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FIVE-DIMENSIONAL DESIGN

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Abstract

The method architectural and engineering design and construction apply for two-dimensional representation is geometry, the axioms of which were first outlined by Euclid. The proposition of his 5^{th} postulate started on its course a problem of geometry that provoked perhaps the most mistaken demonstrations and that remained unresolved for two thousand years, the question if the axiom of parallels can be proved. The quest for the solution of this problem led Bolyai János to revolutionary conclusions in the wake of which he began to lay the foundations of a new (absolute) geometry in the system of which planes bend and become hyperbolic. It was Einstein's relativity theory that eventually created the possibility of the recognition of new dimensions by discussing space as well as a curved, non-linear entity. Architectural creations exist in what Kant termed the dual form of intuition, that is in time and space, thus in four dimensions. In this context the fourth dimension is to be interpreted as the current time that may be actively experienced. On the other hand there has been a dichotomy in the concept of time since ancient times. The introduction of a time-concept into the activity of the architectural designer that comprises duration, the passage of time and cyclic time opens up a so-far unknown new direction, a fifth dimension, the perfection of which may be achieved through the comprehension and the synthesis of the coded messages of building diagnostics and building reconstruction.

Keywords: fifth dimensions; construction design, virtual model of the building, the schedule of construction, life-cycle of the building.

Architectural and engineering design and construction make an attempt at representing three-dimensional space in a two-dimensional, plane drawing-paper. The method of representation is geometry.

1. The Mathematical Approach to Dimensions

1.1. Euclidean Space or There is Something Fishy Around the 5^{th} Postulate...

The fact that geometry is applicable for the analysis of nature is primarily due to the deduction of its statements from a few basic truths or *axioms*. It is not necessary therefore to know all phenomena of nature through direct experience, being simply exposed to these few self-evident truths is enough to be able to prove several other facts hardly accessible to experience on the basis of the truth of the axioms *through mere thinking*.

The axioms of geometry were first outlined by Euclid, an Alexandrian mathematician around 300 BC. There is a proposition among those axioms under the name of 5^{th} *postulate*, the truth of which is not at all so evident as that of the other axioms. To put it as simply as possible this postulate states that only one parallel line can be drawn with any straight line in the plane through any point which is off the line. (Hence the name: axiom of parallels.)

This axiom differs from the rest not only due to its complexity but also because in contrast with those it cannot be verified through direct experience, it is not self-evident, therefore its truth seems to require demonstration.

It was with this axiom that a problem of geometry set out on its course, one that provoked perhaps the most mistaken demonstrations and that remained unanswered for two thousand years, namely the question if the axiom of parallels can be proved.

That is because two straight lines of a plane are named parallels if they do not ever intersect. Whether two straight lines are really parallel with each other might only be decided in practice if by walking along the full length of one of the lines we could verify that it never intersects the other line. Since it is impossible even in thought to walk along the full length of an infinite line direct experience can never give us perfectly precise evidence of the parallelism of two lines.

Linear directions of *Euclidean space* have only *three dimensions*: they point upward, to the right and forward, or in other words, they define height, length and breadth.

1.2. ‚What is Smoking There in the Plane Afar?'

The axiom of parallels infers that the straight line is *infinite*. That gives the *notion of direction* a completely new definition. Postulating that straight lines are infinite makes the direction of the *parallel* straight lines the common direction. That is to say parallel lines are lines that share a common direction but the common point they are both pointing at is removed to non-existence, a place 'beyond' the plane. In other words *the common point*, that both lines are pointing at *differs in quality from the points in the plane*. It is 'transcendent' compared to the objects in the plane and represents a qualitatively different *new dimension*. Consequently the common direction pointing at it and thereby parallelism itself has a greater weight emanating from its relation to this 'transcendence' or higher dimension.

While the three dimensions are relatively easy to see and experience, even the fourth dimension in geometry is something that is for people in their senses simply 'beyond their grasp'.

1.3. The 'Gordian Knot' of Bolyai János

Bolyai János, the knowledgeable Hungarian mathematician also discussed Euclid's 5^{th} postulate, a problem unresolved for two thousand years. His genius mind led him to revolutionary conclusions that inspired him to lay the foundations of a new geometry (the absolute geometry) that also incorporated Euclidean geometry as a borderline case, but that treats space in a much wider sense. Planes bend and become hyperbolic in his system.

That was a discovery of incredible significance that opened up new vistas for research in a wide range of fields. As soon as it was demonstrated that the Euclidean geometry was not the only truth the question naturally emerged which geometry lent itself to the reflection of the material world: the Euclidean or the non-Euclidean.

1.4. That is When Einstein Entered the Stage...

For a long time there was no perfect answer for that question and it is only recently that it was demonstrated on the basis of Einstein's general relativity theory that the spatial structure of the material world was correctly described by a certain kind of non-Euclidean geometry.

It was thus Einstein's relativity theory that created the possibility of the recognition of new dimensions by discussing space as well as a curved, non-linear entity. It follows that there may be not only four but more 'directions' (more dimensions!), which is beyond our understanding...

1.5. May Time Be the Fourth Dimension?

Many people define the fourth dimension as time. If, however, we regard time simply as a kind of direction we soon have to realise that time has many characteristics that contradict that definition.

It is conceivable that it is only the nature of the 'new dimension' that makes the fourth and fifth dimensions appear before us as time-based phenomena.

Fig. 1.

The problem (transformed to a lower level of dimensions) is well illustrated by the figure below, that shows us what an insignificant and essentially uncharacteristic part of a three-dimensional ‘human being’ is observable in two-dimensions when he is ‘falling through’ that imaginary two-dimensional space...

2. The Approach of Architectural Theory and Philosophy to Dimensions

In the realm of art paintings and drawings are traditionally understood as two-dimensional forms of expression whereas sculptures are known as three-dimensional static objects. The embeddedness of architecture in three dimensions is more than that of sculptures, it is characterised by motion and thus we have to add time (for want of a better) as a fourth to the three dimensions.

2.1. Kant and the Dual Form of Intuition

Kant, the philosopher worded the statement that whatever we perceive is set in time and space. He named that setting *the dual form of intuition*. The representation of the essence of architectural creations and their perception take place in different settings. While the perception of a finished building exists in the dual form of intuition, its design and representation are carried out with the application of two-dimensional methods.

Computers do not essentially change the problem since the image seen on the screen is only a two-dimensional illusion, just the same.

2.2. How Did Our Forebears Design?

Until the end of the 19^{th} century the design of a building and the construction itself could not be separated, which gave the creator the opportunity to experience ’the dual form of intuition’ ’in situ’. That era can be briefly characterised as in the following.

The instruments of building design:

- Two-dimensional floor plans – sections but coloured and shaded to create a spatial effect;
- Stereoscopic, coloured and shaded elevations and details;
- Spatial models, large scale models;
- Design and implementation were performed in close harmony.

The (concealed) presence of the time-factor may also be spied in the design process:

- in the professional experience of generations of designers and builders;

– in the application of durable building materials;
– in the long duration of the construction;
– in the commissioners’ demand for ‘everlasting’ buildings.

2.3. *The ‘Palmy Days of Peace’ – and What Followed Them...*

The designer’s direct contact with the construction ended at the end of the 19^{th} century. Since then buildings have been designed with two-dimensional projections and in better cases with small three-dimensional static models. It is through these that the four-dimensional essence of a building has to be translated, comprehended and represented.

Thus the set of designers’ instruments was narrowed down to:

– Two-dimensional black and white floor plans and sections;
– Two-dimensional black and white elevations (perpendicular projections);
– Two-dimensional black and white detail drawings;
– Design and implementation are alienated from each other;
– The time-factor plays a diminished role in the course of design.

2.4. *Design and Construction at the Turn of the Millennium*

A typical trait of our days is the harnessing of the computer, which brought along significant changes. The designers’ instruments were replaced once more:

– Two-dimensional digital floor plans and sections
– Two-dimensional digital elevations (perpendicular projections)
– Two-dimensional digital detail drawings
– *Three-dimensional computer-generated models – animations in space and time*
– Design and implementation are once again approaching each other in time.

Computer generated animations can project navigation in space onto the two-dimensional surface of the screen and thus create the illusion of space in time and lets us experience succession.

2.5. *Have We Found the Fourth Dimension?!*

What we have here is an interpretation of the fourth dimension, the time-factor of which is characterised by the active perception of the *present* and navigation in space that can be *repeated* at will. We took *current time*, a narrow section of infinite time, and added it to the original three-dimensions of static space.

A completely different system of relations in the concept of space-time is observable in the design of the central buildings of the Technical University of Helsinki (HUT) (Alvar Aalto /1898-1976/) at Otaniemi, in the close vicinity of Helsinki.

A set of designing, simulation and analytical devices, the so called *Product Model and Fourth Dimension, PM4D* has been applied for the optimisation of the design, construction and the future operation of the buildings.

By 4D modelling *they connected the virtual model of the building with the schedule of construction* to be able to view the implementation of the parts of the building in advance. The PM4D method significantly increased the precision and the efficiency of design and construction and at the same time it gave specialists the opportunity to concentrate on *various factors of the complete life-cycle of the building* as well.

2.6. Heureka – or How About One More Dimension?

It is another bunch of qualities of time that is foregrounded here: *duration*, *cyclic change, the process of the passage of time*, that does not exclude the possibility of the application of four-dimensional representation (characterised by current time) for minor tasks of design.

But here we are clearly talking about *more than the 'simple' four-dimensional experience of space*. Taking into account changing time, the effect and the consequences of the passage of time added the fifth dimension to the designer's work, enriching it with a direction so far slumbering unsuspected.

The method of construction design that is just taking shape and that takes into consideration the life expectancy of the whole of the building as well as all of its parts, their mutual interaction, the speed of their ageing and the technical consequences of their cycles of renovation, can be rightly regarded as *the fifth dimension of design.*

3. The Mythological Background of Time-Based Dimensions, or there is Nothing New Under the Sun...

There has been a dichotomy in the concept of time since ancient times. *Chronos and Aion* both symbolise time in Greek mythology. Chronos stands for *relentless time* that consumes its own creations, Aion is the incarnation of intinite time, the *sequence of events* that keeps returning but always in a different form, perpetual circulation.

The construction designers of the future shall combine the three Euclidean directions with the linear time of Chronos and Aion's cyclic time and work to the best of their skills in the five-dimensional space defined by these five directions. The road to the proper application of five-dimensional design leads through the acquisition, the comprehension and the synthesis of the subject-matter of *building diagnostics and building reconstruction.*

4. Conclusion

Euclidean space recognises no more than three dimensions of linear directions. However, the 5th postulate contains the hypothesis that the direction of parallel lines is a common point that is different in quality from the points of the plane, which paradoxically means a qualitatively new dimension. The contradiction was solved two thousand years later by Bolyai János's system of hyperbolic space. Space in Einstein's relativity theory is conceived as a curved and non-linear phenomenon comprising more than four directions (dimensions).

In the course of architectural and structural design the two-dimensional world of the drawing board is expanded into three dimensions by spatial models and 3D computerised representations. Computer generated animations have enabled us to take a virtual tour of the designed space, current time experience of space constitutes a 4^{th} dimension. It is in our days that duration, the passage of time and cyclic time, conceivable as a 5^{th} dimension, are being integrated into the methodology of building design and facility management.

The structural designer of the future will act most fully in a five-dimensional space formed by the unification of the three Euclidean directions with Cronos's linear time and Aion's cyclic time. That in turn requires the thorough comprehension and the synthesis of the subject matter of building diagnostics and building reconstruction.

References

[1] NAGY, L. T. – JOHANN, S.: Bolyai János élete és munkássága www.bolyai.port5.com
[2] GERALD, : An Introduction to the Fourth Dimension and Beyond! www.angelfire.com/ultra/nerdsandgeeks/index.Dimensions.
[3] Enter the fourth dimension www.cwru.edu/artsci/engl/VSALM/mod/ricca
[4] MATTHEWS, G. M., Invasion of the Body Snatchers: Architecture and Virtual Space www.dmu.ac.uk/ln/4dd/synd3h.
[5] SURÁNYI, L., Szabadság és geometria: logosz és ananké harca a geometriában www.home.fazekas.hu/$\sim$lsuranyi/logoszesananke.
[6] MOSCU, K., Ezredvégi kísérleti építészet www.arch.eptort.bme.hu/kortars9
[7] ROSENMAN, M. A. – GERŐ, J. S., Collaborative CAD Modelling in Multidisciplinary Design Domains www.arch.usyd.edu.au/$\sim$mike/PAPERS/collabCAD.
[8] Milyen kérdések foglalkoztatnak egy Amerikában élõ magyar építészt az ezredfordulón? Részlet egy Halász Antallal készült interjúból. www.epiteszforum.hu/epiteszek