DIGITAL BIO-TRANSFORMATIONS INSPIRED BY PLANTS: URBAN INSTALLATION AS 3D MODEL INSPIRED BY SKETCH OF SPATHODEA CAMPANULATA P. BEAUV (NANDI FLAME)

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Abstract: The field of biodesign, as an art and scientific discipline, deals with the exploration of the principles of organization and functioning of living organisms and the practical application of the acquired knowledge in different digital technology projects. Two famous urban installations, one created by HQ architects in Jerusalem – four 9-meter high by 9-meter wide inflatable flowers that interact with people, and "My Equilibria", an urban furniture design created by Vito Di Bari and Alfredo Tasca, which people could use as exercise tools, were the main inspirations for his research as these two urban installations were inspired by different elements found in nature. Some of the previous studies and created 3D urban models were Natalie's Ramonda pavilion and Bellflower bench and candelabra. Natalie's Ramonda pavilion was inspired by endemic herbaceous plant in Serbia (*Ramonda nathaliae* P. et P.). This 3D model was 3D printed in Tokyo, Japan and exposed in several exhibitions in Serbia. Then, the next digital bio-transformation model was the 3D urban model of a bench and candelabra inspired by the flower and linear shaped leaves of Bell flower (*Campanula persicifolia* L.). The representation of the digital bio-transformation process obtained in the *ArchiCAD* software environment, which had as a result a 3D model proposition for a possible urban installation, was the main aim of this research. The unique geometric patterns found in the flower of *Spathodea campanulata* P. Beauv represented a good example of how we may transform nature ideas into innovative urban design solutions. African species *Spathodea campanulata* P. Beauv, whose common name in Kenya is Nandi flame was selected for the purpose. Nandi flame is an indigenous species in Kenya, with a very decorative flower. This flower was the basic model, or more accurately, the precise

botanical sketches of it. These sketches were imported in the digital modeling software – *ArchiCAD*. The next step was creating a 3D model in the shape of a possible urban installation, such as a bench. The results of these modeling processes are represented as 3D urban models in open space. This innovative design solution, in this research, represented as a 3D model, was proposed as an urban installation in an open fitness space. The unique nature pattern found in the flower of *Spathodea campanulata* P. Beauv was a good base of transformation into an actual design solution.
Keywords: digital bio-transformation; biodesign; *Spathodea campanulata* P. Beauv (Nandi Flame); *ArchiCAD*; 3D model; urban installation

BIODESIGN INSTALLATIONS IN URBAN ENVIRONMENTS

The imitation of various nature forms, which as a result represents new and original models of urban environment, represents the basis of the biodesign approach. Designing according to biological principles and forms seeks to use the properties of nature structures and geometric forms that exist. By applying different geometric forms and biological knowledge in the process of modeling and by copying models from nature, it is possible to produce various different new structures. Nature forms are unique to every species. They represent an aesthetics form, which comes from well-organized geometries already present in nature. Different plant species have served as inspiration for modeling completely new urban installations, which also have their function in urban space in the form of benches, pavilions, fitness equipment, etc. Biodesign (actual or conceptual) solutions represent a design movement which incorporates the use of very different living materials. This, we could say, is a part of the more complex fields, such as biomimicry. The word bionics comes from the Greek word *bios* (βιος), which means life, i.e. a living element, i.e. an element of the biological system, and the suffix –ics, which comes from the word electronics, i.e. the area of electronics. The combination of biology and technology is thus represented by the concept of bionics. The term "biomimetics" comes from the Greek words: *bios* (life) and *mimesis* (imitation). Close to this is the term "biomimicry" which comes from the words *bios* – life and mimicry. In addition to these terms, there are a large number of synonyms that are similarly related to bionics or can be related to it, such as: bioinspiration, bionic architecture, biophilia, biognosis, biotechnology, biophysics, biomechanics, bioengineering, biomorphology, etc. In general, bionics promotes ways of harmonious coexistence with nature. Interdisciplinary, multidisciplinary, i.e. transdisciplinary science, bionics includes a variety of knowledge from biological sciences, botany, neurophysiology, and ecology, as well as from technical-technological sciences, electronics, cybernetics, mechanics, but also many other scientific fields. Today, due to the degree of permeation of different scientific disciplines, it is considered that the term transdisciplinarity has already been surpassed, so within bionics we are actually talking about a hybrid scientific approach. The biomimicry field represents the process of creating solutions to different problems of mankind – and the inspiration is in nature. Conceptual design

solutions, and the results of applying the biodesign approach, could be of technical nature, in building industry, medicine and others. Biodesign is the creative part of these solutions. The one aim for biodesign is to use natural patterns and materials in a way that means 'not taken more than can be given back' – reflecting the sustainability purpose. Biodesign essentially crosses traditional art-design-science boundaries and creates new design solutions and technologies.

Urban installations, also known as street installations, make part of the field of installation art design. Installation art design is an artistic way of creating three-dimensional works that are often, though not always, site-specific, and usually designed to transform the perception of a chosen space. This term is generally applied to interior spaces, while for exterior space interventions they are usually called public art, or land art, or art intervention. All installations can be temporary or permanent. Installation artwork represents the results of these installation art design processes. Street installations are a form of street art often connected with street space. Some of the well-known types of street art are the art on walls and surfaces and street installations in urban environments. Sometimes, these art installations have an interactive component for users. Public art is an art approach whose form, function and meaning are created for the public. These are art works visually and physically accessible to the public; the results of this creative approach are installed or staged in public space, usually outdoors. Usually, the art works or installations have some effect on users of the selected urban space. Land art is a different part of installation art design, variously known as Earth art, environmental art, and Earthworks. This art movement emerged in the 1960s and 1970s. Land art expanded boundaries of art by the materials used in other fields. The materials used were often the materials of the Earth (the soil, rocks, vegetation, and water found on-site), and the sites of the works were often distant from urban centers – rather using very large areas for art installations, which makes this art approach different from the above-mentioned ones. The main field for this research was urban installations commonly designed for open spaces in cities, i.e. urban environments.

The world has become a highly urbanized place – migrations towards cities are present on almost all continents. Around 72% of the population on the European continent lives in urban areas.[1] Many people have adopted urban lifestyles, i.e. the cultural, educational and health services that a city has to offer. Cities are the engines of economy. However, it is important to remember that all cities depend heavily on regions outside the city in order to satisfy their needs for resources such as energy, water, food and others. This means that we depend on natural resources and that it is very important: first – to protect all those resources, and second – to use those resources sustainably so our urban environments – cities could ensure their survival.[2] The main challenge for city authorities is to find a way to accommodate an increasing number of people, also reducing impacts on the environment. A radical transformation of the current model of urban development and growth is certainly needed. One way to improve the quality of life of people in cities and to protect urban environment itself could be found in this new and sustainable field – biomimicry, as well as in biodesign solutions. There are many examples on how

1 About Urban Environment — European Environment Agency (europa.eu)

2 B.S. Jović, A.A. Čučaković, M. N. Grbić. "Circle in Space – Space in Circle: A Study of Ratio between Open Space and Built-Up Area in Historical Circular Objects." *Sustainability* 2021, 4662.

these solutions could improve urban environment in many different ways, such as solar benches or Wind trees that make energy.

EXAMPLES OF URBAN INSTALLATIONS AS 3D MODELS INSPIRED BY PLANTS

Patterns in nature are visible forms and structures found in the diverse natural-living world. The biological processes of natural selection often explain patterns in living things. The most known nature pattern is a snowflake – with its hexagonal symmetry and infinite varieties. This natural structure is a beautiful example of what forms and structures are usually formed during different natural processes. Snowflakes are formed by the simplest natural process – by water vapor freezing in humid air.

Nature is rich with many different inspirational designs – some abstract, some symmetrical. The beauty that people perceive in nature is derived from different layers of nature – some patterns are visible to our eyes, like a tree canopy, and other seen only with the microscope. Different scientific fields like mathematics, physics or chemistry explain patterns in nature at different levels, based on the study ratio.[3]

Studies of pattern formations nowadays include the use of computer modeling processes to simulate a wide range of natural patterns. Natural patterns recur in different contexts and can sometimes be modeled using the parametric modeling approach. Natural patterns include symmetries, trees, spirals, meanders, waves, foams, tessellations, cracks and stripes – very different structures and forms.

Flower is a very important part of the world of nature. Flowers all around the world, with their obvious material and mechanical function as a fertility mechanism in diverse plant life, speak the language of beauty to us on multiple levels. The social or psychological level refers to how flowers affect human perception. Besides that, its symbolism in different cultures is also interesting to all of us as humans. There is a special cultural and mythological level that implies a deeper importance of flowers and flora, and it is different in each civilization. We all know that red roses in many cultures symbolize love, yellow flowers jealousy and white tenderness. Nearly every sentiment imaginable could be expressed with different flower species, some based on their color, some based on the gorgeous smell and some based on their original form. The flower offers to the observer numerous values, from the enjoyment of finding, to the beauty in its appearance – smell, color, size or form (symmetries). The symbolic language of flowers has been recognized in many countries in the world for centuries. The inspirational level is the most important for the design that moves or inspires people.[4]

The shape (forms and structures) of flowers represents not only the harmony of colors, scents and shapes, it is an example of a strong connection of the symmetry and geometry principles based on which nature functions and which connect all other natural species to achieve universal spatial and natural order. According to the symmetry principles, flowers can be actinomorphic (polysymmetric), zygomorphic (monosymmetric), bisymetric or asymmetric. Actinomorphic (polysymmetric) flowers have structure in which more planes of symmetry are set, while in zygomorphic

3 B. Jović, M. Tripković, A. Čučaković. "Geometric correlation of cultural landscape patterns and Prunus domestica L. species leaf." *Bulletin of the Faculty of Forestry* 2011, 29–40.

4 K. Critchlow, *The Hidden Geometry of Flowers Living Rhythms, Form and Number*, Edinburgh, UK, 2011.

(monosymmetric) flowers, there is only one plane. Two planes of symmetry through bisymmetric flower structures are also placed through asymmetrical flowers – there is no plane of symmetry that could be set up in their specific structures.[5]

Geometry as a universal analog model that describes and simulates the relationships in the structure of natural systems is here the most valuable tool in comparative analysis. Using the methods of Voronoi diagram and Delaunay triangulation within the available software applications, the results are easily obtained. The Voronoi diagram is a method set up by Russian scientist Georgi Voronoi. A Voronoi diagram is a geometric structure that gives a graphical representation of the distance between a set of objects or points. The Voronoi diagram shows the areas to which each point is closest in the set of points in the plane. A plane is divided by assigning to each point the closest spatial unit when observing a group of objects or spatial units. The points on the Voronoi diagram are at an equal distance from two or more spatial units, i.e. the points whose nearest spatial unit is not unique form the Voronoi diagram. Finally, the Voronoi diagram is obtained by joining the centers of the described circles of triangles, that is, it consists of the bisectors of the sides of the triangles of Delaunay triangulation. Delaunay triangulation is a structure dual to the structure of the Voronoi diagram, where duality implies the possibility of linearly connecting two vertices of the Voronoi diagram if the Voronoi polygons contain one common edge. The Delaunay circle is the circle described in the process of Delaunay triangulation. Landscape architectural design using biomimetic principles requires a geometric description of three-dimensional spatial structures, and this paper favors the use of the Voronoi diagram, i.e. the dual structure of Delaunay's triangulation.

Design solutions whose inspiration came from the nature of water lead to further evolution of the methodology related to solving current problems. Nature offers an inexhaustible source of inspiration while the biomimetic approach does not fix entities such as function, form, material, and structure, but unites them by defining them as organic or semi-organic compositions. By imitating natural models with the application of geometric principles and biological knowledge, and with the use of modern technologies, solutions are reached that are layered, networked and sustainable.

As an example of designing models of urban space based on inspiration found in nature – we could present a few selected examples of urban installations. One of the innovative urban installations created in the world is a 9-meter high and wide flower installation in the form of a pavilion in Jerusalem, which opens as the users of the space pass by it. The Flower Lamps Bloom in Vallero Square, Jerusalem, and these wondrous flower lamps provide a great feeling while people are under the flower. However, when there are no people, the flowers close automatically (Fig. 1a).

Another urban installation is the design of "My Equilibria", a model of outdoor fitness equipment where users can exercise on equipment designed in the forms of tree branches. This brilliant, innovative and nature-inspired design just describes the essence of this approach. This model of outdoor fitness equipment, known as The Leopard Tree (see Fig. 1b), was designed by Vito di Bari. It is a futuristic tree design created for outdoor fitness. The Voronoi diagram was used in the design process. This model, with its natural design, attracts people to stay in nature and exercise for their health.

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5 B. Jović, A. Čučakovic, M. Marković, K. Cvijić, "Biomimetic Approach to Parametric Flower Modeling", in *Proceedings of 19th ICGG* 2021, Sao Paulo, Brazil, 2021.

Fig 1a

Fig 1b

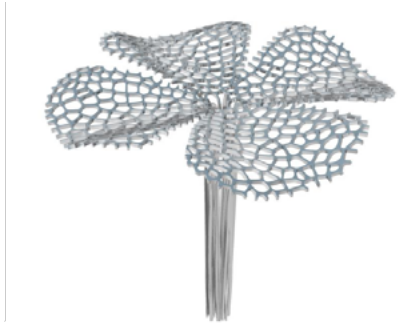

Fig. 2a

Fig. 2b

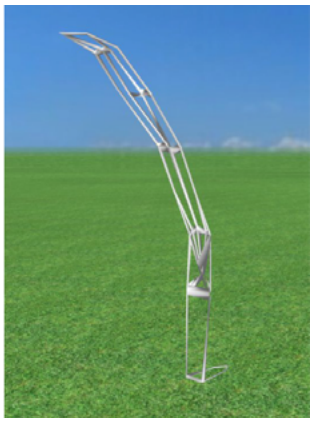

Fig. 2c

Some of the 3D models, created within previous research, represent also future urban installations and exploration of the modeling process by using the biodesign approach in different parametric software (Fig. 2). The first example presents the pavilion of Natalia's Ramonda (Fig. 2a),[6] a pavilion design inspired by an endemic herbaceous plant species in Serbia (*Ramonda nathaliæ* P. et P.). The base model for this pavilion was the flower of the chosen plant. This 3D urban model was generated in famous Rhino software, but using also a very popular parametric tool – Grasshopper.[7] The 3D model of the pavilion was 3D printed in Tokyo, Japan, to participate in an international competition, where it entered the top 11 finalists. Besides that, this 3D model of Natalia's Ramonda pavilion printed in Japan was also exhibited at several exhibitions in Belgrade, Serbia, such as the Students' Cultural Center, University library "Svetozar Marković" and the Gallery of the Serbian Academy of Sciences and Arts (SANU) within 8th Landscape architectural exhibition.

In addition to the pavilion, the other designed urban models were the models of benches and candelabra. Both of these urban models were inspired by the species *Campanula persicifolia* L. (see Fig. 2b and Fig 2c).[8] The bench model was created by using the form of Bellflower as the selected plant (Fig. 2b). The candelabra model was designed using the simple geometric form of leaves (Fig. 2c). The first, bench

6 B. Jović, "Biomimetic principles in landscape architectural design", in *Symposium "Landscape Horticulture 2018*, Belgrade, Serbia, 2018.

7 A. Čučaković, B. Jović, M. Komnenov, "Biomimetic Geometry Approach to Generative Design" in: *Periodica Polytechnica Architecture*, 2016, 70–74.

8 B. Jović, A. Mitić, "Introduction of nature forms through urban design: Biomimetic method in the process of designing candelabra model", in *Proceedings of 12th Asian Forum on Graphic Science*, Kunming, China, 2019.

Fig. 3

Fig. 4

model, was designed in 3DMax software, and the other, candelabra model, was created in the Blender model.

With the application of this innovative biodesign approach in the design process, urban design solutions can continue to push and change the boundaries of form in all their aspects. These creative and original design installations in open spaces can be a direction toward nature-inspired urban design. Besides, as their patterns come from nature, creating new urban environments could strengthen the connection between people and nature, which has recently been highly neglected.

BIODESIGN INSPIRED BY NANDI FLAME FLOWER

African species *Spathodea campanulata* P. Beauv, whose common name in Kenya is Nandi Flame (Fig. 3), is the plant species selected for this research. Nandi Flame is an indigenous species in Kenya, with a very decorative flame-like flower and it represented the basic model for the design of the proposed urban installation.

Spathodea campatulata P. Beauv[9] is one of the most spectacular flowering plants that is indigenous to the tropical dry forests of West Africa. Nandi Flame belongs to the family Bignoniaceae and the order is Lamiales. This plant is popularly known as the fountain tree, the African tulip tree or the Nandi Flame. This beautiful plant is often used in gardening in tropical and subtropical areas, including South America.[10]

It is a very decorative tree (see Fig. 3), with flowers that bloom in great abundance, and at such time, the tree can be seen from a great distance. It is widespread in

9 *Nandi Flame* – Infonet Biovision. https://infonet-biovision.org/EnvironmentalHealth/Trees/Nandi-flame

10 A. S. Wagh, S. R. Butle, "Plant profile, phytochemistry and pharmacology of Spathodea campanulata P. Beauvais (African tulip tree): A review". *International Journal of Pharmacy and Pharmaceutical Sciences*, 2018, Vol. 10, no. 5, pp. 1–6.

the tropics in large gardens and parks and has numerous healing properties. This woody species is rarely affected by diseases or pests, but can temporarily shed its leaves during periods of severe drought. The fungus *Ceratocystis fimbriata* and the scolytids *Xyleborus affinis* and *X. ferrugineus* have been reported attacking the ornamental plant *Spathodea campanulata* in Cuba. The affected plants presented yellow leaves, later died and fell leaving the trees bare. These plants did not produce new shoots.[11] This type of plant is highly recommended as a shade tree for parks and yards in the landscape architecture. It is also valuable as a barrier plant or a windbreaker. This species, either planted or growing naturally, is often used for hedges. Parts of this plant are also used for food, medicine and various products in everyday use. Its flowers are used as a diuretic and for anti-inflammatory purposes, while its leaves are used against kidney diseases, urethra inflammation and as an antidote for animal venoms. Its stem bark is used against fungal skin diseases, herpes, stomachaches and diarrhea.[12] It is planted during afforestation, for soil protection and as a plantation crop for the production of plywood. This species is native to Angola, Ethiopia, Kenya, Sudan, Tanzania, Uganda and Zambia. In Kenya, Nandi Flame is concentrated in Western and Central parts of the country.

The African tulip tree is an evergreen or semi-deciduous tree with a dense, bushy oval crown. This tree can grow from 10 to 35 meters in height. The leaves grow about one to two meters and have a bronze color. Horn-shaped buds, which appear in large clusters, are formed on the tops of the branches. The lowest layers of buds become red-orange (in some varieties yellow), bell-shaped like tulips. The leaves are deciduous, opposite leaflets, with 13–17 elliptical lamina. The large, compound leaves are dark green on the upper surface, and lighter in color below. On the stems, the leaves are opposite. The leaves are bright green and pinnately arranged with an odd number of elliptical leaves. As an invasive species, it reproduces aggressively and creates winged seeds that are scattered by wind and water. Its fruit, in the form of pods, are capsules, spears or in the shape of boats on thick stems. It is about 75 cm large, with elliptical pods held upright, full of winged seeds that are easily scattered by the wind. An upright, brown, ship-shaped spear accompanies the flowers, up to 25 cm long, within which are woody seed capsules with paper, winged, wind-scattered seeds.

The most spectacular element of this species is its flower. The flowers of Nandi Flame grow about 10 centimeters long. The tree blooms all year round (flowering period: from March to December), but the peak of the flowering season is spring. The flower is a hermaphrodite, in the shape of a bell, claw-shaped with wrinkled orange-red to crimson-yellow petals, with four pale yellow anthers and dark brown anthers (Fig. 4). Horn-shaped buds, which appear in large clusters, are formed on the tops of the branches. The lowest layers of buds become red-orange (in some varieties yellow) and bell-shaped like tulips. Large flowers are grouped in large clusters.

This incredible decorative species, also has some other uses,[13] as previously mentioned in the text. The first is its use as a food: the seeds are edible in many parts of Africa. Then, its timber is soft, light brownish-white wood and it is used for carving

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11 L. Herrera Isla, H. Grillo Ravelo, "Spathodea campanulata Beauv., new host plant of Ceratocystis fimbriata Hell & Halst and Xyleborus spp.", *Centro Agrícola*, Vol. 16, No. 2, 1989, pp. 91–93.

12 R. Kowti, R. Harsha, M. G. Ahmed, A. R. Hareesh, S. S. Thammanna Gowda, R. Dinesha, B. P. Satish Kumar, M. Irfan Ali, "Antimicrobial activity of ethanol extract of leaf and flower of *Spathodea campanulata* P. Beauv.", *Res J Pharm Biol Chem Sci*, 2010, 691–698.

13 African Tulip tree – *Spathodea campanulata*. https://candidegardening.com/ZA/plants/eaabf98455d9bdfef9c454fdb2ea58cd

and making objects. Besides that, it contains poison: the hard central portion of the fruit is used to kill animals. It is used for certain medical purposes, too, as the bark has laxative and antiseptic properties. Its seeds, flowers and roots are used as medicine also. For urban areas, when the tree has a lot of growing space and conditions are favorable, this species becomes wide spreading and its large roots can damage sidewalks and driveways in urban environments. The African tulip tree could be artificially grown in a container or pots. The pots are moved indoors when the temperature drops, so the tree is protected in that way from cold weather. The tree has become naturalized in Hawaii too. In Florida, it is in full bloom in early April and in scattered bloom during the rest of the year. It grows in Southern California but displays its full glory in the summer and fall. It does not tolerate much frost and lesser still when it is young.

DIGITAL BIO-TRANSFORMATION PROCESS – FROM SKETCH INTO 3D MODEL

Nandi Flame flower was a source of inspiration for applying biodesign in a current landscape architectural design project as a multifunctional urban installation – a bench and a small fountain as one element. The one aim of this research was to use two visualization techniques, one traditional – sketch, and one modern – computational modeling.

The best way to describe and explore some plant species was through a drawing process. This method was effective for the purpose of delineating and providing detailed descriptions of different plant species, and all drawings made are known as very significant botanical illustrations. Botanical illustration is the art of depicting the form, color and very small and significant details of plant life. Prior to today's modern visualization tools, botanical illustration was the only way of visually recording many plant species. Many skilled artists and illustrators shared the beauty of botany and also saved some of them from oblivion. Great artistic skill, attention to fine details and some horticultural knowledge, patience and passion for drawing are needed for this "job". This practice first began between 50 and 70 BC.

For this research, the first visual technique used was free hand drawing of flower Nandi Flame (Fig. 5). The aim of this sketch was to capture the external form of the flower so it would be further used in computation modeling. Only one sketch was selected for the further modeling process. The second step was to import the free hand sketch of the flower into the chosen BIM software. The digital drawing started after that scanned and the obtained picture imported into BIM environment.

The third step of the modeling process was the final step of creating 3D model of future urban installation. The BIM software chosen for the modeling process was *ArchiCAD*. The *ArchiCAD* software is one of the most innovative BIM platforms available. A very powerful software can meet the design needs of many different fields. In this research, a 2D sketch (the chosen botanical illustration) was introduced in *ArchiCAD*[14] and converted into a 3D model. Even though the name of the software has "CAD" in it, *ArchiCAD* is most definitely BIM software. Some of the users call *ArchiCAD* the real – original BIM software, as it was the first one to reach the market in year 1987. At its launch, it was considered revolutionary for being able to store large amounts of information within the 3D model. This software still remains one of the strongest solutions for data-heavy models. It also has the 2D function-

14 ArchiCAD. https://myarchicad.com/

Fig. 5

ality for producing documentation from the BIM, and a very strong interface for linking between different 2D and 3D elements of the model. There is a lot of other BIM software on the market now, so it is also important that software can import different file types, which is especially important for this research approach, as it was necessary to import a drawing file into the software so that the modeling process could start. *ArchiCAD* supports a wide range of file formats for import and export. It supports *ArchiCAD* DWG and DXF file formats, Microstation DGN, Navisworks NWC, Solibri SMC, Sketchup SKP, OpenBIM formats IFC and BCF, and many more. Another great type of BIM software on the market is REVIT – a BIM software from the Autodesk software family. Revit and *ArchiCAD* are both great pieces of BIM software and widely used by architects around the world. Revit is mainly used in

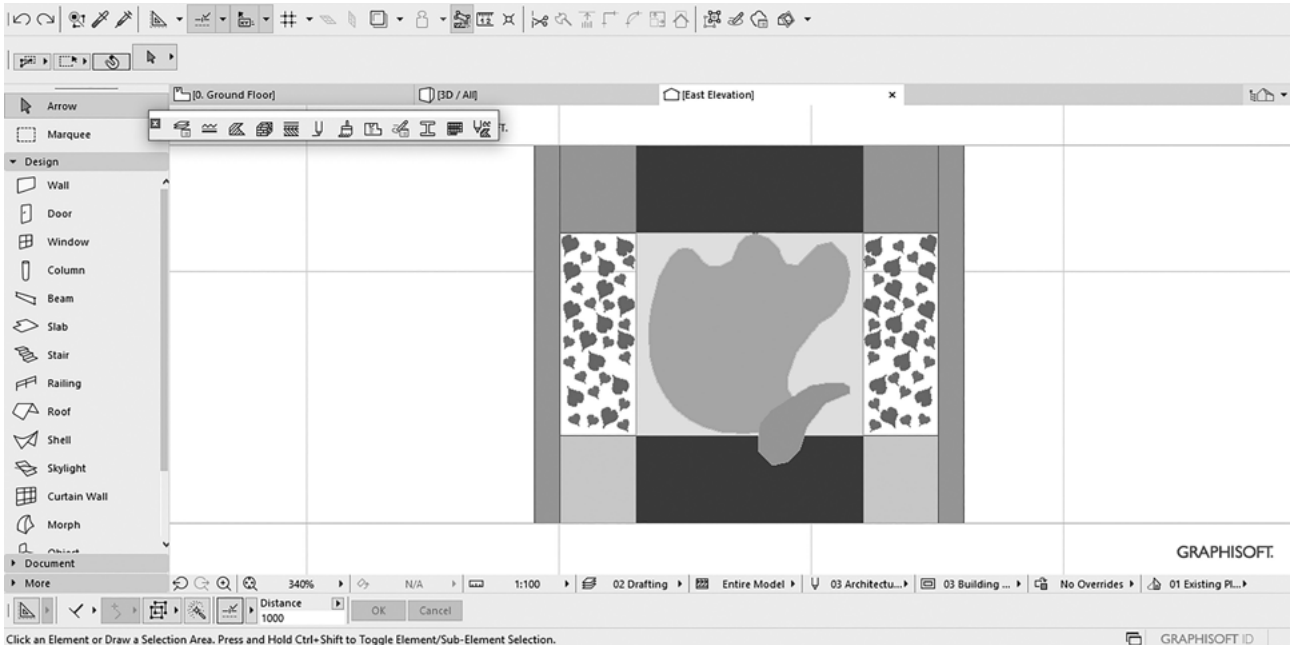

Fig 6

North America, but also in other parts of the world. Models can be linked for live collaboration in BIM 360, which is a very good option for many users today. It is customizable with a wide range of Add-ins and it represents strong support for structural & MEP design. *ArchiCAD*, on the other hand, is easy to use, with intuitive design libraries out of the box; it can manage large models in a single file, has strong 2D/3D interface and has strong OpenBIM/IFC support. For the purpose of this research, the *ArchiCAD* software was chosen, based on its support of a wide range of file formats for import and export.

The modeling process covers several steps. The first one is importing the chosen picture into BIM environment using the Plan mode option, so the sketch is used as a 2D plane object, by applying available tools in the software. The flower can get its external form, by setting the freely chosen parameters according to some often-used measurements in the landscape architectural field for the bench model, and be finalized as a 3D model by giving it thickness and colors (Fig. 6). It is important to point out that this 3D model – urban installation – represents an innovative and original design model, so most of the measurements used are according to the author's creative vision. The last step of this research was to design also the urban environment where this urban installation would be presented.

The biodesign approach consists of three basic steps: biological (selecting proper model from nature), geometric (generating the geometric form into computer environment) and technical (physically representing the 3D model by using 3D printing tools or some other designing tools). Geometric analysis in this research focuses on a geometric pattern of the selected plant species. The geometric pattern is further observed in detail and in accordance with biodesign principles. By applying a separate geometric pattern of the selected plant species to the geometry of conceptual landscape/urban design, original solutions were proposed. The initial sketch of the flower of *Spathodea campatulata* P. Beauv. was used as the conceptual model for designing the landscape architectural element like a bench with fountain. Inspired by the geometric structure of the flower of Nandi Flame, we used the external form of the flower, which was drawn and scanned so it could be used in adequate soft-

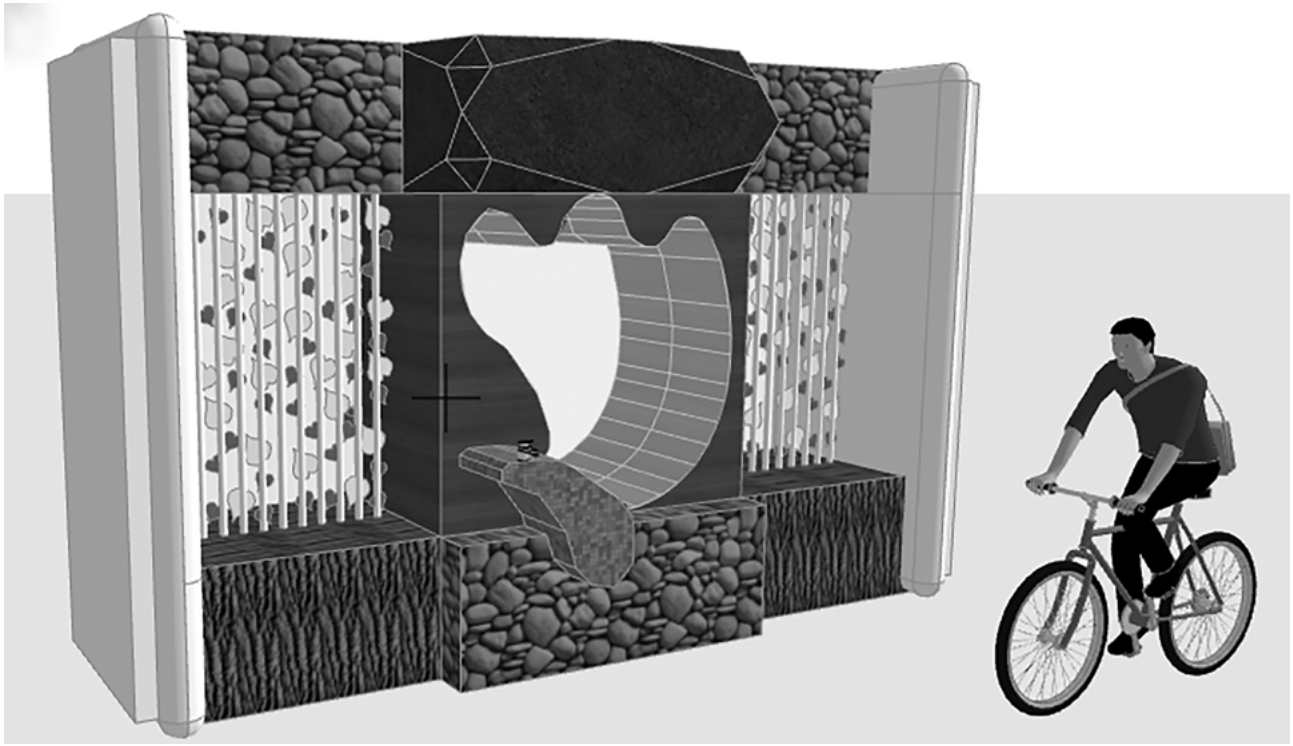

Fig 7

ware for parametric modeling, like *ArchiCAD*. In the Plan mode, where it is possible to automatically generate heights, sections and 3D views, the scanned sketch was imported and according to that plane model, by using basic computational drawing tools – the 3D model of the bench and fountain was created (Fig. 7). When creating objects and details that are multi-store and multi-layered, like in this research, minor flaws in the design are simply corrected through a 3D viewer, which makes this tool perfect for use in finding potential errors.

Starting with the import of the sketch drawing into BIM environment as a Plane object, the modeling process begins by using Element Parameters in *ArchiCAD* software. In this software, there are libraries with defined parametric objects like doors, windows and others, mostly used in architecture and the building design field. For the purposes of this research, these elements were not needed. We used the general parameters in the modeling process. First, we adjusted the 2D view of the plane object for further use of the parametric tool – in this case a shell option, to draw an external form of the flower of Nandi Flame. The desired design was drawn in the 2D view as the front view of the imagined future urban furniture. We defined the parameters like length and area, and then started to work in the 3D view environment, to add the volume, thickness and surfaces to the model.

The 3D modeling process of the bench-fountain model included defining the surface area that follows the external flower form. The desired design image is such that the users of the open space could be set in the flower structure, more precisely in the external flower form of Nandi Flame. Therefore, the external flower form is recognizable in the rectangular structure such that the sitting part is near the fountain. The small sized element is possible to design as a usable urban model. After defining surfaces, the next step was to adjust the parametric elements, such as the volume and thickness of the model. The fountain element modeled as lower bud near the flower sit. In this way, all users could sit on the “Flame” bench, and drink

water to lower their body temperature. This is why this urban model is imaged to be in an open fitness space, where people actively exercise.

The special element of this urban model is the net-design located on the right and left side of the flower sitting form. On the net, small objects are modeled based on the heart-like seeds of the Nandi Flame plant. They were modeled like plane objects with very small thickness parameter.

After finishing the design of the bench-fountain as a 3D model (Fig. 7), the final step was to create a proposition of the type of open space where the imaged 3D model would be installed. As it is mentioned above, this urban model was imaged to be in an open fitness space, a place where people actively train, exercise and fast-walk. The 3D model was finally placed between two racetracks, so everyone who gets tired could sit and take a little rest. The open space model of the fitness space was designed simply – with two racetracks and one sitting place for socializing. The modeled urban bench-fountain was imaged to be for one user.

The result of this research was an urban bench-fountain 3D model in an imaged environment for this model to be implemented. The technical step of the biodesign approach has not yet been realized, so this research covers the biological and geometrical step of the biodesign approach. The design solutions whose inspiration came from nature lead to further development of the methodology related to solving current problems. Nature offers an inexhaustible source of inspiration while the biomimetic approach does not fix the aspects such as the function, form, material, and structure, but unites them by defining them as organic or semi-organic compositions. By imitating natural models with the application of geometric principles and biological knowledge, and with the use of modern technologies, the reached solutions are multi-layerd, networked and sustainable.

MULTIFUNCTIONAL BENCH-FOUNTAIN URBAN FURNITURE – *"NANDI FLAME'S PARADISE"* INSTALLATION

The results of the research described in this paper were presented through the unique shape and geometric patterns discovered in the flower of the Nandi flame tree in order to conceptually design urban structures such as a bench with fountain for use in open spaces (Fig. 8a). Digital modeling was included to further develope the ideas by mimicking the patterns present in the flower of this woody plant. Results were obtained by using digital technologies like *ArchiCAD*.

The 3D model of the bench and fountain and the proposition for urban installation created in this research was named "*Nandi Flame's paradise*" (Fig. 8b). This urban furniture, designed for open fitness spaces, is mentioned in the section above (Fig. 8c).

Urban equipment elements have always followed the artificial urban environment, created by people. Urban furniture is designed as the formation of different elements to contribute to the communication, aesthetics and functionality of the city. These urban elements facilitate the personal and social urban life and shape society. The more specific definition is – "urban furniture are all elements used in landscaping arrangements that respond to basic functions such as sitting, sheltering, transportation, lighting, consultation, communication, games and sports in areas such as streets, roads and squares."[15] Urban furniture today has the important role also in achieving sustainability goals defined by the city government. That is one

15 E. Uslu, A.E. Bölükbaşı Ertürk,. "Urban Furniture in Historical Process", *Journal of History Culture and Art Research* 2019, 2147–0626.

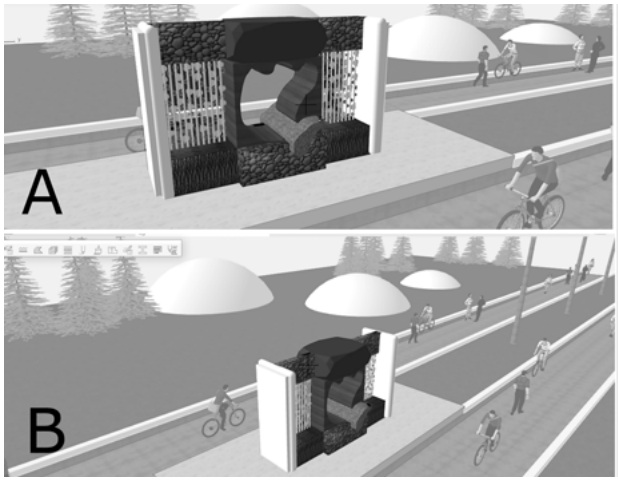

Fig 8a, 8b

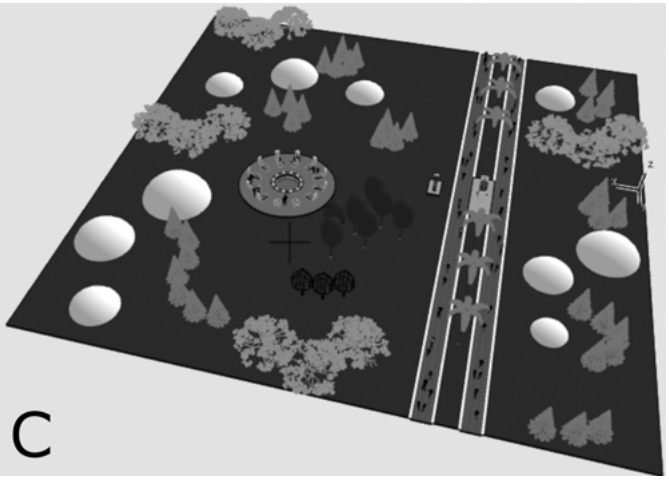

Fig 8c

of the possible ways of the many different urban models that could use the sun's energy to charge cell phones while sitting in the park or to use wind energy while also preserving the city air. Recently, there have been many different urban models for whose design nature was the first inspiration.

Today, the design of urban spaces is approached from the aspect of interdisciplinarity, by professionals striving to connect different dimensions of the city[16] The design of open public spaces significantly affects human behavior and perception, their everyday activities and social relations. Custom-design of urban models can provoke various activities and different user experiences of the space and its elements.

One specific purpose of nature-inspired urban elements can be recognized in the biophilic approach. Biophilic approach is a design concept used to increase occupant connectivity to the natural environment through different nature forms, structures, materials, process and urban elements and spaces. According to this approach, this idea has health, environmental, and economic benefits for urban environments. Although this term has only been used in recent history, indicators of biophilic design have already been seen in architecture, such as the Hanging Gardens of Babylon. Large green areas and plant diversity in such a closed object and structure could be the main example of biophilic approach to urban development strategies and planning. The word "*biophilia*" was first introduced by psychoanalyst Erich Fromm. He stated that *biophilia* is the "passionate love of life and of all that is alive…whether in a person, a plant, an idea, or a social group", in 1973.[17] Urban elements can have a big impact on people living in urban environments from the psychical and social points of view, and could improve the city environment from the climate point of view, using different nature elements. This approach promises to have significant implementation in the future as more and more cities are trying to find the best solutions for many city problems.

With the help of geometric relations, a design model was creatively formed, and the outcome depended entirely on the chosen parameters. For the further development of this design idea and this biological approach to the design process, it is necessary to explore much more complex geometric forms found in nature and try out various kinds of digital software.

16 M. Dragićević Šešić, I. Šentevska. *Urbani Spektakl*. CLIO, Beograd, Srbija, 2000.

17 E. Fromm. *The Anatomy of Human Destructiveness*. Fawcett: New York, NY, USA, 1973, 366.

CONCLUSIONS

Nature is full of wonderful inspiration through which we as designers can add beauty to the artificial inventions that we are constantly creating. During the observation of natural structures, it is important to notice their forms and processes and devise how to apply them as easily as possible in technology and design. In nature, each element is multifunctional and functions in conjunction with other elements, with all of them transferring action to each other. In nature, elements are constructed so that they have more characteristics or the composition of several elements fulfills a certain function. The morphological structure is the result of the harmonization of the natural world and its unique environment.

Digital modeling is one of the contemporary ways of generating different biodesign patterns, i.e. the digital bio-transformation process. Natural patterns organize and define relationships in nature and they are integrated into biodesign models with the help of digital technologies. Thanks to the permanent development of digital technology, the process of designing and modeling various shapes and forms is greatly facilitated today. Modeling is a creative process that results as the creation of an appropriate model. Today, digital modeling, as a parametric process, is an integral part of every 3D modeling software. Digital modeling is called 3D modeling software because it uses three dimensions: length, width and height, so it involves defining and manipulating certain parameters. Each complex model or shape is constructed and modified by using simple geometric models and changing various parameters. Thanks to these features, parametric models are flexible to operate.

Parametric biodesign, or a parametric biodesign model as the result of this modeling process, has innovative and original models as the results. The model built in the software is based on the flow and modification of a lot of information from the base model applied to a physically defined object. Different digital modeling programs, such as ArchiCAD, Fusion 360, 3Ds Max, Maya, Cinema 4D, Blender, Rhinoceros and others, have various tools that enable shape transformation. Biodesign is an art and scientific discipline that deals with the study of the principles of organization and functioning of living organisms and the practical application of the acquired knowledge in present day digital technology projects. Principles and methods of biodesign research involve the analysis of natural forms translated into geometric patterns that provide a basis for further experimentation. The results of the conducted research have application in generative landscape architectural/urban design.[18] The development of interest in geometric shapes that occur in nature and their implementation in design solutions is in expansion. The help of modern technologies is very valuable because it enables the application of generative models in different designs. The models obtained in this way carry a strong visual message that leaves a spatial impression implemented in the artificial structure, and whose living origins make such a hybrid composition semi-organic.

The aim of the research is to emphasize the importance and explain the possibility of applying the biodesign approach through the analysis and procedure of digital modeling of urban installations. This paper included the research of the digital bio-transformation of the species *Spathodea campatulata* P. Beauv., more precisely, the geometric pattern of flowers. A geometric pattern is generated in the

18 B. Jović, A. Čučaković, J. Tomićević Dubljević, A. Mitić, "Examination of the visual experience of biomorphic form materialized in urban design", in *Proceedings of The 18th International Conference on Geometry and Graphics*, Italy, Milano, 2018.

well-known parametric modeling software – *ArchiCAD*, in order to obtain an appropriate geometric form which further finds its application in the design, actually the biodesign process. The generated geometric form is materialized in the form of conceptual solutions for the design of a unique model for urban spaces such as a bench with fountain.

Using the biomimetic principle in landscape architectural design in the same way as can be seen in the plant species which served as the inspiration for this work, developed the form, function and ability to adapt to environmental conditions. By the same logic, biomimicry offers quite serious solutions that represent a great potential for neutralization and overcoming of potential problems. Applying generative design as a perfect tool offers a practically unlimited range of possibilities for obtaining various shapes, thus overcoming all potential problems in the realization and materialization of landscape architectural solutions. Confirmation of the acceptability of these research results will certainly continue,which can be carried out through additional analyses and research of public opinion by using different types of visual questionnaires that should verify the recommendations for the use of adequate software packages and be an affirmation of the results of previous research.

This type of design approach is innovative, bearing in mind the fact that such approach as used in the biodesign process, is relatively new within any design profession. The derived pattern, shown it this research, could find application in small-scale structures such as elements of interior design suitable for 3D printing and also as innovative outdoor elements. The effectiveness of the biodesign approach lies in its practical application in many areas of innovative design. There is a great potential for further research resulting in the design and innovation of complex structures for human use, achieved by exploring the diverse natural patterns evident in different plant species.

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ILLUSTRATIONS

1. Urban installations: The Flower Lamps Bloom and “My Equilibria”.
   Source: https://www.hqa.co.il/home/warde and myequilibria.com
   Урбане инсталације: Цветне лампе и “My Equilibria”.
   Извор: https://www.hqa.co.il/home/warde and myequilibria.com
2. 3D models of urban furniture: Pavilion of Natalija Ramonda, Bench and candelabra of Bell flower.
   Source: Biljana Jović (author), Mirjana Komnenov (landscape architect) and Anđela D. Mitić (author)
   3Д модели урбане опреме: Павиљон Наталија Рамонда, клупа и канделабар Звончић. Извор: Биљана Јовић (аутор), Мирјана Комненов (пејзажни архитекта) и Анђела Д. Митић (аутор)
3. Nandi Flame tree (Spathodea campanulata P. Beauv.).
   Source: https://suntrees.co.za/spathodea-campanulata-african-tulip-tree-flame-of-the-forest/
   Дрво Nandi Flame (Spathodea campanulata P. Beauv).
   Извор: https://suntrees.co.za/spathodea-campanulata-african-tulip-tree-flame-of-the-forest/
4. Flame-like flower of Nandi Flame species.
   Source: https://www.pinterest.com/pin/521854675570667779/
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   Извор: https://www.pinterest.com/pin/521854675570667779/
5. Botanical illustration of Nandi Flame flower. Source: Benjamin Chemarum (author)
   Ботаничке илустрације цвета врсте Nandi Flame. Извор: Benjamin Chemarum (аутор)
6. Plane object in ArchiCAD. Source: Benjamin Chemarum (author)
   Plane објекат у ArchiCAD окружењу. Извор: Benjamin Chemarum (аутор)

7. 3D model of urban bench and fountain. Source: Benjamin Chemarum (author)
   3Д модел урбане клупе и фонтане. Извор: Benjamin Chemarum (аутор)
8. Urban installation—Nandi Flame innovative bench-fountain design model. Source: Benjamin Chemarum (author)
   Урбана инсталација— Nandi Flame иновативна клупа-фонтана дизајн модел. Извор: Benjamin Chemarum (аутор)

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ДИГИТАЛНЕ БИО-ТРАНФОРМАЦИЈЕ ИНСПИРИСАНЕ БИЉКАМА: УРБАНА ИНСТАЛАЦИЈА КАО 3Д МОДЕЛ ИНСПИРИСАН ЦРТЕЖОМ ВРСТЕ SPATHODEA CAMPANULATA P. BEAUV (NANDI FLAME)

Овај рад у свом првом делу издваја неколико примера биодизајна – 3Д модела дизајнираних у виду урбаних инсталација (поједини модели су изведени у просторне инсталације, док су поједини примери остали на нивоу 3Д модела). Област биодизајна, као уметничка и научна дисциплина, бави се истраживањем принципа организације и функционисања живих организама и практичном применом стечених знања у различитим пројектима применом дигиталних технологија. Сваки од издвојених примера има две заједничке карактеристике. Прва је да је инспирација за њихов дизајн пронађена у природном окружењу, тачније у разноврсном биљном свету. Друга заједничка карактеристика изабраних модела јесте коришћена методологија која се састоји од три корака: биолошки, геометријски и технички. Различите биљне врсте послужиле су као инспирација за моделовање потпуно нових урбаних инсталација које имају и своју функцију у простору у виду клупа, павиљона, фитнес опреме и др. Две познате урбане инсталације, које су биле главна инспирација за ово истраживање, јесу интерактивна инсталација у Јерусалиму и фитнес опрема "My Equilibria", јер су ове две урбане инсталације инспирисане различитим елементима који се налазе у природи. Позната интерактивна урбана инсталација изведена у свету јесте 9-метара висока и широка инсталација цвета у виду павиљона у Јерусалиму који се отвара када корисници простора прођу поред ње. Инсталација у простору – дизајн "My Equilibria", јесте модел фитнес опреме на отвореном простору на коме корисници могу да вежбају на опреми дизајнираној по угледу на форме грана дрвећа. У раду је приказан и павиљон Наталије Рамонде, дизајн павиљона инспирисан ендемском зељастом биљном врстом

из Србије (*Ramonda nathaliae* P. et P.). 3Д модел павиљона је 3Д штампан у Токију, Јапан, при учествовању на међународном такмичењу где је ушао у првих 11 финалиста. Такође, модел је изложен на неколико изложби и у Србији. Поред павиљона, у раду су приказани и модели клупе и канделабра. Оба наведена урбана модела јесу инспирисана врстом звончића (*Campanula persicifolia* L.). Приказ процеса дигиталне био-трансформације добијене у *ArchiCAD* софтверском окружењу, који је као резултат имао предлог 3Д модела за урбану инсталацију, био је главни циљ овог истраживања. У овом раду приказан је метод моделовања 3Д модела на основу цртежа биљне врсте *Spathodea campanulata* P. Beauv, познате као *Nandi Flame.* Ово је аутохтона врста у Кенији, са врло израженим цветовима. Цвет ове врсте је представљао основни модел, тачније, за процес моделовања коришћена је ботаничка скица цвета. Скице су имплементиране у одабрани софтвер за дигитално моделовање. За ово истраживање одабран је *ArchiCAD*–BIM софтвер за параметарско моделовање. Резултат овог процеса моделовања представљен је у виду 3Д модела. Даље, модел је представљен у 3Д просторном окружењу у виду урбане инсталације на отвореном фитнес простору. Јединствени природни образац пронађен у цвету врсте *Spathodea campanulata* P. Beauv, послужио је као одговарајућа основа за трансформацију у иновативну урбану инсталацију.
Кључне речи: дигитална био-трансформација, биодизајн, *Spathodea campanulata* P. Beauv (Nandi Flame), *ArchiCAD*, 3Д модел, урбана инсталација