

Uneasy Coincidence? Massive Urbanization and New Exotic Geometries with Algebraic Geometry as an Extreme Example

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Abstract. *We investigate the recent coincidence of rapid global urbanization and unprecedented formal freedom in architectural design and ask whether this coincidence is an uneasy one. To study an extreme case of the new exotic geometries made possible through CAAD, we employ algebraic surfaces to experimentally design architecture in an university-based research and experimental design project. Such surfaces exhibit unprecedented complexity and new geometric and topological features yet are highly sound and harmonious. We continue and extend our research presented at the eCAADe 2009 conference in Istanbul.*

Keywords. *Algebraic Geometry; Shape; Sculpture; Design; Tool. Experiment; Methodology; Software.*

"Architecture has to follow the diversity of society, and has to reflect that a simple square or cube can't contain that diversity." Toyo Ito

"[Anthony Cragg] has succeeded where many before him have not, namely in decisively expanding the general horizons of human experience, or, to put it more tangibly, to give birth to forms which we can no longer imagine the world without." Peter Anselm Rield in 'Anthony Cragg', Exhibition Catalogue, Chemnitz 2001

The coincidence between urbanization and computerized shapes

Today for the first time in history, more than half the world's populations live in cities. This percentage will rise steadily. Cities will not only become more

numerous, but also much larger. At the same time, architecture is becoming more and more able to design and build shapes that are as unprecedented and new as the cities are large and populous. Is this coincidence an uneasy one, or is it a blessing? Will new methods of design and production soil the emerging megacities with shameless vulgarities or do we require new shapes and spaces to meet new social and political needs arising from globalization and urbanization? Will extravagant shapes be understood as l'art-pour-l'art, alienate people and instigate desires for antique and conservative spaces and buildings - or is it necessary to invent new shapes and thereby provide spaces that emerging and changing urban societies can identify with? Is it nonsense to employ new shapes and design spaces that do not even have clearly defined functions - or

is it necessary, because arising spatial needs cannot be anticipated but maybe be met by unprecedented and inspiring polyfunctional spaces that offer themselves to multiple interpretation and occupation?

Though we cannot offer completely satisfying answers to those questions in a short paper, we can begin surveying the field of possible answers. In order to be able to study spaces that are geometrically as extreme as possible, which have shapes that are as unprecedented as possible, not to mention technologically as challenging as possible, we employ algebraic geometry to generate our designs.

Algebraic Surfaces

Algebraic surfaces are the zero-sets of certain polynomials [see Barczik, Labs, Lordick 2009]. They are geometrically and topologically highly complex yet very structured, sound and harmonious. They have been studied by mathematicians for almost two centuries and already influenced modern art and architecture when artists and architects discovered models built by mathematicians and incorporated them into their work, adapting or bluntly copying them [see Vierling-Claasen 2000]. These inspirational contacts between mathematics and the arts, though important and consequential, remained short-lived because of the technical difficulties and the conceptual hurdles involved in studying algebraic surfaces and producing two- or three-dimensional representations of them. Artists and architects had to accept the shapes produced by mathematics as 'manna from heaven', only to be painstakingly reproduced but not really to be understood and generated. Artists were unable to create them so that they met their questions and not only the mathematicians'. This has changed fundamentally. Today, software exists to visualize the surfaces and generate three-dimensional models that can be imported in standard modelling software [see Barczik, Labs, Lordick 2009]. This software is furthermore free and easily accessible. Objects which were once elusive and could only be studied by experts can now be grasped

easily and toyed around and experimented with by laymen. Now the aesthetical and sculptural qualities of the surfaces can be investigated. Many of them are completely new, objects never seen before because non-existent in the natural world and only to be discovered in mathematics. The shapes employed in any design activity so far can be described as algebraic surfaces of degree 1, 2 and sometimes 4 [the degree of a surface is that of its corresponding polynomial]. All surfaces of degree 3, almost all surfaces of degree 4 and all surfaces of higher degrees have never before been seen not to say used. Designers are presented with a new abundance of shapes, a Cambrian explosion of forms.

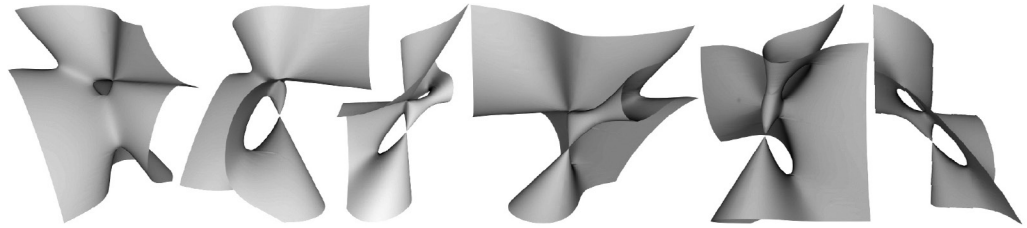
The shapes are also geometrically and topologically highly complex: very convoluted, containing self-intersections and openings that cannot readily be classified as holes or tunnels. We propose to call such a feature 'Diodos' after the Greek word for a passage that has a surprising goal. Furthermore, the surfaces sometimes have singularities where the regional geometry converges in a single point and generates a spike-like feature. Moreover, most of the surfaces appear quite differently from each direction. Sections through various planes also often bear very little resemblance to one another even though stemming from one and the same object. We propose to call this quality 'polyoptical' after the Greek word for an object with many faces (Figure 1).

Algebraic geometry therefore, with the help of CAAD, provides us with shapes which are new and have mostly never before been used in architecture. To see what architecture might result from them, and how such architecture might be used and how it might relate to its context, we undertook an experimental design project.

Experimental design and research project based on algebraic surfaces

The project sought to design buildings with unprecedented shapes by deriving those from algebraic surfaces.

Figure 1
Different views of one algebraic surface displaying polyoptic, diodos and singularities.



It was structured into four steps: Creation and Exploration, Interpretation, Adaptation and finally Design.

At first, algebraic surfaces were created in software. Various polynomials were attempted and altered, and the resulting surfaces visualized. The more unusual and still aesthetically pleasing were selected, three-dimensional models created and transferred into CAD software. Multiple sections

were cut through the models and certain areas rendered from selected viewpoints to explore in more detail the new sculptural qualities (Figure 2).

In a next step, the resulting shapes and sculptural configurations were interpreted as to how they might be inhabited or used by humans. The goal in this step was not to develop buildings but merely to find individual situations within the surfaces that might lend themselves to human use (Figure 3).

Figure 2
Sectional studies of an algebraic surface: Student project Cottbus University, Stefan Schreck 2009.

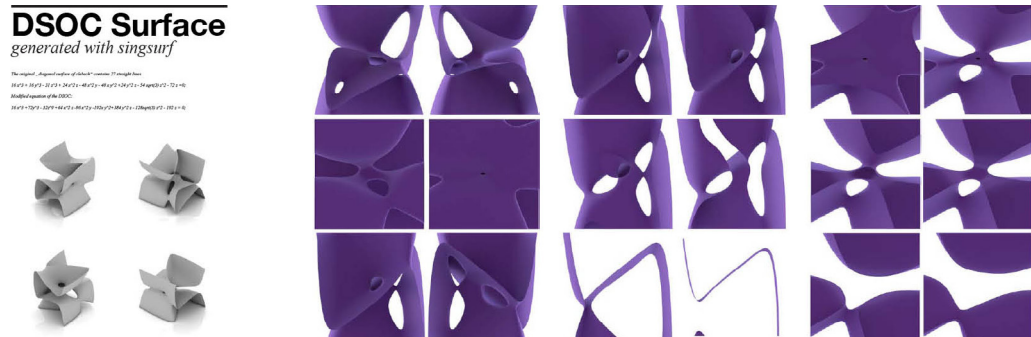
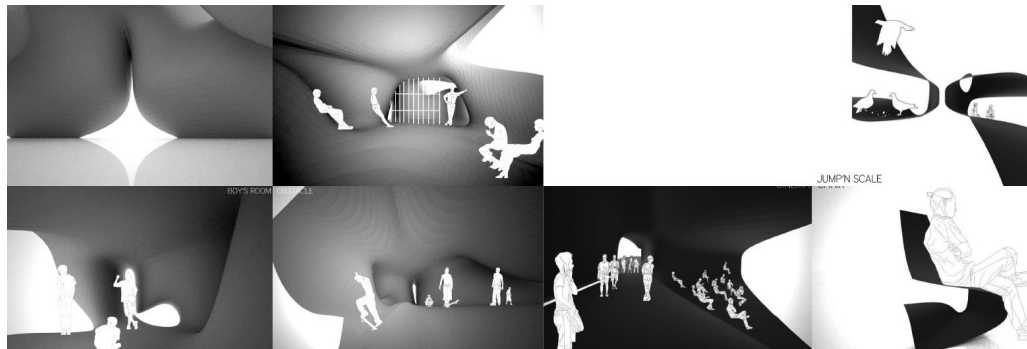


Figure 3
Usable situations on an algebraic surface: Student project Cottbus University, Anne Groß 2009.



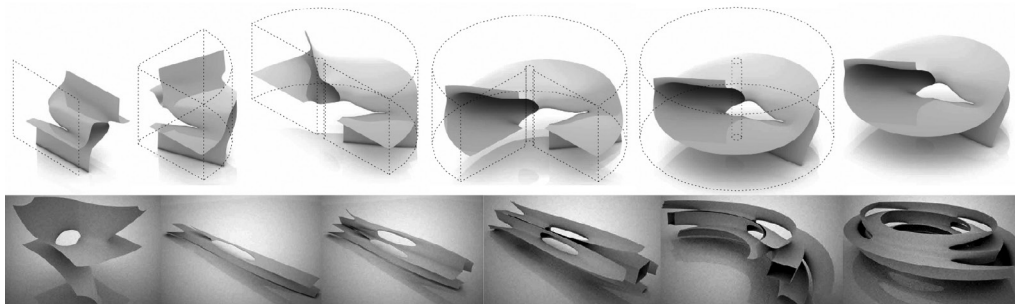


Figure 4
Creating a volume through
distortion: Student proj-
ects Cottbus University;
Stefan Schreck + Nicolas
Oevermann 2009.

As third step, surfaces were adapted to become spatial enclosures. Two types of procedures were found to accomplish this: Distorting the surface through stretching and rotation until it enclosed a space (Figure 4), and using Boolean operations to slice a given solid with an algebraic surface (Figure 5). This cutting-off of a surface is necessary in any case, as the surfaces mostly stretch endlessly in all

directions. We found that the choice of size and shape of the cutting volume became very important. Certain surfaces corresponded better with round or cutting volumes like spheres or ellipses, others corresponded better with edged surfaces like cuboids. In this step, functionality was not regarded, the focus lay on enclosure.

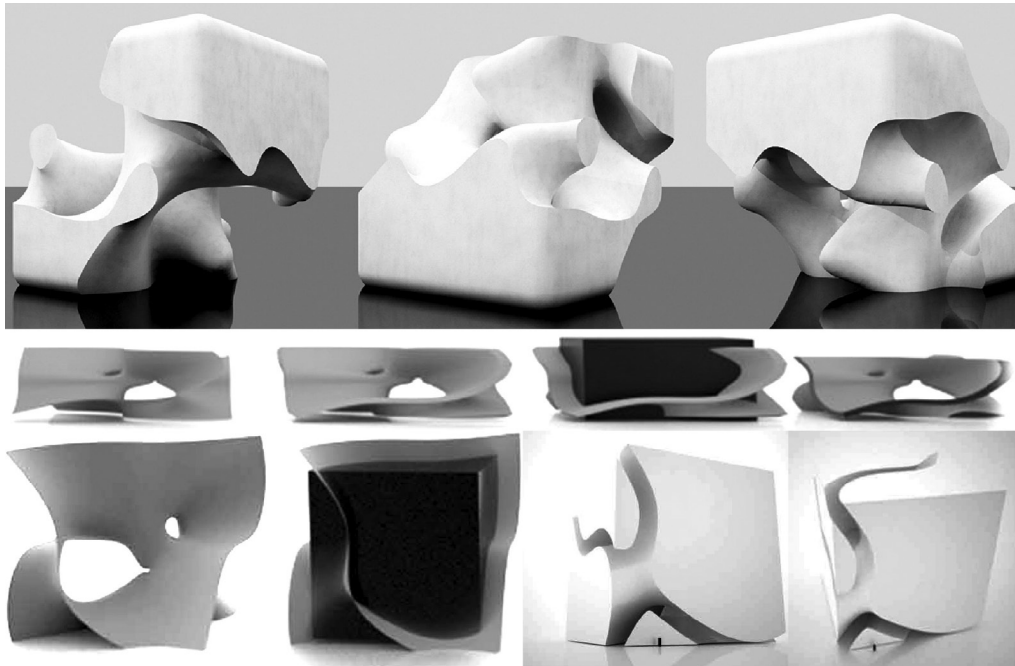


Figure 5
Creating a volume through
merging: Student projects
Cottbus University; Andreas
Hoppe + Anne Groß 2009.

Figure 6
Creating an inhabitable volume from an algebraic surface: Student project Cottbus University Anne Groß 2010.

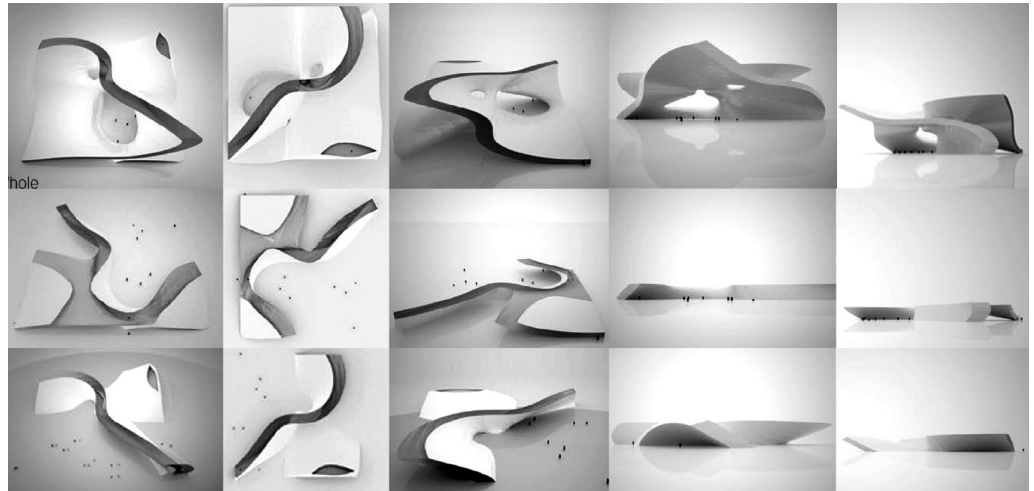
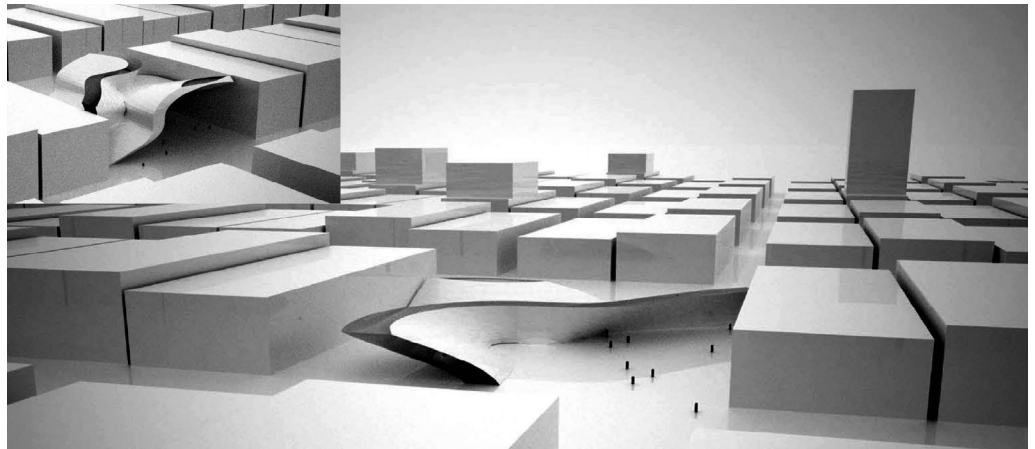


Figure 7
Placing an algebraic-surface based volume into an urban context: Student project Cottbus University Anne Groß 2010.



In the last step, the former two were combined to produce enclosed spaces that could be used by humans (Figure 6) and placed in urban contexts (Figure 7).

The resulting building designs were rendered in CAD software and printed as models using a 3D printer (Figure 8)

To adapt a given surface or space to a functional requirement means to have the function follow the

form and not the other way round, as designers would ideally operate. We think that in the case of our project such inversion is justified and even necessary. One of our goals is to extend designers' sculptural vocabulary, and in order to do so, new shapes must first be found, tested and played around with. Only at a later stage, once they are within the vocabulary, can they become part of the form that follows the function.



Figure 8
3D Prints of designs derived
from algebraic surfaces:
Student projects Cottbus
University Stefan Schreck,
Nicolas Oevermann and Xing
Jiang 2009 + 2010.

Unusual shapes in urban contexts: misfits or mavericks ?

Throughout the history of human dwelling in aggregations, there has been - and still is - a dialectic between many buildings which are similar and constitute a mass of individual, yet closely related houses, and buildings that stand out as singular and separate from the mass. The latter type most commonly houses a special social communal function related to politics or religion. For example the places of government, be they places for meetings of citizens or tribe members or the palaces of rulers. Important communal functions like schools or libraries, too, belong to this category, as do the places of spectacle for entertainment or sports. And places of spiritual or religious worship: temples, mosques, synagogues, churches, cathedrals. All have three aspects in common: a special shape signifies a special function, it

attracts people's attention, and its inside provides unusual spatial experiences. They are in the truest sense of the word extra-ordinary: out of the ordinary. Thus, they provide an important counterpart to the ordinary of everyday existence, in the best of cases elevating the citizens' spirits and inspiring them, adding new experiences and ideas to everyone's lives. The appearance and shape of these buildings has always been a showcase for the inventiveness and ingenuity of the culture that built them, exploring the limits of the possible and pushing them outwards to demonstrate a society's capabilities and to expand the range of the thinkable through experiencing something hitherto unimaginable.

With the range of building possibilities and the complexity of societies grew the range of functions. New ideas about society, politics and religion have always sparked new shapes for new buildings, new spatial experiences relating to those new ideas and

functions. Not seldom they were associated with utopian ideas; most clearly, perhaps, in the ideas about a Stadtkrone or City-Crown put forward by Bruno Taut in the early 20th century which was meant to accommodate and inspire new communal functions for a new urban society.

Traditionally, special buildings have often been amongst the first ones in hamlets and towns and provided a starting point for aggregation. Other buildings assembled around them. The aesthetical relationship between the many ordinary buildings and the one extraordinary one therefore developed over time in incremental adjustments - building per building. And if extraordinary buildings were inserted into existing urban structures at a later stage, a contrast was most often sought and little attention played to the surrounding cityscape.

The balance between extraordinary building and ordinary context has always been delicate. For a long time, a limited range of building skills, technologies and available materials has ensured a relative proximity between special and ordinary. Yet a striving to be as extra-ordinary as possible can almost always be observed. Today, the possibilities of technology for designing and building and the means for transportation of material are unprecedented, and the contrast between the mass of the ordinary and the possibilities of the extra-ordinary as high as never before. Will this tip their delicate balance?

We think that no definitive answer can be given. What can be said, though, is that the responsibilities of the designers are higher than ever. Where before there were regional limits to technological skill and material possibilities that ensured a relative homogeneity regardless of the designers' capabilities, these limits have today evaporated through technology.

To get the balance right is purely in the hands of designers. Additionally, the time of designing and building has shortened to moments compared to earlier times. Buildings that used to require decades or even centuries are now erected in years and soon maybe months. This means that the time to adjust ongoing work both in the extraordinary and the surrounding ordinary buildings does not exist anymore. Again, it is solely in the designers' hands to take them into account. Taken together this means that the amount of care required from designers has risen in the same rate as their technical capabilities.

What also has risen, though, is the need for new and extraordinary buildings. Societies are ever more diverse, and new means of social interaction and political action emerge and are being invented. Additionally, increased medialization means a decoupling of mental processes and bodily experience. To close this gap again and to respond to the new societal developments, new shapes for new spaces and new buildings must be invented. These spaces must increasingly be polyfunctional because we do not know today what tomorrow will be required. A building that takes this into account can either be adaptable or invite and lend itself to many different uses - like an undulating park landscape perhaps in which people gather in the most different ways, where each group of users finds a spot that with its unique topography meets the individual group's needs (Figure 9).

To accomplish these tasks, designers can let algebraic surfaces help them in several ways: As discussed, these surfaces are mostly new, their application unprecedented and the resulting buildings therefore necessarily progressive in spirit (Figure 10).

Figure 9
Interiors of a design derived from an algebraic surface: Student project Cottbus University, David Schwarzkopf 2009

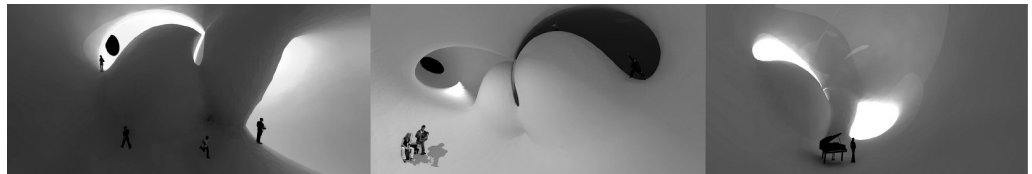
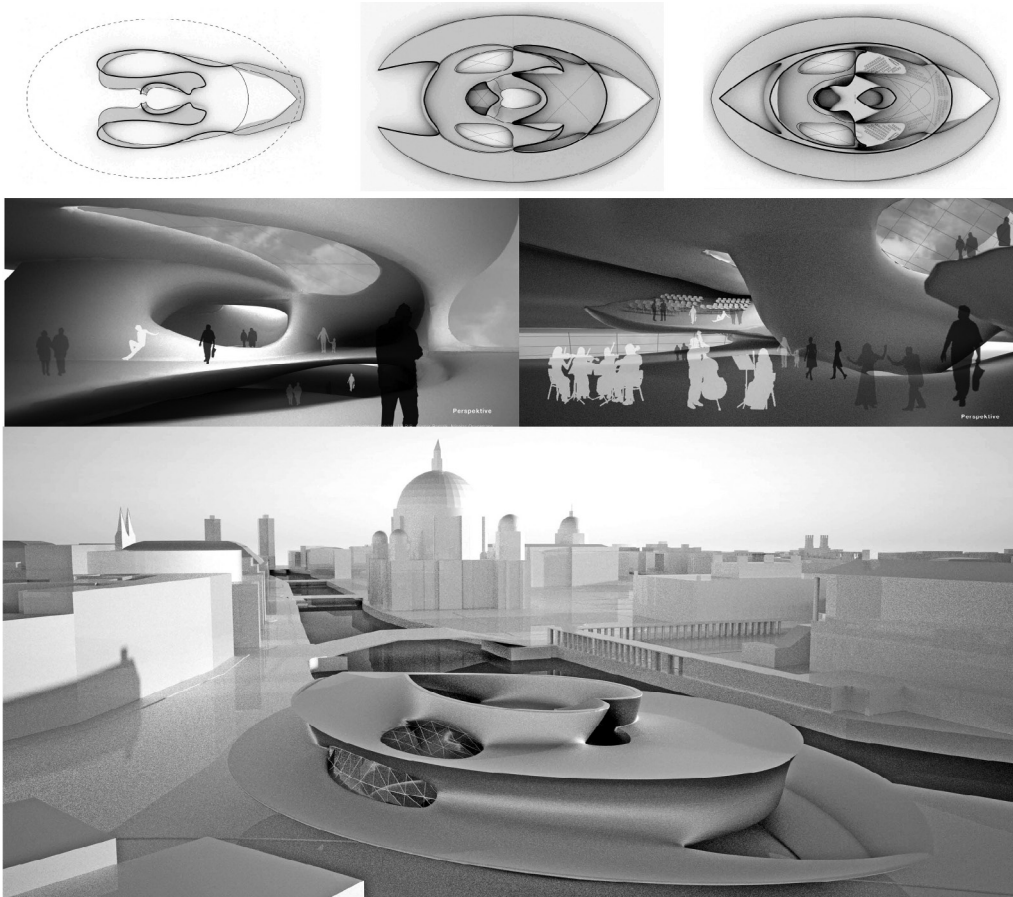


Figure 10
Experimental design based on
an algebraic surface. Student
project BTU Cottbus, Nicolas
Oevermann 2010



Furthermore, internally new topological relationships between different regions of the spaces and unusual geometric features denying the 'dogma of horizontality' that defines most architecture lend themselves to accommodating and inspiring new forms of social gathering and use - much like the aforementioned undulating park landscape, where an absence of horizontality precisely provides accommodational quality.

Additionally, algebraic surfaces can help with the relatively new task of inserting a special building into an existing ordinary context: So far, unusual

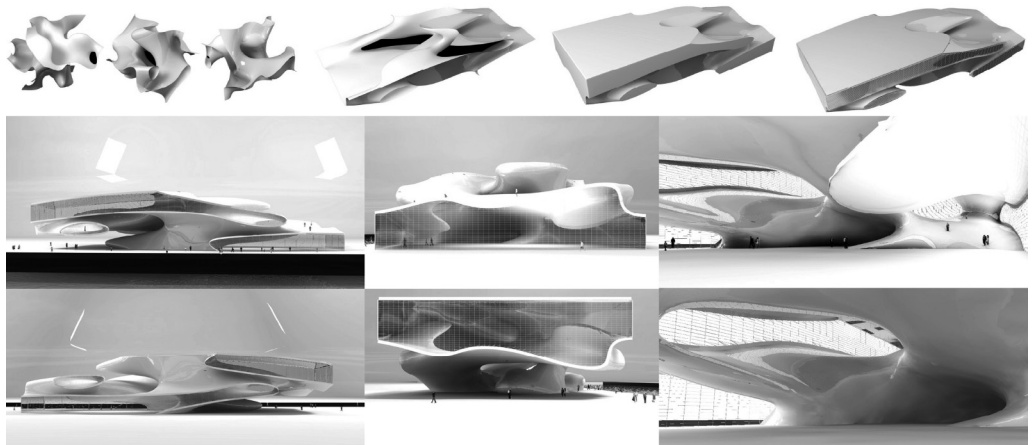
shapes have most often be developed as free-standing sculptures that shy away from the delineating borders of their sites. As explained before, algebraic surfaces can only be applied to design tasks when they are cut with a boundary volume. Existing urban context can provide precisely this cutting volume (Figure 11).

And lastly, algebraic surfaces are usually 'Poly-opts', looking different from every direction. Thus, they can more easily connect to the diversity of their surrounding cityscapes, reacting to the specificities of their contexts (Figure 12).

Figure 11
Experimental design based on
an algebraic surface. Student
project BTU Cottbus, Izabela
Kajzer 2010



Figure 12
Experimental design based on
an algebraic surface. Student
project BTU Cottbus, Andreas
Hoppe 2010



So the initial question whether the coincidence between massive urbanization and computer-based unprecedented geometrical possibilities is an uneasy one can not be fully answered. What can be said, though, is that a sculptural vocabulary broadened by algebraic geometry can help designers to

face the expanded responsibilities and the growing challenges facing them today and enable them to provide new societal requirements with newly inspiring places.

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