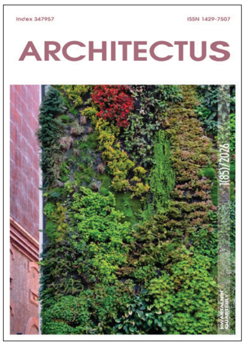

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Identification and description of bio-innovations in architecture using the dedicated CLM Tool

Abstract

What is innovative activity in architecture? This question lies at the core of identifying a research problem situated at the intersection of the multithreaded decision-making and creative processes undertaken by various entities focused on the commercialization of knowledge. The conducted review confirms a lack of a systemic solution for identifying and validating innovations related to this knowledge. This observation allows the authors to hypothesize that it is possible to construct a potentially objective, universal, and intuitive diagnostic system, adapted to the specific of interdisciplinary design innovations.

The article provides a revision of the theoretical framework and methods for measuring innovation, based on an original research model called the Centrifuge Logic Machine (CLM). The aim of the paper is to identify and describe various aspects of innovation in the form of a synthetic diagnosis. As the first in a series of articles, it presents the general rationale for applying this novel apparatus and the results of testing it across three scales: architectural, urban planning, and industrial design. These represent three examples of bio-innovation characterized by a level of complexity adequate for an effective CLM test.

The study demonstrated the ability to compare innovations from various perspectives: social, cultural, technological and creative, above all, using a single apparatus. This allowed for a unified image of innovative thought, despite the radically different projects tested. The diagnosis of individual innovation aspects was performed by determining their specific paths using the CLM. The multiplicity of these paths created the map of innovation, characteristic of a given object, resulting in a unique pattern of "fingerprints". Their diversity and complexity demonstrate that innovations in design create networks of complex trajectories, the discovery of which is a form of decoding thought.

Key words: architecture, innovation, processuality, personalization, organicity

Introduction

What is innovative activity in architecture? This seemingly simple question, which any architect will intuitively answer correctly, hides a research question that is less obvious and much more complicated. At the outset of its analysis, one should refer to the origins of the word "innovation", which comes from the Latin word *innovare*, meaning "to renew or introduce something new". Its modern interpretation dates back to the middle of the previous century, when the term was relatively quickly adopted in the economy (OECD 2015). As a result, economic categories – hard and quantifiable − began to be used to describe innovation issues, with a simultaneous lack of space for creative – soft and non-quantifiable – categories. And yet, paradoxically, the greatest "innovative" capability that humans possess is abstract thinking. Many definitions and interpretations of innovation have been proposed to date; however, they can be ignored, because none of them are complete from the point of view of the architecture and twin disciplines. The interpretations that have been presented to date are at best quantitative and statistical (EC 1995), but there is much more to innovative thought, as is well-explained by the concept formulated more than sixty years ago by art theorist George Kubler, who claimed that the existence of unmet needs while having the means to meet them, can, under the right conditions, foster innovation (1962). Kubler illustrated this with the example of Chicago

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in 1876, when the city became extremely attractive to architects after the Great Chicago Fire. This tragic event was followed by a golden age of the Chicago School, with such talents as Daniel Burhnam, Louis Henry Sullivan and later Frank Lloyd Wright. However, the reconstruction of the city would have been just […] *a provincial extension rather than an epochal renewal of American architecture* (Kubler 1962, 117), had it not been for a favourable convergence of socio-economic and technological-aesthetic needs reaching beyond purely architectural concerns.

One can agree on the fact that the contemporary parameters included in the definitions of innovation, originally formulated for the economy, do not fully reflect the scope and nature of architectural works that one could declare to be a *novum* in their discipline. This observation resulted in the formulation of a research problem identified at the intersection of the multifaceted decision-making and creative process undertaken by research organizations, universities, and experts as well as accrediting bodies, government administration bodies and other entities. Their activity focuses on the commercialization of knowledge produced by the so-called creative class: scientists, inventors, artists, designers and other professionals with the ability to combine art, modern technology and business, providing a competitive advantage in their fields (Florida 2010). From this perspective, the entirety of the activities undertaken by various design disciplines should enhance the value of human existence, which can be expressed in innovation. An historical example of this approach is the visionary Memex system developed by Vannevar Bush (1945), which anticipated the coding that mimics the way humans think and associate information, and is used in today's hypertext and search engines.

Research problem

The research presented herein is based on the assumption that various ways to map the same thing can produce different results. This is influenced by, among other things, the research model used, with its strengths and weaknesses, which is the main tool for conceptual reasoning in shaping a space, an object, a system and the processes that accompany the designers' works (Słyk 2018). On the one hand, specialized issues and the complicated research technique prevent extensive knowledge of the subject, and on the other hand, […] *despite this impossibility, we still seek to arrive at a general view* (Giedion 1968, 34). Based on this observation, the following research questions are formulated in this article: Is it possible to effectively track the evolutionary paths of design bio-innovation based on a universal research and diagnostic tool? Are there areas of knowledge from which one can draw an idea for solutions to such an issue?

Why are architects best able to answer this question? Due to the specific nature of the tasks entrusted to them and the learning process they go through, architects are endowed with the ability to have a dual view: a soft, artistic one that synthesizes the vision of the world and a hard, technical one that focuses on solving a complex problem analytically. Architects therefore operate in a "hybrid" mode that goes beyond one specialization as well as beyond one scientific and creative method. This unique "affliction" of a designer's mind leads to the creation of original research methods based on analogy and metaphor − unusual for the world of innovation, but typical of the language of thought (Arendt 1989). These methods make it possible to assimilate new concepts: to connect the internal, intuitive and invisible with the world perceived by the senses, the quantifiable and orderly world, at a deeper level than, for example, the Technology Readiness Levels (TRLs), which ignore the potential of innovative thought while describing and validating the advanced level of innovation in a technological context. This discrepancy reveals a gap in the area of interpretation of what innovation is today.

This gap is addressed by the subject matter of a study − the Centrifugal Logic Machine (CLM) − a proprietary research model and at tool at the same time[1], the construct of which is based on a laboratory centrifuge. As in a centrifuge, a selected architectural "sample" is fed into the machine, where it is filtered sequentially through fields, parameters and levels, collectively called attributes. The article thus presents the hypothesis that the centrifuge-based principle can be used to examine architectural innovations, which are filtered and mapped as "samples" (Fig. 1). The purpose of this article, which constitutes the first part of a larger series, is to show the theoretical basis for the CLM construct and mechanics, and to provide preliminary verification of its operation based on a test carried out on three architectural "samples" selected according to three criteria: (I) they are interdisciplinary; (II) they present three different project scales: urban planning, architectural, and industrial design; and (III) they are considered bio-innovations. Although these three criteria reduce the area of analysis, they also allow a semantic comparison of "samples", which are characterized by unprecedented flexibility and adaptability (example: *NSA Muscle*), processual nature and personalization (example: *Bone Chair*), circularity and organicity (example: *PhotoSynthetica Tower*). The analysis carried out resulted in research paths derived from the three philosophical categories of Motion, Time, and Space, moving towards three directions describing bio-innovation: organicity, processuality and personalization. Identifying paths through a set of attributes allows diagnosing the potential of innovative solutions. This results in the creation of individual innovation maps − unique diagrams called "fingerprints", as shown in the conclusions. Given the sophistication of the research model, it should be emphasized that the test results presented are not intended to clearly evaluate the "samples", but are rather intended to show the general idea and development potential for the CLM. The next phases of the study, which will include empirical validation of the tool, its verification in terms of objectivization of the criteria, and results by comparing them with other similar systems (e.g., TRIZ, ARIZ, C-K Theory, and KTH), will be the subject of subsequent articles.

[1] Research based on Grant of the Scientific Council of the Scientific Discipline of Architecture and Urban Planning of the Warsaw University of Technology and connected with Patent Application titled: "Method and system for determining the level of innovation of a technical solution" (P.452198, 2025.05.30 Warsaw).

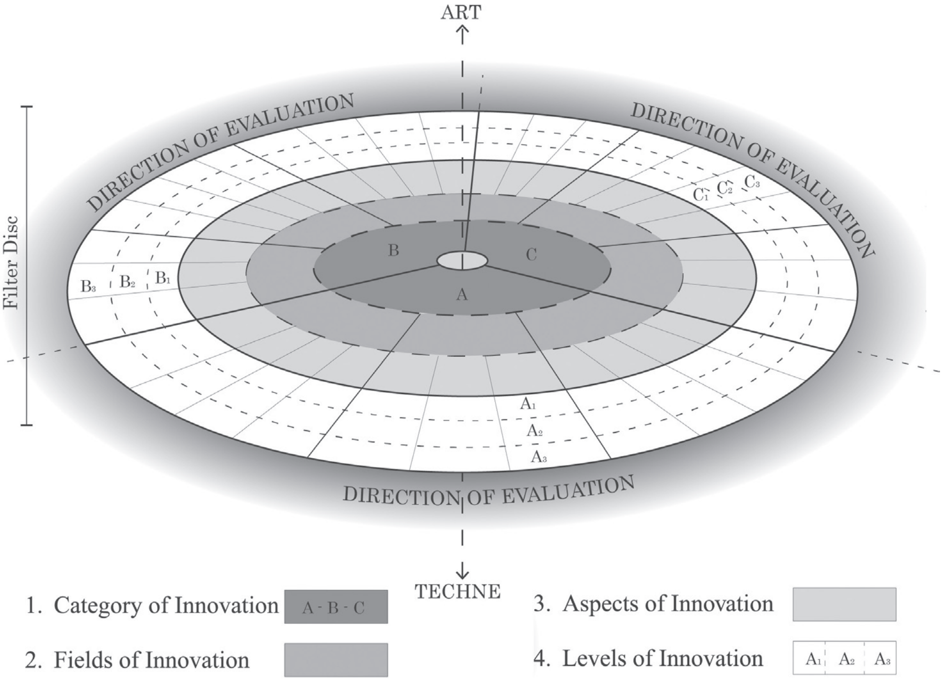


Fig. 1. Centrifugal Logical Machine – scheme (elaborated by R. Achramowicz, E. Kuhnert)

Il. 1. Centryfugowa Maszyna Logiczna – schemat (oprac. R. Achramowicz, E. Kuhnert)

State of research

The search conducted revealed the lack of an intuitive yet universal system for identifying and validating interdisciplinary design innovations. Even though there are various solutions − methods, models and tools − that partially address the problem described herein, none of them is a single coherent diagnostic solution of a systemic nature, one that responds to the problem comprehensively[2]. This is probably due to the fact that the origins of the definition of innovation should be sought in the economy and, as a result, none of the definitions used adequately addresses architectural innovation. An analysis of available publications − both domestic and foreign − revealed quite a few approaches to identifying and describing innovation, but few of them directly address the architectural context. Some of the most relevant publications for the research undertaken include *Using Design Thinking for Interdisciplinary Curriculum Design and Delivery* (Wang 2024), which provides empirical insight into interdisciplinary collaboration and the limitations of existing methods for evaluating innovation in teaching practice, and the article titled *Research on Interdisciplinary Design Thinking and Methods Based on Programmable Mechanical Metamaterials* (Liu et al. 2023), whose authors attempt to capture the multi-level relationships between different disciplines, in which one can see an analogy to the topic addressed here. On the other hand, in Poland, in the publication titled *Wybrane narzędzia pomiaru innowacyjności* [Selected Tools for Measuring Innovation] (2013), Angelika Wodecka-Hyjek points to the dispersion of tools for its measurement in different sectors and the difficulty of developing universal indicators. A similar tone is also adopted by the monograph titled *Innowacje a dobrostan społeczeństwa, gospodarki i przedsiębiorstw* [Innovation and the Well-Being of Society, Economy and Businesses] (Malara, Tutaj 2019), whose authors emphasize the need to measure the relationship between innovation and socioeconomic well-being.

One may also consider publications addressing bio-innovation in architecture and design, for example: *Nature Design: From Inspiration to Innovation* (Museum für Gestaltung Zürich, Angeli Sachs 2007) and *Biomimetics for Designers: Applying Nature's Processes & Materials in the Real World* (Kapsali 2021). Both show the transfer of conceptual solutions from biology to the broader field of creative disciplines at the formal, processual, and material levels, but they omit the topic of innovation as such. One should also mention books titled *Biomimetics for Architecture and Design* (Pohl, Nachtigall 2015), where evolution is presented as a source of inspiration providing innovative, optimal and sustainable design solutions, *Biomimicry: Innovation Inspired by Nature* (Benyus 1997), which does not refer directly to architecture, but broadly describes the impact of biomimicry on the socio-cultural context, and *Biomimicry in Architecture* (Pawlyn 2011), in which attention is focused on sustainable aspects of design. The post-conference article titled *Biomimetic Approaches to Architectural Design for Increased Sustainability* (Pedersen 2007) presents a similar tone. Numerous articles also include those that focus on only one aspect, for example, materials (Addington, Schodek 2005) or technology and production processes (Mang, Reed 2012).

[2] The authors draw this conclusion from a survey of existing patents worldwide. Due to the nature of this text, we can only cite the names and numbers of patents that illustrate the thesis, for example: "Method and system for measuring innovation level of product using part-whole relations" (KR101546365 B1); "Future technology value appraisal system and method" (KR101265975 B); "Method for evaluating technology contribution and method and system for evaluating technology using the same" (KR101228969 B1); "Technological innovation method based on innovation dimensions and innovation rules" (JP2020510247 A); "Innovation content evaluation system" (PT118270 A).

Thanks to the search carried out, it was also shown that there are numerous approaches and tools for identifying and verifying innovation, which can serve as a reference point for "calibrating" the CLM. Among the most recognizable are well-established methods in engineering and design, such as the TRIZ (Russian: Теория решения изобретательских задач, The Theory of Solving Inventive Problems) and its algorithms (ARIZ), which systematize the detection of design contradictions and indicate paths for transforming solutions; they provide a useful example of a systemic approach to innovation analysis. Another approach is the Concept-Knowledge (C-K) theoretical framework, which provides a formal way of thinking about the relationship between the space of concepts and knowledge resources and is widely used to generate and validate new concepts in the design process. Of particular note is the KTH Innovation Readiness Level™ tool, which is provided on an open access basis. It offers a ready-made methodical framework for monitoring and evaluating the progress of innovations in multiple fields: technology, market, business model, intellectual property, teams, and funding, while having a clear visual representation of the results changing over time. If one were to focus on biomimicry and biomimetics, it is worth mentioning that there are dedicated classification frameworks and tools, such as Biomimicry Design Lens and Biomimicry Taxonomy/Ask Nature. They segregate biological solutions by function and principles of operation. Although they provide concrete solutions that refer to the "function" and "strategy" of nature, they do not operate in the field of architectural creation.

Two conclusions can be drawn from the above discussion. First, despite the considerable number of studies devoted to the technical and economic aspects or describing the transfer of solutions transferred from the biological sciences to architecture, there are basically no studies that synthetically address the issues of identification and description of *novum* with respect to the interdisciplinary nature of architectural matter. Second, there is not a single systemic research approach that would result in an effective analytical tool for the identification and in-depth qualitative analysis of this type of innovation.

Methods

The course of the research is presented in the diagram (Fig. 2), within which the following steps can be distinguished: defining the need for research, conceptualizing the

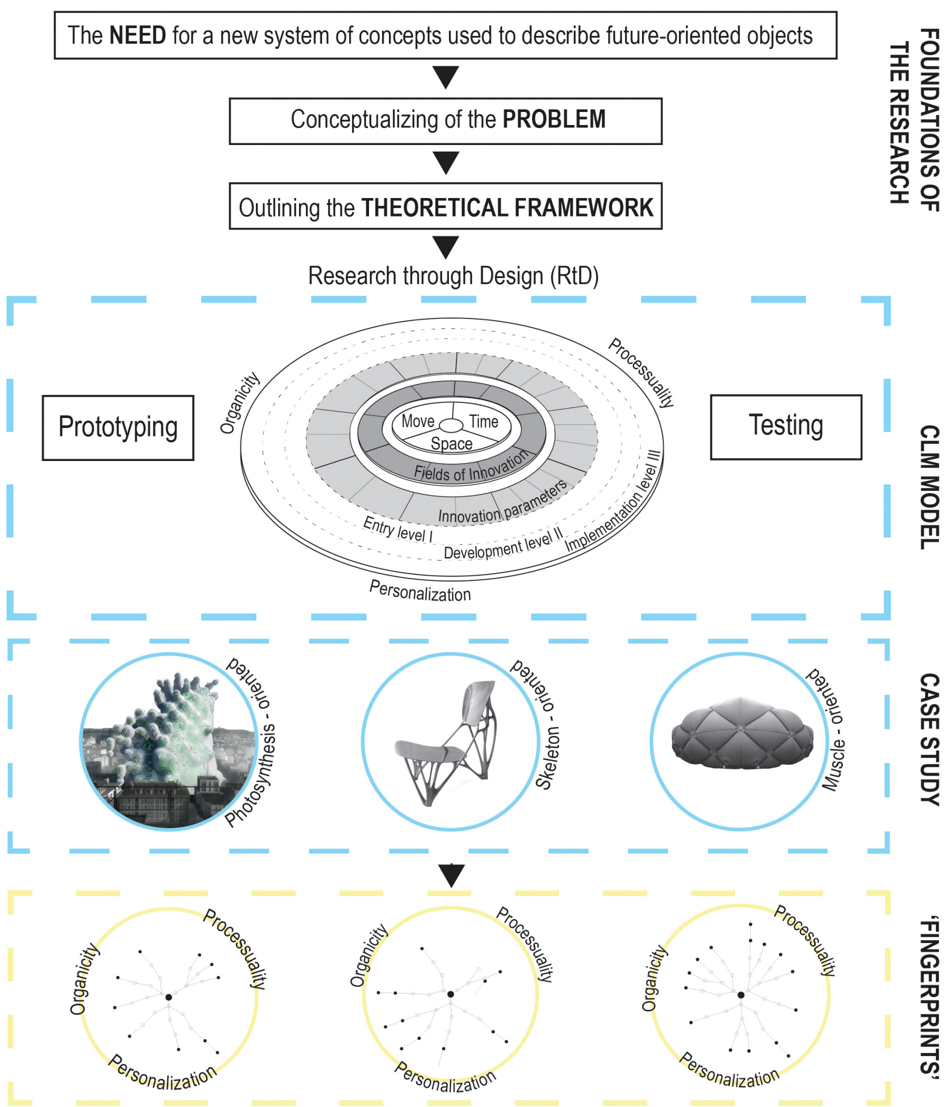
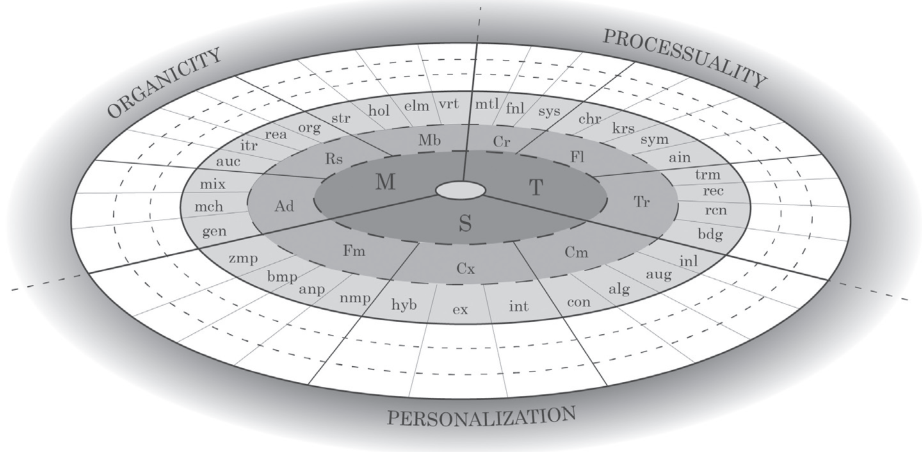


Fig. 2. Diagram illustrating the process of research (elaborated by R. Achramowicz, E. Kuhnert)

Il. 2. Schemat przedstawiający przebieg badań (oprac. R. Achramowicz, E. Kuhnert)



Paths of Innovation:

M- Movement	T - Time	S - Space
Ad – Adaptivity gen – genetic mech – mechanical mix – mixed Rs – Responsiveness auc – autonomous itr – interactive rea – reactive org – organic Mb – Mobility str – structural hol – holistic elm – elemental vrt – virtual	Cr – Circularity mtl – material fnl – functional sys – systemic Fl – Feeling sym – simulacrum krs – kairos chr – chronos ain – aion Tr – Transience rec – recyclability rcn – reconfiguration bdg – biodegradability trm – transmutation	Cm – Comfort aug – autogenic inl – intentional alg – algorithmic con – constant Cx – Context ext – external int – internal hyb – hybridized Fm – Form zmp – zoomorphic bmp – biomorphic anp – anthropomorphic nmp – nonmorphic

Fig. 3. Detailed description of CLM (elaborated by R. Achramowicz, E. Kuhnert)

Il. 3. Szczegółowy opis CLM (oprac. R. Achramowicz, E. Kuhnert)

problem, and outlining the theoretical framework, which ultimately leads to the creation of a CLM idea. In the next step, the machine is tested with three sample designs-samples. The general idea is that the structure of the CLM is based on the philosophical categories of Movement, Time, and Space, which are reflected in Organicity, Processuality, and Personalization, which in turn establish an envelope to which innovation paths lead through various fields and levels (Fig. 3). The individual study paths lead to a total of nine fields of innovation: Movement towards adaptability, responsiveness, and mobility; Time towards feeling, circularity, and transience; and Space towards comfort, context and form. To the various fields of innovation are assigned numerous parameters (adaptability, interactivity, functionality, recyclability, simulation, comfort, among others, as well as purely formal issues), which can be considered at three levels: entry, development and implementation, as alternatives to the technological readiness levels (TRLs) adopted today that are inadequate for design disciplines. In this context, the first level is interpreted as a conceptual phase and therefore a barely initiated path of innovation; the second level shows the potential of a particular pathway for evaluation, for example, by prototyping or developing partial technologies; and the implementation level involves the implementation of fully developed innovative solutions in practice.

Initially the CLM model was shaped through microtests conducted on a larger set of architectural cases[3]. In subsequent iterations of the model, the relationships between fields, parameters and levels were verified, both changing their number and scope of impact, and introducing alternative evaluation criteria. This allowed the CLM's construct and mechanics to be gradually refined. The verification process was open and heuristic, e.g., in the course of the work on subsequent designs, it turned out that the parameters in the Comfort field, initially included as a set of rigid input parameters, had to be expanded with additional variables. This is because the design tests demonstrated that some aspects of comfort are much more complex than originally envisioned in the model. As a result of the CLM modelling, its various elements – such as the parameter layout, hierarchy and levels of advancement – were replaced, simplified or expanded, so as to produce the most universal model possible, adapted to different types of design innovations – formal, processual or material alike.

In the diagnosis produced with the CLM, two extremes – understood here as two extreme views of innovation – were distinguished, which can be described as follows: (A) high innovation potential, but low entry level (Fig. 4) – as represented by the example of *Photosythetica Tower*; (B) low innovation potential, but high level of implementation (Fig. 5) – as represented by the example of *Bone Chair*. Thesis A can be found in the following situation: innovation

[3] Sample projects used as microtests included built works as well as design experiments associated with the work of the following designers: Greg Lynn (Embryological House, RV PROTOTYPE House), Kas Oosterhuis and ONL Rotterdam (Saltwater Pavilion, Muscle), the group R&Sie(n) (Water Flux), Lars Spuybroek / NOX (D-Tower, Son-O-House), François Roche (Dustyrelief), Peter Cook (Graz Kunsthaus), and Terreform ONE (In Vitro Meat Habitat, Fab Tree Hab). Research pavilions of the ICD/ITKE Institute at the University of Stuttgart were also analysed.

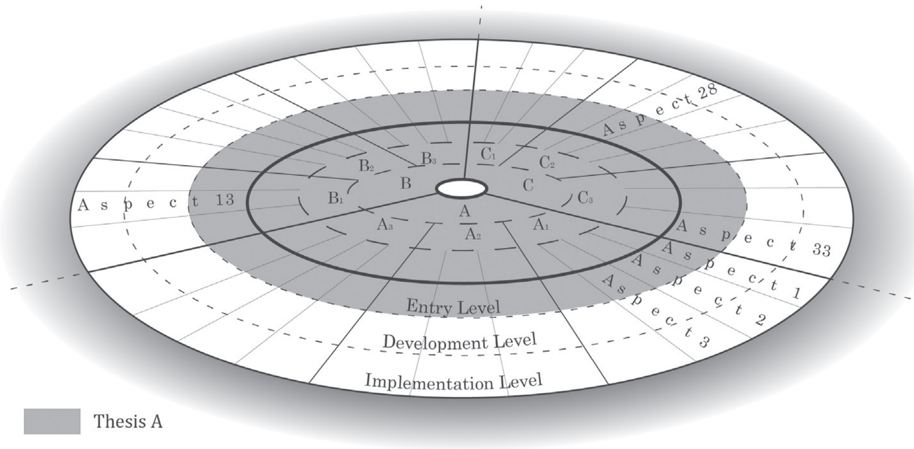


Fig. 4. Diagram presenting thesis A: high innovation potential but a low level of entry (elaborated by R. Achramowicz, E. Kuhnert)

Il. 4. Schemat prezentujący tezę A: potencjał innowacji wysoki, ale niski poziom wejścia (oprac. R. Achramowicz, E. Kuhnert)

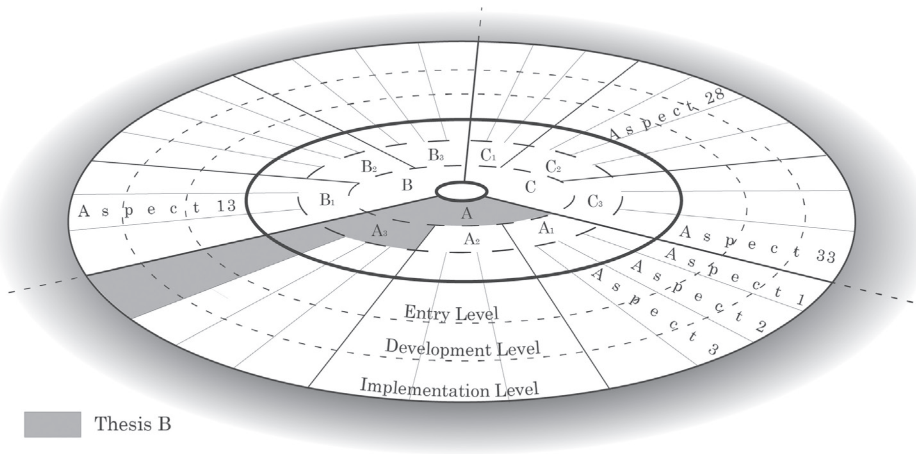


Fig. 5. Diagram presenting thesis B: low innovation potential but a high level of implementation (elaborated by R. Achramowicz, E. Kuhnert)

Il. 5. Schemat prezentujący tezę B: potencjał innowacji niski, ale wysoki poziom wdrożenia (oprac. R. Achramowicz, E. Kuhnert)

of a multifaceted nature, combining multiple disciplines and technologies, stopped at the conceptual level, but with development potential in a broad spectrum. Thesis B can be found in the following situation: innovation of a single-faceted (narrow) nature, which is brought to the level of implementation. For a complete image of the operation of the CLM, Thesis C of an intermediate nature is proposed, which has a multifaceted nature and, at the same time, involves a path of innovation leading to implementation, as represented by the *NSA Muscle* design. The test of the machine therefore involves proving the three theses described above (A, B, C), which illustrate its effectiveness. The tests-diagnoses carried out resulted in three unique "fingerprint" images.

A case study illustrating each thesis

Thesis A: *PhotoSynthetica Tower* (2019) represents bio-innovation of a multifaceted nature, with the potential for multifaceted development, but stopped at the conceptual level. The authors from ecoLogicStudio studied the use of photosynthetic processes occurring in algae to cleanse the air in a city. They proposed façades fitted with photobioreactors (ecoLogicStudio 2025, 20) that could respond to urban smog, dust and particulate matter in the atmosphere. An algae suspension placed in the façades would capture and store carbon dioxide molecules. This biochemical process would be digitally controlled, and the resulting algal biomass, in addition to producing oxygen, could be used to produce biofuels, biodegradable materials, and even animal feed (Wang et al. 2024). The innovations identified are primarily related to the issues of transitoriness, feeling, circularity and adaptability. In this vision, architecture becomes an active participant in the biotope, submitting to the life cycle like any other living organism. The project also touches on aspects of innovation relating to responsiveness and mobility, among other things, demonstrating a broad spectrum of innovation issues, many of which remain at the conceptual level (Fig. 6).

Thesis B: the bio-innovations identified in the case of the *Bone Chair* (2006) are single-faceted − narrow and specialized, dealing primarily with shaping of the form and comfort relative to user-imposed contexts made possible by the simulation level (Fig. 7). As a result of these design and production processes, the assembly line eventually manufactured a customised piece of furniture (Stals et al. 2015). The author of the design, Joris Laarman, inspired by the bone growth, created a personalized process for manufacturing chairs that feature an organic shape and homogeneous structure resulting from material optimization (Laarman 2006). The entire cycle, from design to prototyping and manufacturing, took place at the Adam Opel AG's International Developed Centre, which used simulation of the bone-growing process to produce car bodies. Of note is the fact that the algorithm itself copied the path of evolu-

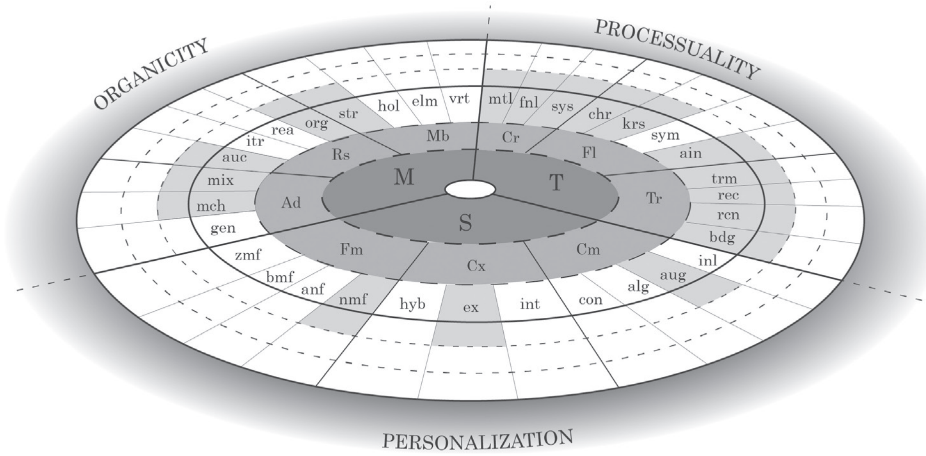


Fig. 6. Bioinnovations identified in the case of PhotoSynthEtica Tower (elaborated by R. Achramowicz, E. Kuhnert)

Il. 6. Bioinnowacje zidentyfikowane w projekcie PhotoSynthEtica Tower (oprac. R. Achramowicz, E. Kuhnert)

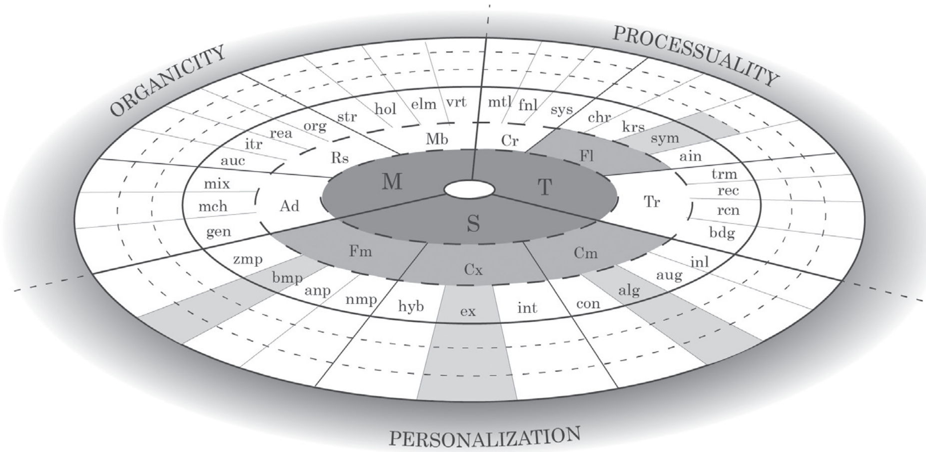


Fig. 7. Bioinnovations identified in the case of Bone Chair (elaborated by R. Achramowicz, E. Kuhnert)

Il. 7. Bioinnowacje zidentyfikowane w projekcie Bone Chair (oprac. R. Achramowicz, E. Kuhnert)

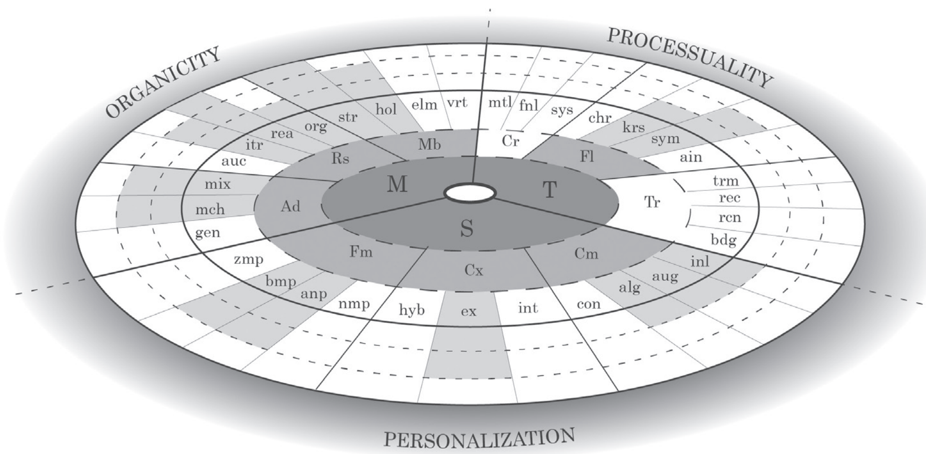


Fig. 8. Bioinnovations identified in the case of NSA Muscle (elaborated by R. Achramowicz, E. Kuhnert)

Il. 8. Bioinnowacje zidentyfikowane w projekcie NSA Muscle (oprac. R. Achramowicz, E. Kuhnert)

tionary development quite precisely, and yet, as the author points out (Troika 2008, 25), this unique software was not only used to create a perfect and optimized chair, but also enabled achieving a biomorphic form.

Thesis C: the bio-innovation pathways in the case of the *NSA Muscle* (Oosterhuis, Biloria 2008) are characterized both by multifaceted nature at the entry level and by bringing some paths to the level of a fully functioning prototype (Fig. 8). In this case, the aspects of innovation primarily concern organicity, revealed through mobility, responsiveness, and adaptability. Individual components of the building, such as sensors connected to a pneumatic system, have the potential for economic implementation, independent of the conceptual thought (Biloria 2010). The project also addresses issues relating to formal and contextual matters connected with real-time sensing, and integrates architectural space with biomechanics and digital technologies into a single space. The biotechnological sensor technology developed by Oosterhuis over the course of more than three decades is the foundation for shaping sentient architecture

(Lan, Luo 2006). In this case, the physical variability of the building is conditioned by the work of dozens of pneumatic actuators that form a unique architectural muscle. The artificial organ tightens, contracts and stretches in response to user-set stimuli coming from sensors placed on the shell. The concept is part of a larger project named Hyperbody – a study focused on bio-architecture shaped and operating like a living organism sensitive to stimuli. According to the architect's idea, the prototype is to be just one link in a chain of many such buildings, which will form a muscular ecosystem, freed from one place and context.

Discussion on innovation paths

The first element of the CLM envelope toward which the innovation paths lead is **Organicity**, which is linked to the Movement category. There is no doubt that everything that is alive is in motion (Aristotle 1937, 441 [698a]). In architecture, it is generally accepted that movement can be interpreted in one of two traditional (dating back to the mid-20th century) ways: imagined and real (Bloomer, Moore 1977). With the advent of the digital age, there appeared a new approach to simulated movement that is inextricably linked to digital processes. In the public awareness, which is based on the established classical model, space is associated with mathematics, while time and movement are linked to physics; geometric (Platonic) shapes give the impression of being static, while objects in motion are perceived as dynamic. In the case of the *Photosynthetica Tower*, one can look at movement as a change in composition of elements and the transitivity in time of entire organisms. The issue of time is developed slightly differently in the case of the *Bone Chair*, which arises from an evolutionary process, where the initial bone tissue evolves to yield a series of differentiated target objects. As if coincidentally, the design shows that new tools define the production and design processes, fundamentally affecting also the aesthetics of the objects themselves (Museum für Gestaltung Zürich, Sachs 2007, 74). In the *NSA Muscle*, innovation aspects are related to the communication between the object, the user, and the environment. In this case, the search for innovative thought leads to the tactile dimension of space that is not so much visual as tactile and responsive. In this case, the tactile properties of an artificial muscle cause its shell to take on the characteristics of a skin capable of receiving stimuli from the environment, and consequently the architectural space itself becomes, in a way, an extension of the human being and takes on the characteristics of a medium (McLuhan 1964).

This observation leads to the second element of the CLM envelope, *Processuality*, which delineates the paths of innovation derived from the category of Time, according to the principle that time inscribed in the design process makes all movement possible. Looking from a philosophical perspective, one can refer to Deleuze and Guattari's description of an abstract machine, which consists of a certain kind of code that is embedded and stored in it (Deleuze, Guattari 2017, 44) – this code records of all the transformations taking place within the body (here: architecture). In the context of architecture, which is pertinent to this article, time simulated in design processes is the crucial factor. This approach is reflected in the case of the *Bone Chair*, developed through computational coding. One can also look at the issue of time in a different way, as a matter of experiencing it in the work, as reflected by the *Photosyntetica Tower* and the pneumatic structure of the *NSA Muscle*, whose deformations occur in real time. On the one hand, the shell is active in terms of senses, like a real muscle, but on the other it adapts to the behaviour of the interacting entity – the participant in the game with the building. Such "smart cities and biodomes" (ecoLogicStudio 2025) lead toward Personalization, the third path set out based on the category of Space.

Personalization directs attention to the user rather than to geometry, and thus appears less obvious than the previous two directions – after all, in public awareness, architecture is defined as the art of space shaping. The breadth of this concept has been shown by the digital revolution, due to which reality has become an organization of information. This resonates particularly strongly in *NSA Muscle*, where the three-dimensional deformations of a building taking place in physical space are nothing more than the manifestation of information transmitted between the environment, the user, and the architecture. Another example of adaptation of an object to the user's need is *Bone Chair*, in which the establishment of an interactive connection between the conceptual (modelling) and manufacturing (material processing) phases has made it possible to simplify the product customization process. The result is an object that represents a unique type and is diverse at the same time – in other words, no single piece of furniture can be assumed to be perfect. Each is unique in its own mutation, which meets the conditions imposed at the time – whether it be context, comfort, or formal issues. In contrast, in *PhotoSynthetica Tower*, personalization refers to the behaviour of living algae, which can be controlled to a smaller degree. In the context of the deliberations on form, there is a shift in emphasis from a mechanistic approach to an organic approach and a transition from abstract to natural forms.

Conclusions

The test conducted showed the functionality of the CLM and its potential for further evaluation to achieve the following objectives:

– the objectivization of the conceptual apparatus, which will serve to offset the subjectivity of evaluation of innovation initiatives;

– the universality of the research model, which will improve the transfer of content between different design disciplines; and

– the intuitiveness of the way of depicting innovative thought, which will facilitate the work of individual stakeholders.

It was shown that CLM makes it possible to diagnose individual aspects of innovation on the basis of designated individual decoding paths. The multiplicity of these pathways creates an arrangement of "fingerprints" unique to each example tested (Fig. 9), which indicate the complexity of bio-innovation. Despite the fact that the study concerned only three selected designs, the test showed that CLM has the potential to identify novum in twin disciplines, in dif-

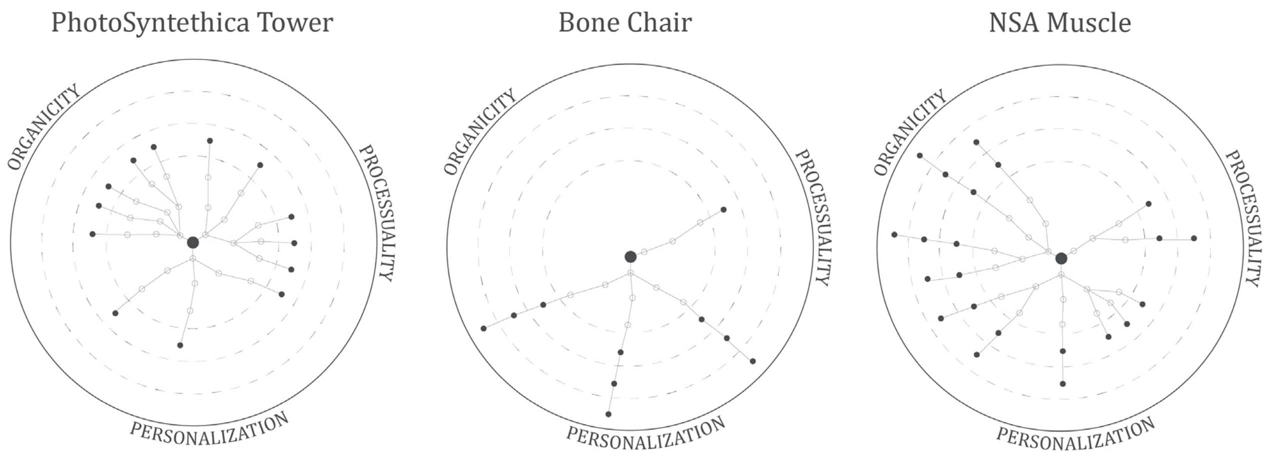


Fig. 9. Unique image of "fingerprints" that represent three theses (elaborated by R. Achramowicz, E. Kuhnert)

Il. 9. Zestaw unikalnych obrazów „linii papilarnych" reprezentujących trzy przedstawione w artykule tezy (oprac. R. Achramowicz, E. Kuhnert)

ferent types of designs and at different scales for which bio-innovation is the common thread. The proposed tool also has its limitations related to the geometry and mechanics of the centrifuge, which were found to work for the proposed designs-samples, but they could be transformed to test other areas of science, such as robotics. The answer to this problem is the flexibility embedded in the CLM construct, based on interchangeable bricks – the aspects. This will make it possible to adapt the tool to the conditions of a rapidly evolving world, where keeping up with innovative thought is correlated with going beyond rigid criteria and beyond accepted ways of thinking.

Summary

Only immovable elements can be arranged. Anything that changes, especially innovative ideas, eludes rational cognition – this observation in the context of innovation analysis is represented by commonly accepted indicators for its measurement, such as TRLs. While existing methods of measuring innovation serve to determine the state of advancement of the technology, they also overlook the incalculable potential of various innovative concepts. Clear examples supporting the above statement are provided by design bio-innovations that go beyond the rigid definition. They abandon the structured nature of innovations in favour of the responsive, flexible, and communicative ones that the CLM serves to identify. This research model enabled the comparison of innovations across related disciplines, while also considering them from different perspectives. In conclusion, it has been shown that the CLM can be useful at different scales: industrial design, architectural and urban planning, unifying the image of innovative thought, despite the extremely different projects. One should bear in mind, however, that the recognition and identification of paths of innovation does not take place automatically in the CLM and requires explanation − an issue perfectly illustrated by the words of Ludwig Wittgenstein, that every interpretation rests in the "logic of representation" (Wittgenstein 1922, 40).

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References

Addington, Michelle, and Daniel L. Schodek. *Smart Materials and New Technologies: For the Architecture and Design Professions.* Architectural Press, 2005.

Arendt, Hannah. *O myśleniu*. Translated by Halina Buczyńska-Garewicz. EUROPA, 1989.

Aristotle. *Parts of Animals. Movement of Animals. Progression of Animals*. Translated by Arthur Leslie Peck (*Parts of Animals*) and Edward Seymour Forster (*Movement of Animals*; *Progression of Animals*). Loeb Classical Library, 1937. Accessed June 20, 2024, at https://archive.org/details/L323AristotlePartsOfAnimalsMovementOfAnimalsProgressionOfAnimals/page/n5/mode/2up.

Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature.* William Morrow, 1997.

Biloria, Nimish. "Interactive Environments: A Multi-disciplinary Approach towards Developing Real-Time Performative Spaces." In *Entertainment Computing – ICEC 2010*, edited by Hyun Seung Yang, Rainer Malaka, Junichi Hoshino, and Jung Hyun Han. Springer, 2010.

Bloomer, Kent C., and Charles W. Moore. *Body, Memory, and Architecture*. Yale University Press, 1977.

Bush, Vannevar. "As We May Think." *The Atlantic Monthly* 176, no. 1 (1945): 101–8.

Deleuze, Gilles, and Félix Guattari. *Anty-Edyp. Kapitalizm i schizofrenia.* Translated by Tomasz Kaszubski. Wydawnictwo Krytyki Politycznej, 2017.

ecoLogicStudio. *Photosynthetic Architecture: Human to Non-Human Co-Living*. The Bartlett School of Architecture, 2025. Accessed May 15, 2025, at https://www.bartlettdesignresearchfolios.com/media/folio_docs/Design-Research-ecoLogicStudio-Photosynthetic-Architecture.pdf.

European Commission (EC). *Green Paper on Innovation. COM (95)688 final*. AEI, 1995. Accessed June 10, at https://aei.pitt.edu/1218/1/innovation_gp_COM_95_688.pdf.

Florida, Richard. *Narodziny klasy kreatywnej oraz jej wpływ na przeobrażenia w charakterze pracy, wypoczynku, społeczeństwa i życia* *codziennego*. Translated by Paweł Laskowicz. Narodowe Centrum Kultury, 2010.

Giedion, Sigfried. *Przestrzeń, czas i architektura: narodziny nowej tradycji*. Translated by Jerzy Olkiewicz. Państwowe Wydawnictwo Naukowe, 1968.

Kapsali, Veronika. *Biomimetics for Designers: Applying Nature's Processes & Materials in the Real World*. Thames and Hudson, 2021.

Kubler, George. *The Shape of Time: Remarks on the History of Things*. Yale University Press, 1962.

Laarman, Joris. "Bone Chair (2006)." Accessed April 10, 2025. https://www.jorislaarman.com/work/bone-chair/.

Lan, Bruce Q., and Xiaoqu Luo. *ONL: Hyperbody Logic*. Hebei Education Publishing House, 2006.

Liu, Chenyang, Song Qiu, Xi Zhang, Chen Zibin. "Research on Interdisciplinary Design Thinking and Methods Based on Programmable Mechanical Metamaterials." *Buildings* 13, no. 4 (2023): 933. https://doi.org/10.3390/buildings13040933.

Malara, Zdzisław, and Jacek Tutaj, ed. *Innowacje a dobrostan społeczeństwa, gospodarki i przedsiębiorstw. Próba pomiaru*. Oficyna Wydawnicza Politechniki Wrocławskiej, 2019.

Mang, Pamela, and Bill Reed. "Designing from Place: A Regenerative Framework and Methodology." *Building Research and Information* 40, no. 1 (2012): 23–38. https://doi.org/10.1080/09613218.2012.621341.

McLuhan, Marshall. *Understanding Media: The Extensions of Man*. McGraw-Hill, 1964.

Museum für Gestaltung Zürich, and Angeli Sachs, eds. *Nature Design: From Inspiration to Innovation*. Lars Müller Publishers, 2007.

Oosterhuis, Kas, and Nimish Biloria. "Interactions with Proactive Architectural Spaces: The Muscle Projects." *Communications of the ACM*, 51 (2008): 70–8. https://doi.org/10.1145/1349026.1349041.

Organisation for Economic Co-operation and Development (OECD). *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development*. OECD Publishing, 2015. https://doi.org/10.1787/9789264239012-en.

Pawlyn, Michael. *Biomimicry in Architecture.* RIBA Publishing, 2011.

Pasquero, Claudia, Marco Poletto, and Terezia Greskova. "Photosynthetic Architecture in Times of Climate Change and Other Global Disruptions." In *Anthropologic: Architecture and Fabrication in the Cognitive Age. Proceedings of the 38th eCAADe Conference. Volume 1*, edited by Liss Werner and Dietmar Koering. TU Berlin, 2020. https://doi: 10.52842/conf.ecaade.2020.1.583.

Pedersen Zari, Maibritt. *Biomimetic Approaches to Architectural Design for Increased Sustainability.* In *C/Sustainable Building Conference (SB07)*, (2007).

Pohl, Göran, and Werner Nachtigall. *Biomimetics for Architecture and Design. Nature – Analogies – Technology*. Springer, 2015.

Słyk, Jan. *Modele architektoniczne*. Oficyna Wydawnicza Politechniki Warszawskiej, 2018.

Stals, Adeline, Catherine Elsen, Sylvie Jancart, and Frédéric Delvaux. "Challenges in Teaching Architectural Morphogenesis." In *Proceedings of the 3rd International Conference for Design Education Researchers (LearnXDesign 2015)*, vol. 3. Design Research Society, 2015.

Troika (Freyer, Conny, Stuart Noel, Eva Rucki). *Digital by Design: Crafting Technology for Products and Environments.* Thames and Hudson, 2008.

Wang, Chia-Chi. "Using Design Thinking for Interdisciplinary Curriculum Design and Teaching: A Case Study in Higher Education." *Humanities and Social Sciences Communications* 11 (2024): 307. https://doi.org/10.1057/s41599-024-02813-z.

Wang, Min, Ye Xiaoxue, Bi Hongwen, and Shen Zhongbao. "Microalgae biofuels: illuminating the path to a sustainable future amidst challenges and opportunities." *Biotechnology for Biofuels and Bioproducts* 17 (2024): 10. https://doi.org/10.1186/s13068-024-02461-0.

Wittgenstein, Ludwig. *Tractatus Logico-Philosophicus*. Kegan Paul, Trench, Trubner and Co., 1922.

Wodecka-Hyjek, Angelika. "Wybrane narzędzia pomiaru innowacyjności." *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie* 922 (2013): 63–82.

Streszczenie

Identyfikacja i opis bioinnowacji w architekturze za pomocą dedykowanego narzędzia CLM

Czym jest działalność innowacyjna w architekturze? To pytanie leży u podstaw identyfikacji problemu badawczego, ulokowanego na przecięciu wielowątkowego procesu decyzyjnego i twórczego podejmowanego przez różne podmioty, których aktywność koncentruje się na komercjalizacji wiedzy. Przeprowadzona kwerenda potwierdza brak rozwiązania systemowego służącego identyfikacji i walidacji innowacji związanych z tą wiedzą. To spostrzeżenie pozwala autorom postawić hipotezę, że możliwa jest budowa potencjalnie obiektywnego, uniwersalnego oraz intuicyjnego systemu diagnostycznego, dostosowanego do specyfiki interdyscyplinarnych innowacji projektowych.

Artykuł stanowi rewizję ram teoretycznych i metod pomiaru innowacji, opierając się na autorskim modelu badawczym nazwanym Centryfugową Maszyną Logiczną (CLM). Celem autorów tekstu jest identyfikacja i opis różnorodnych aspektów innowacji w formie syntetycznej diagnozy. W pierwszym z serii artykułów przedstawiono ogólne przyczyny zastosowania nowatorskiego aparatu oraz wyniki testowania go w trzech skalach: architektonicznej, urbanistycznej i wzornictwa przemysłowego, które reprezentują trzy przykłady bioinnowacji, charakteryzujące się poziomem złożoności adekwatnym dla skutecznego testu CLM.

Dzięki przeprowadzonemu badaniu wykazano możliwość porównywania innowacji z różnych perspektyw: społecznej, kulturowej, technologicznej i przede wszystkim twórczej za pomocą jednego aparatu, który umożliwił uzyskanie ujednoliconego obrazu myśli innowacyjnej, mimo skrajnie odmiennych projektów poddanych testowi. Diagnozę poszczególnych aspektów innowacji wykonano poprzez wyznaczenie indywidualnych ich ścieżek za pomocą CLM. Wielość tych ścieżek utworzyła mapę innowacji, charakterystyczną dla danego obiektu, dając w efekcie unikalny układ „linii papilarnych". Ich różnorodność i złożoność świadczy o tym, iż innowacje w sztukach projektowych tworzą swoiste sieci złożonych trajektorii, których odkrywanie jest rodzajem dekodowania myśli.

Słowa kluczowe: architektura, innowacja, procesualność, personalizacja, organiczność