Abstracting from the elements of nature – Towards a medial architectonics

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Abstract

The concept of the digital has clearly shifted the emphasis of our worldview, and since its explosively accelerated spreading and implementing since the 1990ies, it is no exaggeration anymore to speak of a 'digital revolution.' We are no longer successful in making sense of what is going on by withdrawing to definite, causal relationships or the possibility of external allocations or precise references; cycles, balances, the concept of negotiation and competition have come to play a "fundamental" role today. That is why we need to understand how information technology can be so essential to architecture. How can we design the prerequisites for sustainable development as well as its realization by initiating competition as well as balance? What are important considerations when evaluating the glut of possibilities? What are the rules operative in networks and communicative processes?

1 Introduction

The mediation between architecture and information technology is, naturally, a challenge. The crucial aspect thereby is that the 'substrate' information technology operates on needs to be conceived as an abstraction of the physical elements: Information is not matter nor energy, as Norbert Wiener has famously stated. We are literally in the course of leaving stone age and its orientation towards a particularly relevant set of scales and processes, that of the mesoscale of solid bodies. Stone age is stone age because of its orientation on earthly materials, on a mid-sized scale, following a simple linear causality. The respective paradigms of mechanically controllable hierarchies are widely recognized to be incapable of supporting and integrating our transforming practices, so aptly characterized by an increasing ability to densify volatile networks into concrete effects.

It is an often discussed phenomenon that the amount of data available worldwide is growing rapidly -there is a glut of data. And yet, the organization of infrastructures serving our essential as well as our immaterial 'needs' still follows, in most cases, the inherited schemes. The massive dams erected for water supply belong in this category, just as, among many other examples, nuclear power stations for the production of electricity, transcontinental oil pipelines for fuel delivery, closed-circuit video surveillance networks for security, huge new cities built on grid systems and designed to relieve housing shortages, and intensively worked fields intended to increase food production. They may do so with ever more differentiation, branching into ever more delicate hierarchies, but most of our infrastructures today still pursue age-old paradigms of mechanistic control. At the same time, we are learning from various 'crises' - from the feared anthropogenic climate change to the energy-shortage crisis to the quakes in global financial systems - how the coupling of new technological possibilities with old paradigms is leaving us out of our depth.

We cannot, so it seems, go on to invest our intellectual capacities in allocating the basic support systems of our living on earth according to the inherited ways of reasoning, the ways - we are well aware - that have allowed our civilizations to live in the present condition. Yet we can't help realizing that we are overstraining our planet. Here, both dimensions are remarkable: the fact that we are actually doing it, and the fact that the very idea of it has been unimaginable only two or three generations ago. In this sense, we not only *belong* to the planet; actually we *are* the planet, exactly due to the fact that such a global statement is meaningful.

If we want to reconsider construction today, we will need to reconsider the nature of our technological means to do so. This 'nature' is not physical. It is, literally, whatever we imagine it to be. As with any idea we might be capable of imagining, it is important to put our ideas to the test, and to negotiate them in order to find out the preferred ranking of assumed objective and subjective return and risk profiles. This might sound somewhat fantastic, but it actually fits well the current situation in architecture. The new dynamics in our discipline allows not only to control and orchestrate the processes on a much more detailed level, but also to continuously negotiate the rules and the goals of each project with much greater flexibility than ever before. With computer aided design, planning and manufacturing procedures, buildings need to be conceived by architects as an ensemble of possible solutions and developments instead of designing them as a fixed end result in the classical - and expensive - sense. This will, rather likely, turn into a far-reaching paradigm change for architecture within only a few years. Admittedly, it is as difficult for architects to grasp as the fact that their skills and creative abilities are being ‘reallocated’ towards two quite diverse fields: The digital templates, shape grammars, generic algorithms of architectural software on the one hand, and the capability to mediate the new flexibility to their clients on the other hand, enabling them in a smart way to surf on this newly available level and harvest its potential.

In the following we will provide a brief description of five projects illustrating the current developments. Furthermore we will also try to step back a bit from the description of the projects in order to elaborate on our interpretation of the presumed larger and embedding cultural trends.

2 The ‘nature’ of our technological means today is imaginary

In order to grasp the first bits of the meaning of these changes, we need to differentiate between data and information. The pure transmission of data is ineffective if it does not deliver information to the recipient - in other words, if it does not change anything. If one has no understanding of the English language, anyone reading this text would certainly ‘receive’ a lot of data, but - at least as far as the text is concerned - would not derive much benefit from it. And for those readers who can speak English, the information they get depends upon the matchmaking of their possibilities to deal with our context. In contrast to this, the electric kettle will heat the water when turned on regardless of what it might ‘want’ to do with it. More generally put: The information transmitted by exchanged data is dependent upon the recipient and her context-dependent interpretation, and must be clearly differentiated from the physical data flow.

There are two main consequences of this. One is that technology operating on the basis of information science cannot be considered as ‘neutral,’ ‘true,’ or ‘natural.’ This was much less obvious prior to the invention of electricity and the symbolical tools to regulate electrical, electronic and data-processing machines. The causality principle of physical mechanisms is thought to embody the principles of nature, as they are conceived by natural sciences. Indeed, the mere functioning of a postulated mechanism, i.e. of a causality relation, has always been considered proof enough for its ‘truth’ - despite the fact that it might have posed a challenge to the traditional body of knowledge at a certain time. In that sense, technology has been a significant driver in the advancement of modern science.

Meanwhile, things have changed. With technology operating on the basis of information and communication, this inherited way of unambiguous reasoning has become problematic, if not altogether inadequate. Here, any ‘functioning’ solution for a problem is but one possible answer to a formulated question. The ambiguity enters on both poles: you might not get the problem ‘right’ either from the way it has been communicated to you, or also in how you formulate it at first hand. As such, any proposed solution embodies but one kind of reasoning, a kind of reasoning that has been selected out of many possible ones. Any information scientist working on encoding the text of a *formulated* problem into a *formalized* problem knows from experience that there are always many possible ways to implement the textual specifications he receives. For the aspect focused on while deciding which way to implement it, the possible ways might all be comparatively similar and held to be equally valid; yet regarding other aspects that might be implied in the formulated problem, and that might perhaps even unfold only later on, these choices bring the solution-process on track into specific directions that cannot be easily reversed anymore. It is here that semantics enters the application of logical formalizations on the level of structure. They work, primarily, on the substrate of our imagination.

Furthermore, it is an interesting observation that the last time when architectonic questions were raised - although then, they have been raised in philosophy - happens to fall together with a new kind of analysis, which was significantly referred to as a ‘deterritorialized’ analysis. Key to this new kind of analysis was a certain kind of numbers - the so-called complex numbers, of which one is even called ‘the imaginary number,’ short ‘i’ as a name for the square root of minus one. These numbers have not been entirely unknown in previous times, but there were no ‘usages’ or ‘applications’ for them beyond purely abstract thought-experiments. It was not until the invention of electricity that there seemed to be a sufficient reason for taking these ‘irrationalities’ serious.

If these technologies operate on our capacities to imagine, then they can also help us to push our imagination beyond the constraints our individually socialized experience will always pose for it. Thus, it is from the unprecedented permeability and availability of different mindsets, beyond the traditionally rather rigid constraints set by traditions, social classes, or other ‘decorums,’ that we see the greatest potential of information technology rising, also for the context of architecture.

3 Architecture as an integrative discipline

Architecture works on an integrative rather than on a particular level, even if it often manifests itself in singular, particular buildings. Any building is integrating many specific, sometimes even contradictory processes into a comprehensive interplay, processes from the side of the building industry as well as from the design or the engineering side. Working on an integrative level poses entirely different challenges than solving goal-defined problems, since the question of interest always regards the possible generalization of any particular solution: looking for the differential, as the working ‘relationality’ of all possible functions among the involved ‘dimensions’ or ‘parties,’ means for architects to also focus on how they identify the legitimate ‘domain’ for integrating - be it simply in terms of the geometrical area spanning between certain borders, or certain kinds of vector spaces (characterized by the interplay of physical forces), measure spaces (characterized by a sensitivity to technological determinism of any model building), or even problem spaces (characterized by a sensitivity to historical constraints for any model building, e.g. scientific paradigms or dispositives). It is this integrative focus which raises architectonic questions today in an altered way, i.e. questions regarding the inner relations for a systematically carried out practice. Neither the planning, nor the implementation of processes have remained the same as in the era prior to information technologies. The processes are no longer unidirectional, they are bidirectional in the least, with a tendency to become increasingly networked.

In our work at the CAAD institute at ETH Zürich we are focusing on establishing what we call ‘narrative infrastructures’ for all aspects of architectural practice - economy and industry, conception and design, as well as construction and rising and running a house. We have conceived, in a broad range of projects, infrastructural platforms for supporting and advancing, by the new means of information science and technology, the discipline of architecture as an ongoing ‘story-telling’ and ‘conversation.’ We hesitate to call it ‘discursive’ because ‘discourse’ denotes a regulated practice of speaking. Strictly speaking, only sets of logical propositions can be regulated entirely. Yet architecture is about culture, not about truth values. Our only grounding anchor thereby is throughout all of the projects that they need to actually function in practice - both in economical terms as well as in terms of technology.

In the following we would like to introduce some of our work, before elaborating in the concluding chapters of this paper in somewhat preliminary terms on how, in the future, it will be important to work on finding also a theoretical abstraction to these examples. Because they represent, rather strikingly we think, the imbalance between what we actually can do and what we are doing, in practice, and what we know and understand of what we are doing. This perspective suggests that the topic of sustainability, and what architecture can contribute to that, ought to become an issue not only on the level of particular implementations, such as throughout the conception, planning or construction of a ‘sustainable’ energy management of a particular building. The examples provide a fresh perspective on how we are practicing architecture in a style, in which digital technologies provide a means to introduce a certain extent of reversibility and reconfigurability into the various processes. This is not only just in line with the general trend fuelled by digitization; perhaps even more important is that it opens a new scene of exploration for *what-if's*, a scene which is limited *on a primary level* by our imagination. In practice, this will deeply redefine the relationship between what we regard as concrete and what we regard as volatile, between building and inhabitant, between builders or architects and their clients.

3.1 Moderating competing ways of reasoning on the level of construction engineering: The Birds Nest

The ‘Bird’s Nest’ is the popular term for Beijing’s spectacular Olympic Stadium, designed by the Swiss architects Herzog & de Meuron. The seemingly randomly ordered steel beams of the roof construction are an illustrative example of the gap between the representational possibilities of a digital model and the feasibility of construction using current materials: What can be put together with comparative ease in Photoshop can lead to a variety of problems on both the drawing board and the construction site.

For the competition, the front elevation of the Bird's Nest was composited in Photoshop. With the competition won, the rear elevation had to be constructed - something that posed an insoluble problem for the then-current CAD tools. For aesthetic as well as structural engineering reasons, and because of the assembly technology, the openings between the steel beams had to fit within a certain size range: neither larger nor smaller than a certain dimension, and certain angles where the beams crossed had to be preserved. As mentioned before, in Photoshop this seemed to pose no problem. However, for the rear elevation - which is tied intimately to the positions of the beams in the front elevation - this was not an option. The irregular ordering of the beams meant that this problem simply could not be solved by hand. As soon as a gap was closed on one elevation, a gap would open up on the other - it was like a puzzle with far too many moving parts, each one influencing the others.

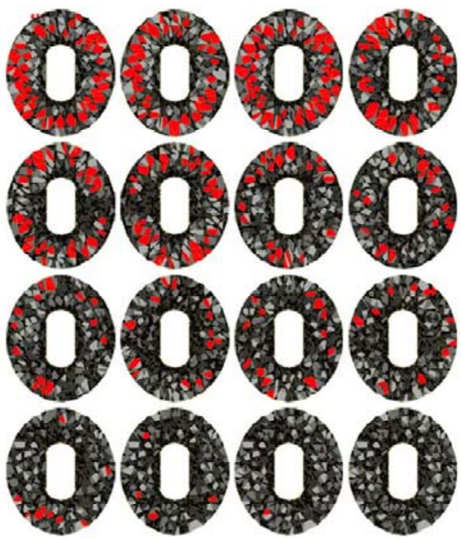

Figure 1: A view of the Beijing Olympic Stadium during various phases of the evolutionary problem-solving process. The task was to place the steel beams so gaps between them were neither too large nor too small (marked in red). Starting with a random ordering (above left) and using inheritance and mutations over 100 generations, an evolutionary algorithm eventually proposed positions for the beams to generate a problem-free solution (bottom right)

Our approach was not trying to master the drawing ourselves, but to distribute the problem onto the level of a 'population' by developing an evolutionary algorithm that would in the end deliver the solution to us. We started off with the 'mother of all solutions': A completely chaotic ordering of the beams. We took, for example, 100 beams, giving us a genetic code for the solution with 600 variables, since the position of each beam can be exactly described by coordinates in x, y, and z and the rotation of each beam by angles of x, y, and z. The first and completely random ordering of the beams threw up a catastrophically high number of errors. We then generated five copies of this solution. However, each copy differed slightly from the original, because we had randomly changed the values of the variables and thus the positions of the corresponding beams. We had let the genetic code 'mutate,' so to speak, and these mutated versions generated solutions with fewer problems.

The solution with the fewest problems was copied/mutated anew, and we again chose the best solutions that were generated, and we kept repeating this process until after 600 generations, we had found a solution that exhibited none of the initial problems anymore. You could say that we had 'shaken' the complicated roof construction for so long, letting the individual members fall where they may, until we finally arrived at the correct solution. This 'platform' to moderate the conversation of competing ways of reasoning (alias a particular formalized model) is one example of what we mean by narrative infrastructures for architecture as an ongoing story-telling, on the level of how to conceive solutions for architectural construction. A note perhaps as to why we call it story-telling: by trying to communicate how we actually ended up with our proposed solution, we cannot reconstruct the problem-solving process in any detail. We regard each model as a 'mathematical fiction' because we could not possible tell the same story twice. This process exceeds the problems on computability in that they are working on a somewhat 'hermeneutic' level. The result cannot, therefore, claim in any strictly scientific sense of the word something like a positive objectivity.

3.2 Moderating competing ways of reasoning on the level of conception and design: The Design 'Automaton'

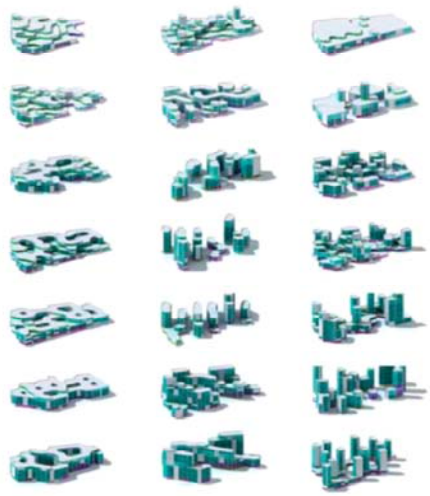

Figure 2: While using the same space allocation plan, different architectural layouts are generated, dependent on the weighting of the various qualities (e.g., view, length of paths, insulation, provision of vertical accessibility); the layouts are shown as 3-D-models here.

In our system, instead of generators, oscillators, modulators, amplifiers, and filters, our synthesizer has rules for the lengths of paths, for neighborhoods, insolation, ventilation, site axes, story heights, axial layouts, and far more besides. Such a machine is capable of taking a complex spatial structure and producing an architecturally feasible site plan according to its initial programming parameters. The results are rendered photo-realistically and entered into architectural competitions. Thus far, we have been able to achieve a fourth placing, but unfortunately no wins. Can architectural design, therefore, actually be automated? Of course! But it's the wrong question. Long live architecture!

3.3 Moderating competing ways of reasoning in situ, on the construction site

In this project we were interested in finding a way to mediate between the specialized expertise to implement high-end technology for intelligent buildings with the skills of craftsmanship and experience of local construction industries. The construction industry is - at least in Western industrialized nations - the industry with the highest gross value creation. It is higher than that of the food, pharmaceutical, engineering, insurance, health, or tourism industries, but this aspect goes largely unnoticed. Unfortunately, the construction sector does not have a very good reputation and has low prominence. This may be due to the fact that in large parts, it remains dominated by artisanal skills with only pockets of academic or even industrial activity. For this reason, it bears an enormous potential for further development.

As long as architecture focuses on the formal level of design and spatial planning, by creating new geometries, new design languages, new planning processes and construction methods, our contribution to the value creation chain is largely paid from within the marketing budget or, in the best case, from the architecture practice's fees. Our challenging idea was that if we successfully abstract from the built forms and architecture, and manage to standardize and industrialize the building process of everyday buildings, our contribution to the value creation chain increases from within the per-mille range of the total investment of a building to a potential 30% value add. This would not take place in some niche market, but in the biggest market in our national economies.

The extraordinarily great challenge thereby, of course, is that the 'solution' for this problem would have to take into account *every form conceivable, now and in the future,* if it wants to be a sustainable solution. As such, it involves a kind of thinking that is genuine to information scientists: Namely to dissolve any aimed-at process into a procedure that can be formalized in terms of rules, and the identification of constants as the necessary complement to the procedure. We simply applied the same kind of thinking to architecture - thus we did not think of industrialized building as the necessary subordination of architecture to a narrow (because technologically optimized) system, but the other way around: We set out to design a system that can function despite its openness to continually integrate new developments. We try to achieve this by strictly separating the formal and the structural domains - the freedom on the level of form is obtained because of a remarkable structural stringency.

The pilot-buildings of this project are constructed following a three-stage model. Firstly, the building shell - and with it a large proportion of the difficult-to-transport materials - is constructed on site, for example, in concrete. Any kind of complexity is being removed from the building shell: No complicated massing, no demands placed upon the tolerances, always the same interfaces to the building technology, and so on. This makes it possible to have the building shell erected by local firms without any special directives or implying any particular risks. The more complex technological aspects of the building (the sanitary installations are excluded from this consideration) were clustered into the facades. The facade elements are produced with modern industrial techniques, rather like cars. The technological kernel consists of a modular concept of decentralized, intelligent building technologies for all aspects, such as climate control, ventilation, lighting, solar protection, electrics, data, communication, security, audio, and far more. This mostly identical technological kernel is being individually packed into facade modules, that can be freely designed. With these technologically autonomous facade modules we clothe the ‘dumb’ shell according to the architectural design, and mount the shell with cutting-edge technologies. The facade modules are connected by software so that the whole building works, as planned, as a high-level system. In the third step, further construction is carried out again by local firms on site. This stage requires consideration of the individual needs of the client. Fortunately, however, it is already relieved of any technological complexity, since the intelligent technological modules can be customized to a wide range of individual needs through software. Concerning their traditional elements, the buildings remain within the remit of the local, and perhaps more artisanal building industry. Here, the buildings may differentiate further, in spite of or just because they are standardized on the level of the building services engineering.

3.4 Moderating competing ways of reasoning within a collective body of experience: Architectural Google

Working from and with references is professional routine for architects and urban planners. Earlier projects constitute a valuable body of experience. Drawing on analogies can serve the illustration and communication of ideas and the determination of specific characteristics, or it can serve as a starting point for further planning. Yet until now, architectural experience has not been amenable to standardization or storage and retrieval. In the best-case scenario, the architect will remember a suitable design solution from personal experience, will be able to draw upon collected projects from within the practice or go back to catalogues of standard plans. The search follows either a subjective and limited selection or a rigid ordering principle. The collections are organized according to certain formalisms or standard forms, and the examples can only be found if the search can be described in the forms. Above all, this constitutes an abrupt change of the scope of the description; the plan will, one way or another, get shoehorned into a standard form. This procedure is, therefore, far too constricting for the storage and retrieval of architectural plans and drawings. Because of this, architectural offices are far too dependent upon the personal - and limited - experiences of the people working there. In comparison, searching and browsing the Internet using one of the larger search engines, such as Google, clearly yields a wealth of results, even if the profusion of irrelevant hits may sometimes be annoying. Still, the advantage remains with Google & Co. that you don’t have to use a predefined form for searching that would demand the aforementioned change in the scope of description; rather, they look for articles containing the text fragments entered. The structural limitations of predefined search forms - with their specific notions about the structure of the possible contents - simply disappear. And despite all the moaning and calls for improvement, it would simply be unthinkable to do without these search engines, which we use on a daily basis. Google, in particular, only gained its pre-eminence because, with its link and usage-based page ranking system, it did away with the need to understand the meaning or to evaluate the information content at the explicit level of the text. The assignment of meaning was left to the user - or to the community of users - of the search result. The user gets the impression that the search engine somehow ‘understands’ the question posed, when in fact it only returns a list based on the usage and linking of indexed articles. Naturally, this gives better results than the textual-analysis algorithms that are known today - in our opinion, a groundbreaking concept for understanding the potential of information technology. Admittedly, there is still no convincing mechanism by which drawings can be searched on the Internet as easily as can text. Together with Professor Matthias Castorph, from the University of Kaiserslautern, we have put together a catalog containing, as of this writing, 1000 ground plans for dwellings.

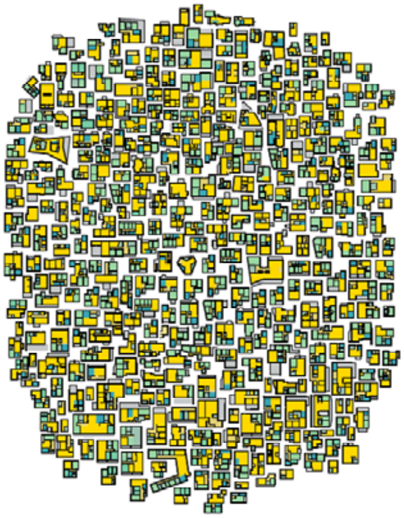

Figure 3: Indexed ground plans of the catalog represented as a scheme.

The geometry, dimensions and topology of these ground plans are translated into words and sentences, and are therefore made searchable by engines such as Google. And with no small success! We can now enter a fragment of a ground plan as a search term in Google, and entire ground plans containing that fragment - or similar fragments - will be returned as search results. What would happen if we used this indexing machine upon the entire building stock of Switzerland, and if we - as in project CRB online - make it available to every architect? New methods of working, new methods of teaching and learning, new business models, and new architectures would, undoubtedly, result.

4 Towards a medial architectonics

The declared goal for our projects is to use the aid of computers to find ways in which to an ever increasing degree, varying mindsets, expectations, evaluations etc. can be integrated into functioning architectural models. All of these examples involve, in a way that is constitutive for the resulting practice, the moderation between different ways of reasoning: architecture in the times of our contemporary media culture. With this approach, the CAAD Institute at ETH holds a somewhat uncommon profile.

The two predominant stances according to which we relate to the world today are those of science and technology. Both of these stances are characterized by the attempt to focus on a certain ‘positivity’ of the world that is held to be ‘primary’ to any interpretation or subjective valuation. This positivity is sought by thinking of the world in terms of a closed system, or a set of (interrelated) closed systems, which can be analyzed as well as constructed by means of logics (as a set of rules) and the constitutive ‘elements’ in the purely formal sense (as particles belonging to a set). Being aware of the stormy developments since the beginning of industrialization some 150 years ago, this is really not surprising! If a mechanism can be proved to function, then why should we not regard it as a contribution to the steady process of deciphering the structure of the world? Why not regard it as a lappet of ‘truth’? It is admittedly extremely tempting to reorient our ancient search for ‘meaning’ as the negative complement of this ‘progress’ in the field of positive science. Yet at the other end of this road we can be quite sure about the lurking presence of what might be called a ‘technocracy of the feasible,’ confronting our seemingly infinite possibilities with ‘factual necessities’ wherever our cultural values of diversity, difference and individual freedom ought to be negotiated. The current debates about ‘informational self-determination’ is but one of the most acute examples here. And yet, we seem to forget that any withdrawal to ‘factual necessities’ is so strikingly at odds with the great imagination that has driven the manifold differentiations of technology into our everyday life. There has been an incredible spelling out of technological narratives since the early geometrization of technology, the mastering of fine mechanics and the subsequent quest for general principles of construction. We have learnt to understand mechanical construction principles, the logics of how to operate them ever more powerfully, and for some 100 years now we are concerned with inventing ever new instances of precision engineering ‘that function’: Today, there are more than 500 billions of electronic devices active all over the world. We think that this is absolutely fantastic. But we think it is crucial to stress the imaginary power that drives this development: Technological progress in our times of the information paradigm is not about ‘truth’ anymore, the ‘nature’ of our technological means is imaginary. The mathematics they operate with is the space of complex numbers, ‘functions’ as the epitome of mechanic systems processing physical power have turned into ‘mappings’ between sets of symbols. They operate in complex ‘problem spaces’ and reveal a multitude of possible and well functioning ‘actualizations’ - whole populations of instances of solutions that actualize in one way or another, relative to the overall behavior of the network in which they are embedded, and relative to the way we look at it. Relative to what we expect from it. It would be a dangerous mistake to assume that such a technological system follows an inherent logic which must be ‘true,’ or ‘good,’ because it ‘functions.’

Many people are getting aware of that. To conceive of the world in terms of a vast number of fully determinable systems, and the exploit and operationalization of it’s ‘compartments’ overstrains our planet. Figuratively spoken, speaking of climate issues suggests that the system we call the world is -for all we know today - an openly determinable one; that our behavior has consequences on the system itself; that in a very existential sense, we *are* in fact the planet: we *are* nature, we *are* the weather, we *are* the stuff, we *are* the energy. A closed conception of the world as a well-described container - as expressed in the popular saying ’nothing new under the sun’ - reveals itself as too narrow for dealing with the ever increased efficacy of our technological cultures. Some people urge to decelerate or even stop the velocity of these developments, many hold that if we only keep on pursuing our investigations of ‘nature,’ we will eventually find out how we can solve the global problems that increasingly enter our awareness. To our mind, both of these stances are as understandable as they are insufficient, practically as well as theoretically. We will need to develop a more elaborated attitude towards experimentation, since we construct and destruct what we call ’the world‘ through experiments which take the world as matter, milieu, subject, and outcome at one and the same time. This new attitude towards experimentation probably needs to be of a less representational or purely operative style, and more anticipative in focus. We also need to develop a certain awareness of what it means to abstract from the elements of nature. That sort of development directed towards identifying ‘elements’ can readily be seen as both, the blind spot as well as the driving force of our cultural evolution.

The articulated joint to understand this perspective is geometry and the role it has played in Western cultural history. The beginning to geometrize technology in early Renaissance, and in consequence the systematic knowledge about construction that characterizes modern science, has had an earlier precursor in ancient times. No one was accepted at Plato’s academy who was not familiar with geometry, as the historians of philosophy will not get tired telling us. There is an ancient relation between the art of organizing territorial planes and the handling of ideas. Ever since the invention to speak of something like ‘nature’ at all (instead of one conception of a mythological being or another), as a ‘system’ whose structure we can learn to understand and know, the formal system of geometrical knowledge with its axiomatic method, with its elements and deductions has been crucial for the conception of ‘nature’ as well as for our process of engaging with ‘nature’ intellectually. Geometry has, roughly speaking, allowed to support the claim that there can be a ‘method’ to distinguish ‘true’ ways of speaking about the world from ‘false’ ones. Obviously, it is the style of thinking inherited into any aspect of our culture through geometry which has become problematic. Of course such a linking between the elements of geometrical shapes and the elements of nature involves metaphysical assumptions that have proved to be all too easily transformable into the dogmas of the dominant religions. The modern revolution of science was thus to a large part motivated by overcoming the constraints of this history, and the geometrization of technology with its subsequent mechanological world view has played a crucial part in this. Nature was not a book to be deciphered anymore, but something we can learn to understand by learning to operate and control its principles of construction. The mathematical symbolizations of these principles, so the new ‘dogma,’ are ‘right’ not when they match one set of metaphysical assumptions or another, but when they function as mechanisms which act on simple elements. Just how much the great success of this approach has in fact strengthened the philosophical meaning of geometry for the modern understanding of science can perhaps best be seen on the great crisis of the foundations of science around the turn from the 19th to the 20th century. This crisis was significantly brought about by the pragmatic success of a new kind of mathematics we have already alluded to earlier in this text, a kind of ‘deterritorialized’ analysis involving a kind of numbers that were, explicitly so, only accepted because they were functioning in the implementations of electronic engineering - such functions were explicitly called ‘monstrous’ functions by one of their inventers, Kurt Weierstrass. He has called these ‘functions’ monstrous because their operations lack a geometrical representation. Mathematics as the backbone of modern science has been brought to deal with the situation that intuition, e.g. in the form of geometrical representation, and the necessary axiomatics to provide its foundations, can no longer be conceived to fall together. Meanwhile, this has even been proved in the mathematical sense of the word by Kurt Gödel, with the consequence that we can no longer assume there to be a kind of knowledge which can be grounded in nature - here is no ‘naturally’ secure knowledge at all. While the gesture to geometrize technology has allowed for the efficacy of pre-modern 19th century technology, electrical technology can no longer be understood within the same mindset. It is not any more operative just within the element of physical forces. The ‘element’ of electrical, and even more so of electronic technology is genuinely symbolic. Its operation principle is not what is ‘natural’ (e.g. physical) anymore, but what we can imagine it to be. And, as we need to add with emphasis, what we manage to imagine and implement in a sustainable way. It is with this tendency to symbolizations as it has begun in the 19th century in a free-climbing manner, so to speak, i.e. without apt conceptual infrastructures to support their outcomes, that we can locate something like a nebula of beginnings for our contemporary way of life. And without much wild speculation we can already guess that this trend towards volatile symbolization will intensify and flash over into many more areas, even into that of concrete building construction.

An entirely new plateau has opened up from those developments. More and more we realize, that here, we are no longer successful in making sense of what is going on by withdrawing to definite, causal relationships or the possibility of external allocations or precise references; cycles, balances, the concept of negotiation and competition have come to play a ‘fundamental’ role today. We put the term ‘fundamental’ into quotation marks because strictly speaking, it seems as if we need to leave behind the very idea that it might be possible at all to find ‘foundations,’ out there somewhere in ‘nature,’ once and for all external to what we are doing, which would legitimate our actions. ‘Nature’ on the new plateau is no longer ‘natural,’ so to speak. Curiously enough, contemporary technology confronts us with a strange kind of self-referentiality. Technology isn’t a neutral thing any longer, somehow external to the human self-conception, we are increasingly getting aware of technology’s influence on what we conceive to be ‘human.’ This self-referentiality can elicit disastrous consequences, but it need not. It is as hard to give any exact prognosis how people will harvest the enormous potential of the ‘system’ for creativity, as it is easy to guess that the systemic creativity will increase the desire for intensified symbolic metabolism in the realm of social. To put it short, the coming societies will elaborate explicitly on ‘non-natural’ symbolization and the medial milieus which we will want to inhabit, even when it comes to the concrete level of buildings and the surfaces of ‘things.’

The new mindset will need to incorporate into its then medial architectonics the possibility to operationalize of the principle ‘openness,’ or in other words, ‘virtuality.’ This perspective will be elaborated further in the concluding paragraph under the focus of applying this open potential which we call the virtual.

5 Applied Virtuality

Let us imagine the following: what if we were in fact already capable of implementing the principle of ‘openness’ as an operator into our concept of applied sciences, or in an enlarged sense, into the engineering sciences? What if the systems we are able to control technologically need not anymore ‘duplicating’ what we have learnt to understand as ‘natural’ throughout the past 2500 years within controllable artificial circumstances? This may appear more fantastical than it actually is. From a technological point of view, ‘nature’ has been what provides us with energy - to cover our existential needs such as having enough to eat, keeping warm enough to survive the inhospitalities of weather, what allows us, broadly speaking, to inhabit and cultivate our niche in this world. The natural energy resources, in turn, have always been ‘powered,’ if you want, by one cosmic energy source: the sun. The finite resources of energy are whole cascades of storage capsulation, from the plants to the sedimentation and transformation of organic materials within the ground, to the animals feeding on these resources. Until now, we have only been capable of indirectly ‘harvesting’ the energy we need. We harvest or exploit it from the produces of the various ecosystems, or from the so-called renewable sources like wind and water. Both of these ways to tap into the cosmic energy flow are indirect - they depend on the ‘natural distribution system’ of that infinite energy stream. With the comparably recent invention of solar technology, the whole situation is changing. We can now plug into the solar flow directly - and this turns our culture into an ‘ecosystem’ of its own. We can metaphorically ‘photosynthesize’ by driving our processes with the electricity gained from the solar radiation. The flow of solar energy exceeds the global needs of today by a factor of 12’000. Our digital energy future will bring us an abundance of potential power, which is be capable also of solving the problem of shifting the CO_2 balance of our globe. Yet it will bring about a new and rather existential challenge: the need to conceive of culture on the basis of principles of elementary abundance instead of scarcity.
We take this step to be infinitely symbolical. Our culture needs not be a sphere that exploits the products of other ecosystems anymore. But this also means that the inherited inner principles of how we have so far

conceived the milieu in which we live cannot provide us with the necessary orientation to evaluate the consequences of our actions. Our architectonics of knowledge has evolved from the age-old experience initiated perhaps with the Neolithic Revolution for which the domestication of the natural streams of energy (alias animals and berries, winter storms and summer heat, draughts and flows of rivers etc.) has been characteristic. While fire, flames and combustions have allowed us to invent the respective tools and eventually also technologies, we are about to abolish this principle from our energy equation altogether. In many ways, we are finally leaving stone age, characterized by the dependence on limited capacities of biological systems to harvest energy and by the dependency of mineralic sources of energy. Amazingly, the resulting cultural-technological structure itself resembles much the geophysical weather system and biological ecosystems. Tapping the solar flow of energy just like clouds and plants do, storing and densifying energy like organisms arranged as trophic pyramids are capable of, distributing energy like the weather system and metabolizing and producing just like 'natural' ecosystems. The vast flow and dissipation of entropy will heat the metabolization of our cultures, thereby increase cultural 'productivity' and quite likely eventually lead to cultural radiation and intellectual as well as physical mobility. Remarkably, all of which can be achieved by zero effect on the global total balance of energy.

Our ways of reasoning which have evolved from our experience in domesticating territories must now give way to a new kind of reasoning yet to be invented. Instead of inhabiting territories, based on the exploitation of the resources we can find on and in the ground, and based on the refinement of mechanical technologies to manipulate, control and administer these scarce existential basics, in the beginning to realize that weather and climate in fact get a cultural subtext. From an engineering and architectural point of view, the challenge consists in inventing genuinely electronic 'irrigation techniques,' in developing infrastructural 'plug & play devices' for cultivating and solidifying the wild and abundant streams our new cultural habitat currently consists of.

The crucially new characteristic of this beginning era, which we propose to call the 'Metalithicum,' is that our technological systems do not duplicate nature. It is us who are creating quasi-natural surroundings for us to inhabit.

Before this background we think that in many ways, engineers have always been the experts of the kind of integrative thinking these developments call for. In their constructions, they allocate and secure principles and ways of how to reproduce an ever increasing range of the ever increasing differentiations of *what-we-can-do*. By that, they are substantially contributing to creating the infrastructures and standards from where new differentiations, onto a next level, can be risked and explored. Now let us again take a closer look at our concern with 'integration.' Integration, we have seen, is about identifying the domain where the performance of certain functions can be carried out in an unproblematic manner, so that no conflicts with the performance of other functions arise from it. A considerable part of the work of engineers is concerned with identifying modules that count as 'elementary' and with creating the interfaces of these elements to other elements so that they can function as 'modules' that can be systematically combined. This transformation takes place by integrating the various sets of rules regulating these elements, so as to establish their compatibility. Even though the difference between 'elements' and 'modules,' for most information scientists, is largely being disregarded, it is in fact a crucial one. Consider, again, the same kind of reasoning within information technology, but in the realm of physics. Here, the process to identify the elements is strictly guided by the two universal principles, by the law of gravitation and that of the dissipation of heat: These two principles grant that any natural body will be affected by them *in exactly the same way*. As 'universals of physics' their role is to legitimize the generalization of any particular outcome - each calculation needs to be transferable to situations that are 'like' the ones analyzed.

In the new era of the metalithicum, we would inevitably go wrong if we related the local to the global just like in the physicalist paradigm the point is related to the field - each being, essentially, conceived as being of the same nature. This would mean to conceive of the 'local' as a spot within an overall grid, where the positionings are basically exchangeable. In the realm of cultures, Miguel Torga's sharp formula is quite telling: "*The universal is the local without walls.*"[1] Without needing to engage in the philosophical dispute surrounding these issues, we can consider ourselves on common grounds with most people when pointing out that at least what we traditionally call the realm of culture, the assumptions to ever find such 'universals' has turned out to be highly problematical if not altogether absurd.

[1] cit. in: Peter Sloterdijk. Weltinnenraum des Kapitals. Suhrkamp, Frankfurt a/M. 2005, p. 400.

The main question for how we understand the potential of our discipline could thus be stated in the following way: How can an engineering approach provide secure and trustworthy infrastructure without needing to act out the somewhat odd role of mere functionaries in the service of conserving established orders? How can we build infrastructures by enacting an open approach to our technological applications when integrating differential equations into systems on the volatile grounds of deterritorialized analysis? Which kind of secure infrastructures can we conceive of, so that they might fit to the global trend of democratization? There is a fundamental imbalance between what we *can*, and to a larger or lesser extent actually *are doing* in practice, and what we can reasonably say to know and understand of what we are doing; the emerging awareness of the fragility of our climate and the urgent call for 'sustainable thinking' is but an expression of this imbalance. At the core of this symptom, we think, lie the mentioned and largely unquestioned assumptions about the relation between what we conceive as 'nature' and what as 'technology.' If the contributions of engineers and architects to the issue of sustainability ought to be effective beyond the level of particular implementations of particular optimizations, and extend onto a generic, structural level, it will be important to question the way we have learnt to conceive of this relation. The elements we are dealing with today cannot simply be called 'natural' anymore.

Unlike a somewhat dominant vector in computer culture to consider the transformative potential of digitalization as a potential that arises from better and better mastering complicated problems by *snapping-to-the-grid-rationality* at ever finer scales, our work at the CAAD institute explores a potential of this same development that we see arising from what we call, by lack of an apt concept at the time being, *beyond-the-grids*[2]. With the spreading of information technologies into everyday situations, and with the unprecedented accessibility of knowledge on the open platforms of electronic media, we are experiencing something like the *popularization phase of the analytical revolution*. Proportional to the fruits of modern analysis, and to the enlightenment program as a whole, there not only comes a certain freedom *to synthesize*, to *build models*, but also a responsibility that accompanies it. Increasingly so, also the broad public is urged to deal with that. And the experts are urged to deal with the public wanting to have a word in the affairs for which they still hold the experts responsible. Trying to balance these two forces, the task of engineering all too often ends up with taking a regimenting, if not at times even a normative role - whenever they join forces to push standards in a top-down manner. In a first step, we think, the potentials of information technologies lies in familiarizing us on a population scale with the new 'common grounds' of 'potential knowledge' to be moderated by knowledge not of 'experts' but of people who have the capacities to realize imaginations. The societal architectonics, which for sure will influence the architectural aesthetics, is all about how to create sustainable conditions for realizing those imaginations.

We hope that the presented projects from our field of Computer Aided Architectural Design have given you an idea of the direction we think this could work in the future. Our current research will concern theory building as a way to abstract from these experiments. We will pursue this research in our newly founded Institute for Applied Virtuality.

[2] For a more extensive and detailed documentation refer to: Ludger Hovestadt. *Beyond the Grid - Architecture and Information Technology. Applications of a Digital Architectonic.* Birkhäuser Basel / Boston 2009.