Navigating Towards Digital Tectonic Tools

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Abstract

The computer holds a great potential to break down the barriers between architecture and the technical aspects relating to architecture, thus supporting innovative architecture with an inner correspondence between form and technique. While the differing values in architecture and technique can seem like opposites, the term tectonics deals with creating a meaningful relationship between the two. The aim of this paper is to investigate what a digital tectonic tool could be and what relationship with technology it should represent. An understanding of this relationship can help us not only to understand the conflicts in architecture and the building industry but also bring us further into a discussion of how architecture can use digital tools. The investigation is carried out firstly by approaching the subject theoretically through the term tectonics and by setting up a model of the values a tectonic tool should encompass. Secondly the ability and validity of the model are shown by applying it to a case study of Jørn Utzon’s work on Minor Hall in Sydney Opera House - for the sake of exemplification the technical field focused on in this paper is room acoustics. Thirdly the relationship between the model of tectonics and the case will be compared and lastly a discussion about the characteristics of a tectonic tool and its implications on digital tectonic tools will be carried out.
Introduction

Sketches, physical models and words are integral tools in the architect’s repertoire; that can support the architectural process. While these tools have been present for centuries, the palette of tools is today - since the introduction of drawing programs in the early 1980ties - increasingly dominated by computers. The application of computer programs in architecture comes in various shapes – from the two-dimensional drafting that can be said to mimic the traditional techniques of the pencil drawing to the three-dimensional modelling and parametric designs. These tools are to some extent already integrated into the architect’s work while the full potential of the computer’s ability to make technical parameters accessible is still to be explored. The potential of breaking down the barrier between the technical fields and architecture is that it becomes possible to develop innovative tectonic solutions by reinstating the architect as a master builder of the digital age.

A natural backdrop for a discussion of the breakdown of the barrier around technique in architecture is the term tectonics that deals with the connection between the scientific and artistic aspects to create architecture. To understand what we should expect from a tectonic tool a closer look into the term tectonic is taken. The term is described by Kenneth Frampton (1995), Eduard Sekler (1965) as well as many other theorists. Sekler writes:

‘When a structural concept has found its implementation through construction, the visual result will affect us through certain expressive qualities which clearly have something to do with the play of forces and corresponding arrangement of parts in the building, yet cannot be described in terms of construction and structure alone. For these qualities, which are expressive of a relation of form to force, the term tectonic should be reserved.’

Sekler thus emphasizes two distinct set of values in tectonics; the expressiveness and the ‘play of forces’, meaning the technical dimension. It seems evident, then, that in order to obtain tectonic architecture, a double focus is needed in order to see the work of architecture as a synthesis of technique and aesthetics.

Recently many theorists, such as Leach (2004), Stacey (2004) and Abel (2004), have emphasized the computer’s tectonic ability. Especially Leach is concerned with an inner correspondence between form and technique which is only possible to achieve by a focus on the very first sketches. He sees the computer’s ability to test designs in terms of technical ability as its primary tectonic capacity and describes the computer as “…an efficient search-engine that is premised on the notion of efficiency”. Leach envisions that the designer would supply the edge-conditions for the design and then with little interference let the computer decide the configuration with regards to structure, acoustics, environmental concerns, constructional or programmatic issues. While Leach is on the right track with a focus on interaction with the computer tools, his excitement about the new media lures him into accepting tools with a focus only on technical aspects and efficiency as tectonic, thus minimizing the architectural impact to a choice between a few options.

The aim of this paper is to investigate what a tectonic tool could be and what relationship with technology it should represent. For the sake of exemplification the technical field focused on in this paper is room acoustics but the findings are supposedly applicable to all technical fields. This is done firstly by a theoretical approach to the problem in order to set up a model of the values a tectonic tool should encompass, secondly to compare this model to a case study of Jørn Utzon’s work on Minor Hall in Sydney Opera House which is seen as a valuable resource in understanding the role of technology and its influence on tectonic architecture, thirdly the model and the case will be compared and implications to for a digital tectonic tool is discussed.

Theoretical model – a navigational tool

One way of setting a frame to discuss tectonic computer programs, is to begin with tectonics and to set up a model of the value system behind architecture. This is set up in a theoretical model – see figure 1. This model can – which will be presented in the case study – be used to identify the various values behind architecture much like we would use a navigation tool to tell us where we are positioned between different areas. Secondly it can be used to point out a direction towards tectonic digital tools – as will be done in the discussion - much like we use a navigational tool to set out a direction for our next move even
though this should not be seen as one route but rather a general direction.

Figure 1. Strategy for tectonic tools

The structure of future and current tectonic tools should make it possible to maintain the double focus which, as described in the introduction, is the main quality of tectonic architecture. In order to understand construction and structure as well as other technical parameters in building, a positivistic approach is needed, but to maintain that it is not only a technical solution that is sought but a tool capable of encompassing the bodily experience in the architectural field, the phenomenological approach is needed too. The model is thus an attempt to navigate in the reality as it is seen: tectonic architecture as consisting of both technical solutions and bodily experiences. These different values can be identified in the following quotes by Pier Luigi Nervi and Gaston Bachelard. A positivistic statement is expressed by Nervi, an engineer known for creating tectonic architecture:

"The design process is fundamental for the creation of buildings and determines their form from the first preliminary studies when the architectural idea is born to the final construction phase where every structural element is studied in detail. It can be defined broadly as the invention and study of the necessary methods to achieve a defined goal with maximum efficiency. (...)It would be senseless, in fact, to make a study which did not aim for an exact and concrete result, and which did not try to reach it with maximum efficiency, that is, a broadly defined efficiency not entirely limited by economic factors." [Nervi 1965, p. 105].

The positivistic approach is evident through the language used: ‘defined goal’, ‘maximum efficiency’, ‘exact and concrete result’ and ‘maximum efficiency’; only in the last sentence; where Nervi describes efficiency as ‘not entirely limited by economic factors’, other values are hinted, but not elaborated upon.

The other point of view, phenomenology, validates the bodily experience of architecture and, in the case of acoustics, enables a focus on the subjective feel for the sound. This focus does not acknowledge definite statements such as an ‘optimal’ acoustical room; rather it understands the human experience as subjective and closely connected to dreams and imagination. Gaston Bachelard describes in ‘The Poetics of Space’ how we perceive our homes:

"...all really inhabited space bears the essence of the notion of home. In the course of this work, we shall see the imagination build ‘walls’ of impalpable shadows, comfort itself with the illusion of protection – or, just the contrary, tremble behind thick walls, mistrust the staunchest ramparts. In short, in the most interminable of dialectics, the sheltered being gives perceptible limits to his shelter. He experiences the house in its reality and in its virtuality, by means of thought and dreams." [Bachelard, 1964, p. 5]

The emphasis is here on ‘essence’, ‘imagination’, ‘being’ and ‘thought and dreams’.

From these two quotes it is seen how different the actors behind architecture and engineering can think. The underlying assumption behind the model is that it is possible to unite these very different value-systems and that it is necessary to create tectonic architecture. This was also argued by Karl Bötticher, a nineteenth century German writer on tectonics (Schwarzer, 1993).

Another theoretical support is the field of social constructivism in which many writers work with dissolving the barriers between technology and society. While the ideal for scientific knowledge in the positivistic tradition is that it is objective and free of value from the researcher and the surrounding society, the work of social constructivists deals with understanding how this actually is not the case and that how and what scientific knowledge is produced, is indeed closely connected to society. A social constructivist, Bruno
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Latour (1988), argues that the access to and ability to apply technology, is to have power and that the ones in charge (the Princes in Latour’s terminology) actually aim at achieving this power; “The two most common clichés about technology, its inertia that would be too strong for anyone to resist, and its inner complexity that would be too much for any one to fathom, are real enough, not as the cause of the Prince’s moves, but as the effects that the Prince strives to achieve.” (Latour, 1988, page 38). Let us for a while imagine that this is true – that technology is not characterized by inertia and complexity but rather should be seen as active and simple, then it becomes much easier to imagine a softening of the edges between technology and architecture and to imagine tectonic tools that can close in on the middle of the model in figure 1 and create tectonic architecture.

This middle-part of the model where the values overlap is the position of the values that is necessary if we should be able to develop computer tools to support tectonic architecture. The technology should in tectonic tools not exist on its own terms but as a support to develop tectonic ideas. This means that these programs are significantly different in interface and functionality than the programs that exist within the field of architectural and technical expertise today.

Social constructivism concludes that technology is not value free but should be understood from the relationship with society. In the context of computer programs it means that the computer tool, as a technological device, is subject to interests. The social constructivist frame of thinking thus enables us to see the current state of computer programs merely as a symptom of the values behind them.

Narrative - Minor Hall in Sydney Opera House

Having argued for the theoretical possibility of a break-down of the barriers between technology and architecture, the existence of such a break-down in reality is sought for in the study of a real-life case. In the case study the model will be used to identify the different values held by the actors, thereby achieving a closer understanding of the role of technology in the architectural process.

The case study chosen is the development of the Minor Hall for the Opera House in Sydney. This is chosen because it is seen as a valuable resource in understanding the role of technology and its influence on tectonic architecture due to Utzon’s insistence on a tectonic solution. To zoom in on the interplay between the agents and their values in the architectural process, Henriksen’s theory of reality – describing four aspect of reality: facts, logic, values and communication (Henriksen et al, 2004) – is applied.

First we need some facts about the case in order to be able to analyze the development and recognize different values. In his competition entry from 1956 it is obvious from the drawings that Utzon had not thought much about the interiors of the halls or of the realization of the structure as a whole. The competition brief asked for a Major Hall which should primarily cater for concert recitals for an audience of 3000 to 3500. A secondary use for the hall was to be opera with no specified seating requirement (Nobis 1994, p. 13). The Minor hall was to be used for theatre performances and seat around 1100.

After having won the competition in 1957, Utzon immediately began work by gathering a team of advisers and collecting their reports in a document known as the Red Book (due the colour of the cover). In the field of acoustics the Danish acoustician Vilhelm Lassen Jordan was hired. The halls showed in the Red Book (March 1958) were primarily done by Jordan which Jordan himself hints at in the quote: ‘Without analysing the cooperation between architect and acoustician too minutely, it is fair to say that regarding this first design, the acoustician was responsible for many suggestions.’ (Jordan, 1980, p. 95). This is further supported by the fact that Utzon himself does not mention this proposal at all in his Acoustical Report from 1965, that recaptures the design development of the halls.

The drawings for this first proposal shows a hall which seems to be inspired from traditional classical halls called shoe box hall for their rectangular floor and ceiling and straight walls. Jordan describes the halls in the Red Book with the remark "The proportions of the area are 2:6:7 (mean height: mean width: depth), which is appropriate for a typical theatre hall, where the stress is laid more upon definition than reverberation." (Nobis, 1994, p.33). The proposal did not have any familiarity with the organic shape
of the sails and it turned out that the proposal did not fit geometrically under the curve of the sails.

For the next years Utzon and Ove Arup, the construction engineer, were fully occupied with the construction of the podium and the sails and it was not until after the Red Book (from March 1958), that Utzon began to be more involved in the design of the halls. In a meeting in mid-1958 it seems that Jordan has been asked to explain some of the fundamentals of acoustics to the architects. He explains how the volume is determined by the shape and functionality of the room and comments on the shape of the surfaces "In Minor Hall the curved surface can be accepted if the surface is highly absorbent" (Author’s translation) (Minutes of meeting 30.6.1958).

Utzon and his employees developed a scheme he called the 'stepped-cloud’ – see figure 2. This is described as the first scheme by Utzon in his Acoustical Report from 1965. One of his former employees Yuzo Mikami, who drew the proposal, recalls the beginning of the development

"Jørn asked me to work on the new design of the Minor Hall auditorium. He took me to a nearby seashore by the Sound in Hellebaek, where the gentle movement of water formed the ridges of waves one after another. The continuous ridge went up higher and higher as it came nearer to the shore, and finally the crest of the wave began to break, overriding the ridge and coming down with a drumming sound onto the wet sand on the beach. We watched the movement of the waves for quite a long time. It was very dynamic and breathtakingly beautiful. Every one of the waves showed a different character in its movement. Jørn said,"Yuzo, can't we design the ceiling of the Minor Hall something like that?" whilst looking at the breaking crest of the waves." (Mikami, 2001, p. 118)

The ceiling of the Minor Hall was conceived as segments radiating from the centre of the stage, each segment having a curved concave shape. The radial configuration would focus the attention of the listener towards the stage, to where the sound was coming from, and would enable entrance to the hall to be hid between the segments. Utzon describes the effect "therefore, for the eye of the seated spectator the theatre appears absolutely closed, even when the doors are actually open" (Utzon, 1965). The first drawing of this scheme occurs in August 1959 (Nobis, 1994, p. 31) and the following three years the scheme is developed extensively. One of the most important aspects of the design of the halls, when addressed by Utzon, was that the experience of the halls should support the whole opera house experience, every aspect in the journey from the city towards the harbour - the rising up the stairs, the entrance into the southern foyer and following the shape of the halls under the sails to the entrance of the halls - were all part of building up to the climax; the performance in the halls. To him the relationship between the sails and the halls was therefore of uttermost importance. In a later interview with Peter Luck he described how he wanted the auditoria to fit under the sails like walnuts. "A walnut…when you see a walnut from the outside, you get a feeling there’s something inside, with a slightly wobbled form. And then you open up, you’re not surprised but it’s quite different inside, but it’s still in harmony with the outside. And I left the shells open so you could see up under the shells, feel the structure." (Nobis, 1994, p. 4)

From an acoustical point of view, however, the 'stepped-cloud’ scheme was not advantageous because of the concave curvature of the ceiling that would result in echoes and focusing of sound. However, Utzon actually did consider sound when the proposal was drawn. He saw the hall as a musical instrument in wood and tried to represent the sound as it radiated from the stage.

Utzon wrote in the Report on Acoustics "The first acoustical engineer to participate in the project was Dr. Jordan. He gave up at a certain stage when we
came up to a dead corner with Minor Hall…" (Utzon, 1965, p. 9), thus suggesting that Jordan was not able to give satisfactory advice regarding the new shape of the hall.

In 1960 Utzon asks Jordan for "a list of literature dealing with acoustical problems" (Minutes of meetings, 17.11.1960). Finally in 1961 Jordan is quoted for that he "agreed on the shape of MI-hall subject to minor modifications" (Minutes of meetings 16.03.1961).

In retrospect Jordan, however, describes the development as such

"In his approach to the design, the winner of the competition (the Danish architect Jørn Utzon) was obviously influenced, primarily by the simplicity of the Greek amphitheatre but also by some profoundly personal ideas, indeed sculptural conceptions, which were original to the point of being revolutionary in architecture, but which, unfortunately, had absolutely no association with the classical design of concert halls." (Jordan 1980, p. 92)

The ‘stepped-cloud’ scheme was presented in the Yellow Book, given to the Australian Government in February 1962 and was, despite its acoustical difficulties, accepted.

On Utzon’s return from Sydney, where he had presented the Yellow Book, he went to Berlin and Vienna. In Berlin he met the German acousticians Professor Lothar Cremer - one of the most important acousticians of this century, Professor Emeritus at the Technical University of Berlin - and Professor Werner Gabler – an architect specialized in acoustic spaces. The meeting is recorded in the minutes "Jørn Utzon explained the drawings for the Sydney Opera House. It was decided that Mr. Gabler and Professor Krämer should, with the help of a model, test the acoustics in the Sydney Opera House together with Dr. Jordan or as a second opinion." (Minutes of meetings 02.06.1962)

In the Report on Acoustic Research Utzon continues the quote above "... and I contacted Professor Cremer and Professor Gabler in Germany, whose halls I had studied and whose Berlin Opera House I admired very much. The Berlin Opera House had dimensions very close to my dimensions for Minor Hall." (Utzon, 1965, page 9). Both of the new consultants were send drawings of the ‘stepped-cloud’ scheme in August 1962. Cremer responds:

"The large radius concave curvature of the ceiling is rejected. Should such curvatures eventuate, their radius must be small. Particularly, the curvature of the rear ceiling area will lead to sound focusing onto the last rows of the stalls. Also of great disadvantage is the dome-like raising of the mid part of the ceiling with its large step toward the stage, in which the lighting is housed…This produces very strong delayed reflections in the middle of the stalls" (Nobis, 1994, p. 38).

Gabler drew a number of sections with arrows representing the reflections of the sound to explain the problems of the current scheme. Furthermore he included a number of suggestions as to how to substitute the large concave curvature with a number of smaller convex curves – see figures 3a/b.

In his report from 1965 Utzon remarks on his acoustical development:

"A number of laws clearly define when disadvantages such as echoes occur, and so on, therefore it is possible to draw on paper the shape which will, in an original way, give direct sound to all the seats. This is absolutely creative work. The shape which gives a certain amphitheatre feeling, as in the Minor Hall, provides the most brilliant and clearest sound from the orchestra pit or stage – it is creative work because such a thing as "This is right" or "This is wrong" does not exist. The solution can only be found by experiment and my experiment became actually realistic only after I had learned how sound behaves. It takes a long time, and good co-operation with acoustical engineers, to understand the properties of sound. On the other hand, it also took a long time for the acoustical engineers to understand the freedom with which my concepts allow us to work. Normally, acoustical engineers are repairing a fixed project." (Utzon, 1965, p. 2)

Furthermore he describes how he in Berlin was introduced to two rooms – one with only absorptive surfaces and one with only reflective surfaces and how this experience was important in his understanding of how sound is perceived and how it behaves (Utzon, 1965).
Figures 3a and b. Letter from Gabler to Utzon - diagrams explaining focusing effect of concave ceiling and to the right suggestion to change the ceiling from concave to convex [Source: Nobis, 1994]

Immediately after Gabler’s letter, the drawings being produced in Utzon’s office to develop the Minor Hall began to show a concern for sound paths – see figure 4. Nobis remarks that this was the first time such considerations were shown in the Minor Hall drawings and that it was investigated how to use the sound path differences as the determinant of the ceiling profiles (Nobis, 1994, p. 40).

The scheme was being reworked completely within a few months to encompass the convex curves – see figure 4b. A great deal of the intentions from the ‘stepped-cloud’ scheme, such as the radiation and the entrance to the hall, was retained. Nobis writes

"When one compares the new scheme with the one shown in the Red Book it becomes clear that Utzon has regained control of the acoustic requirements on his own terms. The Red Book scheme was an engineer’s solution to a set of requirements. The SOH796 scheme was an architectural solution which incorporated the acoustic requirements." (Nobis, 1994, p. 43)

The convex proposal was developed further with regards to the construction of the ceiling profiles. With the ceiling profile almost set, the profiles were further developed to use the full size of the giant plywood sheets manufactured in Australia at that time. The halls were to be constructed as box plywood beams hung from the concrete beams of the sails.

Fromonet remarks that by portraying the ideal acoustic profile with the aid of a single geometry, Utzon was able to integrate his conception of sound with that of the constructive dimension. "In the margin of one of his sketches he mischievously dubbed this synthesis of structure and acoustics: ‘Strucustithese’ " (Fromonot, 1998, p. 166)

In his acoustical report from 1965 Cremer describes the results of the testing of the Minor Hall. Two problems are found – the rear wall and the walls around the stage. Suggestions are made to improve these two problems and Cremer writes in a letter to his assistant Joachim Nutsch, who was working in Sydney with Utzon, that he considers these tests finished. The well-known ending to this story is that despite the acousticians’ and architect’s satisfaction with the project the architect left the project in 1965 and therefore the interiors are different from what had been planned by Utzon and the rest of the team.

Understanding the case

In order to understand the case, the model in figure 1 helps us understand the values and realities of the actors. The first concept, which was drawn by Jordan, should be able to tell us something about Jordan’s values and reality. Firstly, as Nobis has

remarked upon, the proposal tells us about his inspiration from classical concert halls. Secondly the conflict between the geometries of the sail and the hall itself reveals that geometrical studies were not the part of Jordan’s everyday life. Thirdly it tells us something about his understanding of acoustics.

As mentioned it seems that Utzon left it completely up to Jordan to supply a proposal for the Red Book. With this carte blanche Jordan drew a concave back wall – probably to follow the curve of the seating rows – that could produce focusing and thereby strong echoes in the front of the room. When Jordan was asked about the curve he remarks that "In Minor Hall the curved surface can be accepted if the surface is highly absorbent" (Minutes of meetings, 30.6.1958). This reveals to us Jordan’s sense of logic and thereby his underlying set of values. From a positivistic point of view the statement is absolutely true, the desired result is obtained, there are no echoes. Furthermore, from a positivistic point of view, the problem was solved with the proposal in the Red Book: the required number of people was seated in an appropriate room with the desired room acoustic quality.

However, viewed from a tectonic point of view, the Red Book proposal is ambiguous. Drawing a curved wall where a curve works against the purpose of the room and therefore has to be neutralized by rendering it highly absorbent, is a contradiction. If the curve creates a condition that needs to be solved, why draw it in the first place? By creating that solution, new problems arise that has to be solved by adding another layer to the solution. What is interesting here is Jordan’s relationship to technology; it is clear that he is not aiming at an inner correspondence between form and technique, but rather at a goal described by positivism as Nervi described. This value can thus in the model be positioned to the outer left, in the part of positivism that does not overlap with phenomenological values.

The second concept was clearly drawn from a different stand point. The phenomenological values guiding this scheme are evident in both Utzon’s and Mikami’s descriptions of the scheme where they emphasize the expressiveness and the sensation the human being would experience in the hall. Mikami stresses the expressiveness of the waves as "very dynamic and breathtakingly beautiful." (Mikami, 2001). And Utzon, in one of his many analogies of how one would experience the Opera House "A walnut … you’re not surprised, it’s quite different inside, but it’s still in harmony with the outside. And I left the shells open so you could see up under the shells, feel the structure." (Nobis, 1994). The phenomenological values are evident from their language that comes close to Bachelard’s language and emphasizes the human experience. Because the values guiding this proposal were not linked to any technical concerns, it can be found in the outer right of the model; in the area of phenomenology that does not overlap with positivism.

One of the very odd events in the case of the development of the Minor Hall to Sydney Opera House is that Jordan did not comment on the shape of the ceiling in the ‘stepped-cloud’ scheme; there are no documents showing any protests from him. One possibility is that Jordan did not know the scheme; this is highly unlikely since he during the three years of developing the scheme was present.
at several of the regular meetings held at Utzon’s office in Hellebæk. Neither is there any reason to believe that Jordan was not competent in his field. Another explanation could be that Utzon was not interested in the acoustics but wanted to focus on the architectural expression. This probably could be the case for the very first sketches of the idea but this scheme was developed for three years. To support a rejection of this view is also the fact that the ‘stepped-cloud’ scheme actually shows a concern with sound in a conceptual way – the hall is perceived as a funnel-shape that should transport the sound to the audience and Utzon displays a great interest in acoustics by asking for further readings on acoustics. Utzon’s interest in acoustics, with regards to the model in figure 1 be interpreted as an attempt to move from the outer side of phenomenology into the overlapping area of the model in the middle.

The most likely explanation is that what we see here is a representation of Jordan’s understanding of technology. Jordan saw technology as instrumental – a way to realize an architectural idea. He shows this clear distinction between architecture and acoustics in the Red Book proposal where he uses the acoustics to mend the shape of the room. This is supported by Utzon’s comments in his Report on Acoustics "Normally, acoustical engineers are repairing a fixed project" (Utzon, 1965). Jordan did not comment on the proposal because he did not want to interfere with the architectural development of the proposal. This way of applying technology is in good agreement with classic positivistic values, where it is very important that the objects studied are static - or fixed as Utzon calls it – because only that way the scientist can be certain that the only variable is one he introduces. If, for instance, the scientist was interested in knowing the effect of a certain medicine he could ensure the tests’ validity by monitoring the health of two batches of mice – one that was given the medicine and one that was not. The test would, however, not be reliable if the conditions of the mice were not alike - if one forgot to feed one batch of mice that might be a more probable cause of death than the medicine. In order for the test to be reliable, the circumstances around the test thus need to be kept static.

In terms of architectural projects it is possible to apply the same logic if one is repairing a fixed project. A reliable way of doing it would be to begin by determining the problems of the room, which could for instance be an echo. Secondly the acoustician would then carry out a number of tests eliminating elements of the room as cause of the problem. If the room shows an echo and the room with the ceiling covered does not, there is naturally a good probability that it is the ceiling causing the echo and that the ceiling needs some adjustments.

This method, however, has its limitations in a tectonic process because it, as mentioned, requires that the architecture is static. Jordan repeated the procedure with a number of proposals for the Major Hall but the expenses and time consumption of the testing equipment – a 1:10 scale model of the hall – prevented extensive use. The technology available thus only gave room to a one-way dialogue, where Jordan would test a proposal that was believed to be finished aesthetically.

What Utzon wanted to do with acoustics was different. He was searching for the essence in the acoustics and he was interested in the human experience and wanted to work with the audible as an intertwined part of the visible. His approach was both phenomenological and moving towards the tectonic part of the model in figure 1. From this point of view, technology is only a means to reach the greater goal, the human experience, but is never the less important in the search for the best shape of the hall – the one that will support the visual, the audible and any other aspect of the experience of the hall. From this value followed the logic that architecture could not be carried out in different tempi, all the aspects had to be investigated simultaneous in order to be solved in one solution in one instance – to achieve a tectonic solution. In order to do this the barrier between architecture and technology had to be broken down.

When Gabler and Cremer entered the project they brought with them a different understanding of reality. Their basic values were still from within the sphere of positivism but their logic and understanding of technology were different than Jordan’s. This is evident in the communication between them and Utzon. They did not only comment on the ‘stepped-cloud’ scheme but drew explanations of the principles behind their comments. Also they tried to explain some fundamental concepts of sound and acoustics to Utzon by letting him experience the anechoic and the reflective room. Thereby they brought the
acoustics from the field of positivism into Utzon’s field of phenomenology – the figures and data became connected to the human experience of the room. On the model in figure 1 the collaboration thereby moved from the outer edges of phenomenology and positivism to the middle part of the model, where there is an overlap of the values and therefore a possibility to create tectonic architecture.

The reason for this different understanding of technology might be that Gabler himself was trained as an architect and therefore used to translate acoustical requirements into architectural matter. He must also have known that the concept Utzon presented was not necessarily finished, but only to be considered as a step in an iterative process. Also Cremer’s assistant Joachim Nutsch, who was working with Utzon in Sydney, was known to be a talented sketcher able to demonstrate in drawing what he suggested to be altered. When Gabler, Cremer and Nutsch were introduced to the project it is thus evident that it was not primarily technical talent that was added to the project, rather it was another way of communicating technical considerations. Especially Gabler and Nutsch seem to have had a clear understanding of the intimate relationship between the architecture and the acoustics that Utzon wanted to achieve.

Discussion

Values, communication and logic

The differing values held by Utzon and Jordan made it difficult to create tectonic architecture. Utzon wanted advice on what rules to play by when working with acoustics and Jordan wanted a scheme that he could optimize. Jordan’s way of reasoning is very logical when seen within the context of positivism. It was also evident from the case that the creation of tectonic architecture is based on mediation between the two values which was what Gabler, Cremer and Nutsch enabled. As such, the future tectonic tool could be seen as a mediating device able to transcend the barrier between differing values.

While Jordan mastered his field and was recognized as one of the best Danish acousticians at his time he was not able to transfer his knowledge into a creative force. It was difficult for Utzon to obtain access to the technology through him. In order to be able to embed the principles of acoustics into his architecture, Utzon mediated between the two fields by reading about acoustics and ultimately consulting other acousticians. One of the most important aspects in this mediation is the communication. Some of the main points of the case study – and something that can be brought into the sphere of the development of future tectonic tools – are the small tricks that Gabler, Cremer and Nutsch employed in order to ‘translate’ the positivistic values of their field into phenomenological terms. It is seen that the actors in the real-life situation diversify their expected predetermined way of acting of their own field. Gabler and Cremer began drawing in order to communicate their ideas and Utzon gained access to the logic behind the positivistic aspects of acoustics and he on his turn began working with reflection paths on his drawings. Likewise Gabler and Cremer successfully broke down the barrier between the positivistic and phenomenological fields by introducing Utzon to the anechoic and reflective chamber. This experience can be characterized as communicative in the same sense as a dialogue is communicative but is at the same time a completely different kind of dialogue than what would be expected within positivism – it goes beyond facts and deals with the human experience.

One thing worth noting is that Jordan, Gabler, Cremer and Nutsch shared the positivistic values – their aim was the best achievable acoustics. Despite of this, they worked in different ways in the collaboration with Utzon. Their understanding of technology and thereby their logics are one way of explaining this discrepancy. Henriksen et al (2004) describe logics as a way of transforming facts into contours of the future change, a way of envisaging change. While the acousticians agreed on the aim of their involvement in the project it thus seems that their logics led them to different paths to achieve this goal. Timing is one of the most obvious differences between Jordan and the German team. While Jordan was applying technology on a ‘finished’ concept, Utzon, Gabler and Cremer wanted to use the technology as a creative force in the design.

Digital tectonic tools

Translating these findings into consequences for digital tectonic tools, it seems that the tectonic tools should communicate technology in a manner that firstly translates the positivistic values into a
phenomenological sphere by letting the human experience be the focus point. In other words, the relevance of the numbers and figures of the positivistic field should be understood by its impact on the human experience of sound. Secondly the program should be able to maintain a dialogue with the user. From this we should also realize that if the aim is tectonic architecture, existing technical computer tools can not simply be applied to architecture because they are based on other values. Furthermore the logics of the participants in the process indicate that the tool should be based on a timing that allows the architecture to use the technology as a creative force.

The reason why the findings from a 45 year old case are relevant today, is that to some extent we are still working with these divisions in architecture even though the computer has a potential in breaking down the barrier between architecture and technology. In our current digital tools we can recognize the positivistic and phenomenological values in our distinction between the architectural computer tools and the engineer’s analytical computer tools. The architectural tools are primarily drawing programs that vary from a digital version of the drawing board in two-dimensional drawings to sophisticated generative three-dimensional programs. The phenomenological concern of these programs is evident in that they aim to shed light on the visual aspects of the space created. The analytical tools are concerned with analysis, evaluation and optimization of given parameters in construction, acoustics, interior climate etc. and can as such be said to work within the positivistic side of the model.

One of the analytical tools within acoustics is the acoustical simulation program CATT. A test of the potential of this to assist the creation of tectonics (Schmidt and Kirkegaard, 2005) made it clear that the tool is highly deterministic and this positivistic value guiding the program renders it unsuitable to support an architectural design process. Some of the problems caused by this positivistic value was very alike the approach Jordan showed in the case study. For instance the program focuses on a late stage of the architectural process thereby making it difficult to test preliminary concept proposals. Furthermore it is difficult for an architect to ‘communicate’ with the program due to its highly specialized target-group.

Despite the obvious difficulties with the analytical programs, it is surprisingly enough these tools that today are closest to being tectonic, not the phenomenological ones. For instance the development within the acoustic field is interesting. This field has taken a full loop from being a subjective field with only rules of thumb applied to – around 1900 - becoming an ‘objective’ science applied to architecture. Today the introduction of auralization – the process of rendering audible (by physical or mathematical modelling) the sound field of a source in a space – makes it possible for instance to hear how a concert will sound in an un-built room. The ability is still mainly being used as a gimmick to impress clients and is not yet systematically used to base design decisions on, but recent studies have showed the reliability of the programs (e.g. Pancharatnam, 2003). The significance of this, in tectonic terms, is firstly that through the ability to hear architecture the digital media is coming one step closer to the materiality of build architecture. By adding another dimension – sense – to the expressiveness of the architecture, the focus on the image is reduced, which has been one of the discrepancies between the digital and the tectonic. By hearing the materials as well as seeing them there is, for instance, suddenly a representational difference between materials looking like stone and actual stone because they will not sound alike. While the acoustical simulation programs as mentioned are far from being straight forward for architects at the moment, this is only a matter of refining the interface and the structure of the program. The possibilities are evident. The hearing added to the vision will give a closer understanding of the connection between the space and the materiality.

Secondly such a development is significant because a digital tectonic tool allows a continuous dialogue between the positivistic and phenomenological aspects of architecture. Changes in the technical part of the building – for instance by changing materials or the logics behind the constructional system – will become evident in the phenomenological part of the program. In the case of the acoustical program it will be possible to hear and see the difference the changes make as well as detect the changes in a number of ‘objective’ parameters such as reverberation time, sound pressure etc. In the model in figure 1 this development can be seen as a move towards the middle of the model. Thereby the technical choice

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will move from being only technical to being able to encompass the bodily experience in the architectural field. One of the most important aspects of this is to recognize that there is never only one solution to the technical dimension in architecture – we are always confronted with a choice where the answer is subjective.

**Conclusion**

This paper deals with the relationship between architecture and technology. The term tectonics is taken as a starting point for this discussion because the term deals with creating a meaningful relationship between the two. Likewise a great potential to break down the barrier around technology was argued to exist in the digital media. Therefore the paper links tectonics and the digital and investigates what a digital tectonic tool could be and what relationship with technology it should represent. An understanding of this relationship, it is argued, can help us not only to understand the conflicts in architecture and the building industry but also bring us further into a discussion of how architecture can use digital tools.

The investigation was carried out firstly by approaching the subject theoretically through the term tectonics and by setting up a model of the values a tectonic tool should encompass. Tectonics as a meaningful relationship between art and science is seen as mediating between the human experience expressed in phenomenology and a technical view upon the world as described in positivism. As such, these values can be seen as the meeting of the architectural and engineering values in an architectural process. The model thus describes the meeting between these values and is meant as a navigational tool which can be used to identify the various values behind architecture much like we would use a navigational tool to tell us where we are positioned between different areas that are more or less defined. Secondly it can be used to point out a direction towards digital tectonic tools much like we use a navigational tool to set out a direction for our next.

Secondly the ability and validity of the model are shown by applying it to a case study of Jørn Utzon’s work on Minor Hall in Sydney Opera House. It was shown that when positivism and phenomenology existed separately, it was difficult to obtain a tectonic result. When, however, both the positivistic and phenomenological values are combined with a logic to use the technical parameters as a ‘creative force’, the values move towards the middle of the model in figure one and it becomes possible to create tectonic architecture. The case showed that communication, logic and values are all significant components in the breakdown of the barrier between technology and architecture.

These components were taken on to a discussion of digital tectonic tools. It was argued that the current digital tools can be understood from the model as supporting phenomenology and positivism as separate aspects while it – as in the case study – is necessary to mediate between the values in order to work tectonically. Some potential to do this is identified in an acoustical simulation tool that enables both a positivistic approach by calculation and a phenomenological approach by the ability to hear the sound in a un-build room.
References


Mikami, Yuzo (2001) Utzon’s Sphere. Sydney Opera House – how it was designed and built, Tokyo, Japan: Shokokusha


