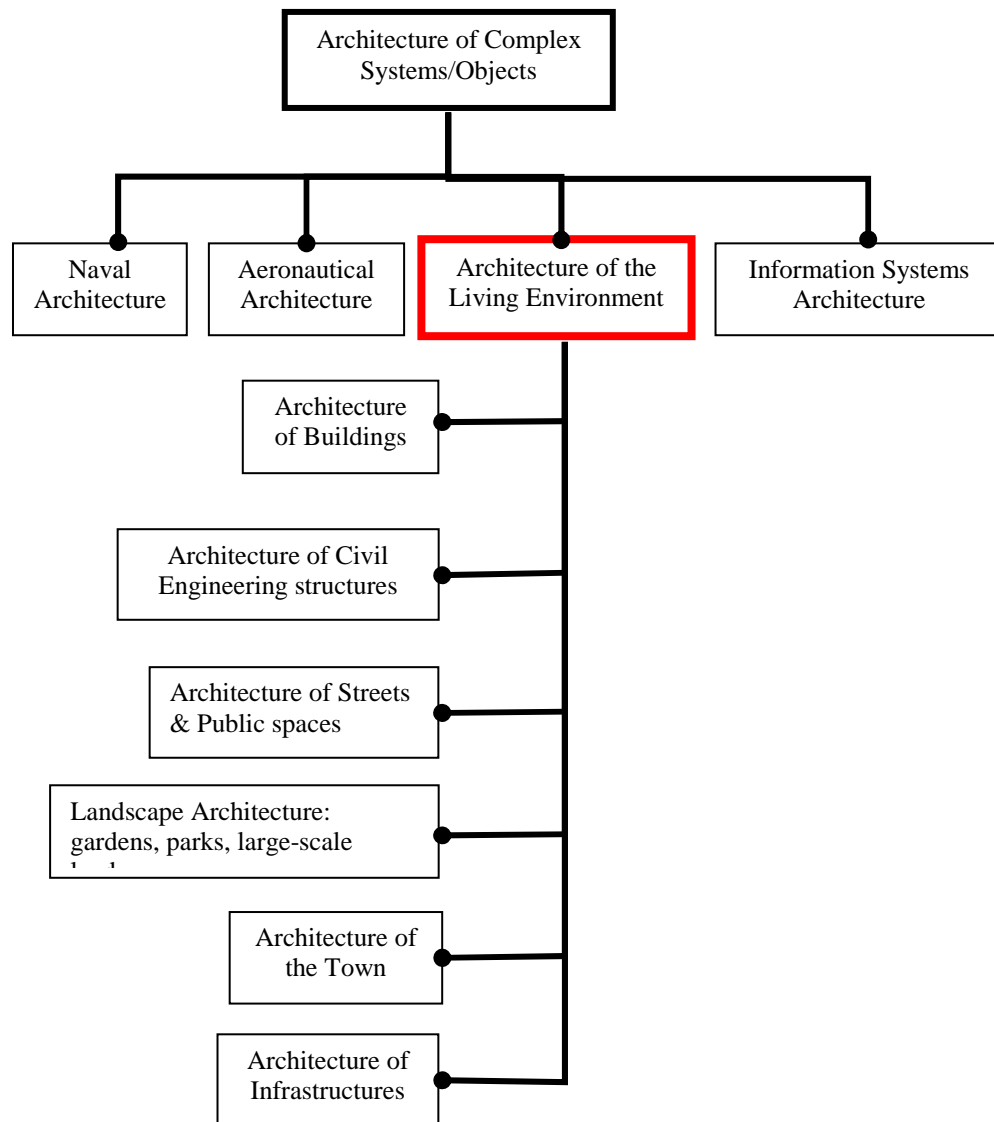
From there, a first level of specialization, establishing different branches, can be established in which one distinguishes the architecture of “objects of the living environment“ from other types of architecture, viz. naval, aeronautical or information systems architecture¹³.

The architecture of such objects itself has sub-classes. Five of the same rank appear relevant: the architecture of buildings and civil engineering structures, of roads, of infrastructures, of gardens and parks, of large-scale landscaping and the town¹⁴.

¹³ This recognition of a wide field of architectural objects does not devalue the idea of architecture, as some purist architects may fear. On the contrary, it makes it possible to establish architecture as a fundamental principle that may consist of many facets or may be specialized, according to the objects in question.

¹⁴ Some may oppose this classification, saying that it may bring to a head the conflict with urban planning by stating that the town has an architecture. Others have proposed this idea before me (“L’architecture de la ville”, A. Rossi, Paris, ed. de l’Equerre 1966), (“Architecture, vocabulaire de” J.M. Pérouse de Montclos, Imprimerie Nationale ed., Paris, 2nd edition, 1989). If Cerda invented the discipline of urban planning at the end of the 19th century, he did so in order to objectivize knowledge on the functions of the town and the multiple systems that make it up, and also the processes of its development. The town, as a complex system, can be “architected” through its forms and spaces, even if this is not done with the same spatio-temporal means and methods as for a building.

Fig-3 - Taxonomy of branches of the architecture of complex objects and systems.



8. Conclusion.

The initial aim of this paper was to assess the consequences of the widening of the field of architectural objects currently observed in the discipline's other fields, viz.: practice, knowledge, research and teaching.

We have seen that the widened field of architectural objects can be organized in a tree structure. Then it was shown that this organization was reproducible in each of the other fields of the discipline. Consequently, we saw that this organization in a tree structure, of which architectural objects are the discriminant criterion, reflected new branches and sub-branches of the architectural discipline.

Evidently, this consequence can be viewed in a negative or positive light.

The negative view may be that of players in the traditional fields of architecture - and particularly building - who may fear a devaluation or a blurring of their professional title and of their social role as an architect. Rather than being an unsavoury form of protectionism, such an attitude would be the result of confusion that is common in these circles, which consists in assimilating architecture to a real object and particularly to a building. For indeed, people often refer to building by saying "this architecture" or "this piece of architecture". Let us promote architecture as an ordering principle that can be applied to different complex objects, and we will thereby remove the confusion, in order to adopt a positive perspective.

The positive vision is to recognize the new branches of architecture (which is inevitable, since they exist already) and to consider their advantages.

Firstly, architects of traditional fields have nothing to lose through this widening of the scope of architecture, since their place is not being taken by anything else. These new branches of the discipline do not replace the old ones - they complement them. The direct benefit gained by the traditional branch of the architectural profession and its architects is the recognition of the architect's competence and usefulness in fields other than building construction.

The most general benefit is that architecture acquires a stronger base, since it becomes involved in more fields of engineering and of creative design. It may then be approached on different levels of generalization and of specialization, and provides new problematic fields for its research and new resources for its teaching.

Without being unreasonably over-optimistic, the architectural discipline thus organized can become a focus for reflection that will be of major interest for all fields concerned with complex objects and their design.

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