A Design Method of Children Playground Based on Bionic Algorithm

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Abstract. A reasonable and healthy playground is an important guarantee for children to develop cognition through physical games. [] However, due to the influence of early childhood psychology and the popularity of stereotypes, the existing industrialized production of children's play space has been defined and designed from the perspective of adults. With the help of interdisciplinary thinking and tools, based on the theory of child psychology and the circular game system, we propose a new method of children's playground design. At first, we reviewed the fallacies of the past children's playground design and their causes and summarized the elements of ideal children's playground construction. Secondly, we introduced the Physarum polycephalum algorithm and brought this algorithm to the path generation of different terrains and environments. Third, we analyze the path and introduce the amoeba bionic algorithm tool to determine the facilities, and then generate a series of play facilities. Finally, we brought this result into the case and discussed its potential applications in interactive design.

Keywords: Space design · Child-playground interaction · Algorithm design · Children psychology · Interactive design

1 Introduction

Education is an activity that is not limited to location, and sometimes it even exceeds the scope of the school. Various institutions or places such as playgrounds and museums are responsible for educating children. Especially playgrounds can be regarded as vital in terms of releasing children's high energy, positive self-development, exploring children's skills, self-esteem and success, as well as children's cognitive, physical and mental development. We need playgrounds to enhance these skills and provide children with options to learn new things [1]. Studies have shown that children are more likely to play in areas where more play facilities is installed, and the density of children in facilities areas is 3.3 to 12.6 times that of open grasslands [2]. In areas with goals and a fixed play structure, children are more likely to be very active than in open areas. Therefore, the facilities on the playground has a great influence on where children play. In order to enable children to carry out the maximum physical exercise, the playground should be designed with enough varied play facilities. In addition, the diversity of plants and terrain corresponds to functionally related structures, providing multiple functions. According to research, there is also a close relationship between landscape structure and

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play functions. The diversity of terrain and environmental elements may be regarded as a dimension of the quality of natural play facilities. It can improve children's athletic ability through a full range of games and exploring the natural game environment [3, 9]. Therefore, diverse children's play facilities and environments are important guarantees for children's games. However, most children's playgrounds in China still use traditional set play facilities. This may bring about a series of issues. Traditional set play facilities only provide a single game mode designed for children. In addition, this kind of facilities usually randomly placed on the playground and has no contact with the surrounding environment. In order to allow children to obtain more diversified games and maximize the benefits of reasonable playground space planning. Here we propose a way to help design a children's playground through bionic algorithms. In this method, terrain and surrounding environment can be taken into consideration as elements of the bionic algorithm. Different terrains will generate different paths, and then designers can choose the next step to generate specific rides based on the path. It is realizing to increase the diversity of children's games, and it can better correspond to the surrounding environment. We hope that this method can provide designers with different needs with a variety of choices and references.

2 The Importance of Children's Play

2.1 The Stereotypical Playground Mode

In China, most kindergartens and communities use complete sets of play facilities including slides, swings, and climbing equipment as playing facilities in children's playgrounds. Such facilities provide children with a fixed game mode. At the same time, these facilities are placed in the space according to the spatial arrangement. For example, this is often seen in kindergartens, where play facilities are usually placed in corner to ensure that the other area of the open space is sufficient for other functions. We analyze the cause of the massive popularity of this design as a misunderstanding of early psychology for children's games. The nineteenth-century psychologist Herbert Spencer advocated the "Residual Energy Theory" in the book "Principles of Psychology", which means that the main reason for children's play is to get rid of excess energy. This popular view has lasting influence on the design of children's outdoor play environment. The playground is regarded as a place for sports activities when children are recuperating. Children are "burning" here, not for other development or learning areas [4]. Based on the lack of understanding of children's games, the designers of children's play facilities have also been shaped into playgrounds based on this theory. It should be designed to manage children and not to stimulate children. In this context, the playground with "slides, swings, and climbing" considered a reasonable mode by most adults has been continued. What most designers do is to change their colors from the perspective of an adult.

2.2 The Importance of Play in Children Psychology

Although the theory of residual energy affects the design of children's amusement facilities. But the psychology of children's play has been developing. Piaget pointed out that games are the most basic way of communication that occurs before language and art. Games are also a means for children to explore and understand the world. Studies have shown that 'active' toys make children tend to be inactive, the smarter the toys, the less room for imagination and creativity for children. Some toys with established patterns may cause children to fall into a single mindset. The traditional complete set of playground equipment has a fixed game setting. It gives children less room for self-development games. It should be noted that this does not mean that children can start creating games on their own without the help of any tools or any outside guidance. Children still need a platform to play games, and this platform needs to provide game possibilities, but there is no certain game setting.

2.3 Circular Play Systems

Japanese landscape architect Mitsura Senda has many large-scale children's space design works. By observing the children, he found that children like to chase and run around. In a place suitable for playing, the flow of the game is cyclic. On the other hand, he found that in cities, places where children can play games are generally selected in blocks that can circle around, and there are shortcuts that can be copied. Mitsura Senda suggested that the play space designed for children should base on circle path. Under the premise of safety, this ring can be full of changes, allowing children to experience the excitement that is so happy and dizzy. The circle must contain a landmark place, large and small gathering places for children to play games, need to have a shortcut route, and be designed as a "porous" space for children to pass through [5].

2.4 Our Ideal Playground Mode

Based on the theory of child psychology and the inspiration of Mr. Mitsura Senda, we hope that through our new method, we can generate a playground space that provides children with game opportunities instead of specific game modes. We hope that the generated space has the following characteristics: connected with surrounding environment, in other words, the game facilities need to be related to the environment. This can inspire children to discover more ways to play. Then the circulation road in the space should be smooth and varied. This is an important guarantee for the safety of children. And it adds fun to the children's game process. The whole space is composed of porous structure. The hole structure is similar to the structure in nature and can bring many game methods. For example, a small hole can be used as a passage for children to observe, while a large hole can become a "short path" for children.

3 The Paths of Playground Space

3.1 Slime Mold Algorithm

Slime mold is a representative of swarm intelligence: individuals are single cells, but the colony's reproduction and movement seem to be intelligent and can find the shortest path between foods. Researchers have shown that Physarum Polycephalum, a widespread eukaryotic microbe growing in nature, can solve several spatial planning problems. A group of studies from Japan used oatmeal to let Physarum Polycephalum find the shortest path in a maze [6]. What is more widely known is the experiment of drawing Tokyo's transportation network using Polycephalum polycephalum in 2010. Scientists took advantage of the light-shielding properties of slime molds, simulated Japanese terrain with light spots, and placed food at the corresponding locations of several important subway stations in Tokyo [7]. The results show that slime mold can spread the path in the most time-saving way to form a network, which is almost exactly the same as the complicated Tokyo subway route. We will apply the slime mold algorithm to draw grid paths in different terrains (Fig. 1).

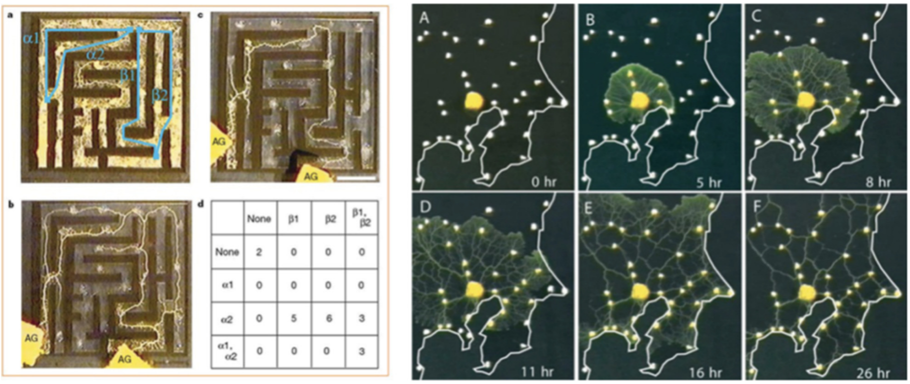

Fig. 1. Polycephalum polycephalum find food in the maze with the shortest path (left). Slime Mold Grows Network Just Like Tokyo Rail System (Right)

3.2 Different Terrain and Environment

Here we have established six sets of terrain to illustrate the application of slime mold algorithm to different grid generation. They are the indoor group (which may have load-bearing structures) and the outdoor group (with undulating terrain and irregular venues). According to the characteristics of different terrains and environments, we set up entrances suitable for them. Use the entrance as a starting point for food and slime mold. In practical applications, designers can create 3D topographic maps by using red lines and geographical features. At the same time, the surrounding environment can be taken into consideration. Designers can avoid obstacles in the surrounding environment, such as buildings and green belts, by adjusting the position of the entrance to the playground. If there is an indoor space with a weighing structure, the pillars can also be built into the terrain (Fig. 2).

3.3 Route Generation

We set up different entrances for different terrain and environmental characteristics and used them as food points and slime mold starting points. After multiple iterations of

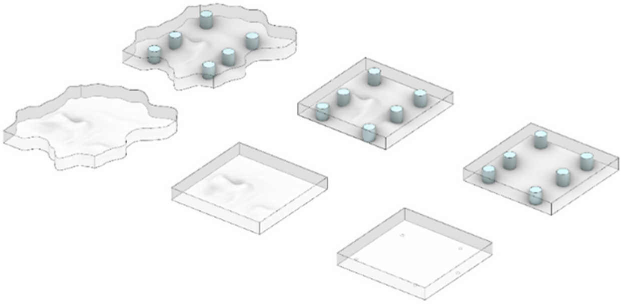

Fig. 2. Six different terrains will be brought into the algorithm to generate paths. They include regular and irregular contours, flat ground and special undulating terrain, and indoor terrain with load-bearing structures.

slime molds, they draw grids that respond to different terrains. These grids show the best path connecting several entrances, that is, the smooth traffic flow pattern in the space. The designer may consider placing the facility in a transportation hub. Here, we use the path as a design element for the next design step (Fig. 3).

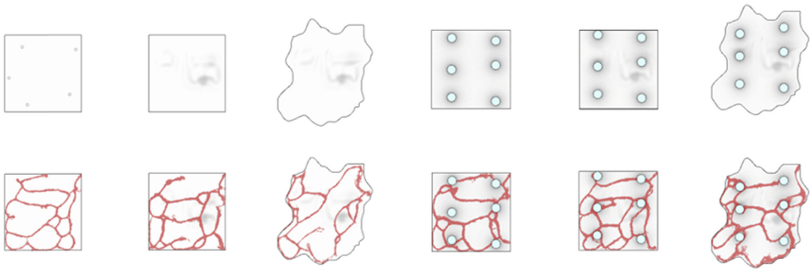

Fig. 3. The terrain and its corresponding path are generated under the slime mold algorithm.

4 Construction of Playground Facilities

4.1 Find the Basic Form

First, we convert the obtained path into a volumetric shape, and then we select the denser part of the path as the basis for our target facility. Next, we take this section of modeling as the basic model, and then use artificial methods to design and intervene this section of basic model. We will use three basic design ideas to demonstrate facility design to provide designers with reference (Fig. 4).

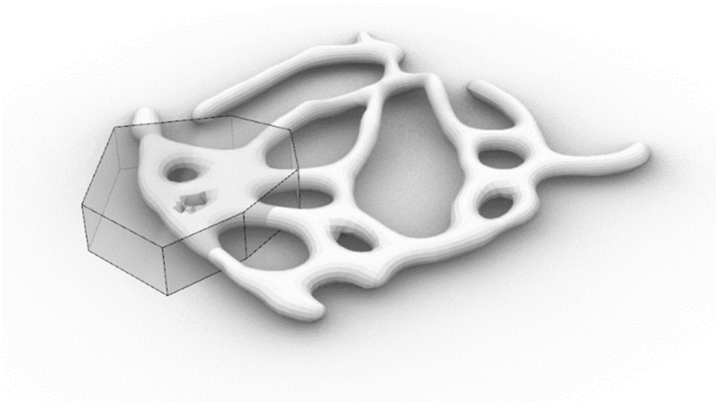

Fig. 4. For the entity transformed from the path, the more parts of the route are selected for design on this basis.

4.2 Trans Path to Entity

Here, we provide three different ideas to transform based on the path. Based the intercepted path of the certain part we plan to generate three different heights, which can divide the space and create more short-circuit porous ring facilities.

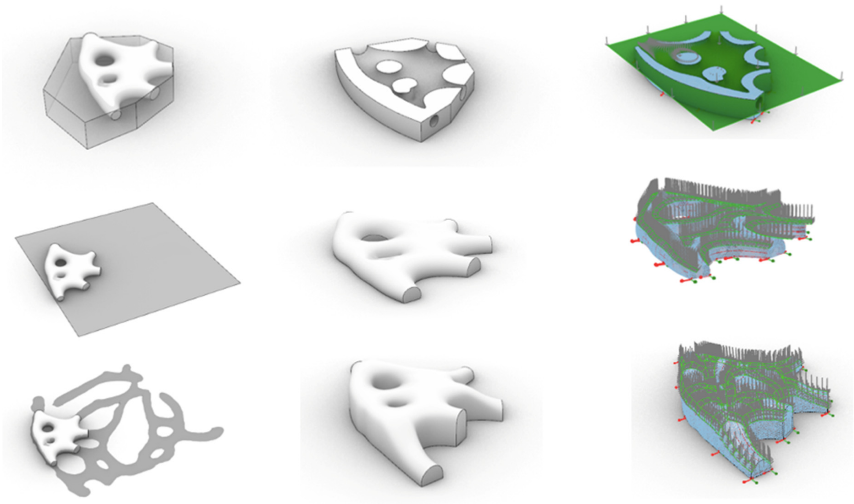

Fig. 5. Generate shapes of three heights for the same path which corresponding to different game modes.

First, we obtain the basic geometric shape according to the outline of the intercepted path, and use the positive and negative shapes to subtract the path. This results in a geometry with path channels as the basic model. Then use the amoeba plugin to optimize its topology. The top part and the part of the runway are regarded as the direction of the force load. For the second one, we hope to generate a low terrain where children can crawl in it. We cut out this section of the path and stretched this shape to make it more suitable for the ups and downs of the terrain. In the third example, we raise and deform the intercepted path to establish continuity with other parts of the terrain and create a slope at the same time. This is a relatively complex shape. We designed it with two layers up and down, so that children can pass through the lower layer, and the resulting bionic structure provides children with climbing and shuttle functions (Fig. 5).

4.3 Two-Way Progressive Algorithm

The basic concept of the progressive structural optimization method is to continuously reduce the inefficient materials in the structure. Through this process, the structure will evolve into an optimized topology and shape. We bring the obtained shape into the ESO algorithm for material reduction iteration. Some materials that do not affect the force of the structure are deleted in this process. The shape of the ESO algorithm can not only save materials under the premise of ensuring the load capacity, but also generate holes with a bionic structure, which meets our vision for children's playground facilities (Figs. 6 and 7).

Fig. 6. Finite element stress analysis of three different facilities.

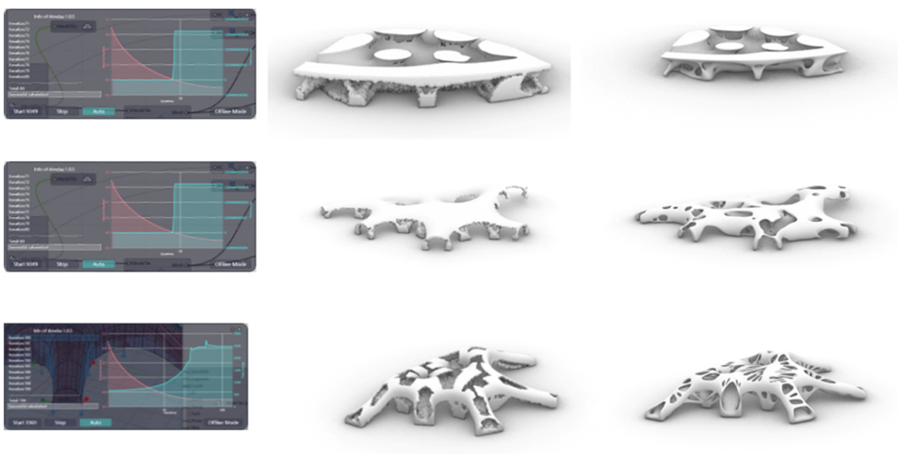

Fig. 7. The BESO algorithm optimizes the structure

5 Application and Outlook

5.1 The Composition of the Playground

We obtained several other basic shapes by intercepting the path and brought them into the ESO algorithm. After the equipment is generated, they are placed on the original path position to form a series of playground facilities [8]. In this playground, we set up the most suitable open space entrance for people to flow in and out according to the surrounding environment and generated a path according to the shape and undulation of the terrain. Based on the path, a porous ring structure suitable for children's play is generated (Figs. 8 and 9).

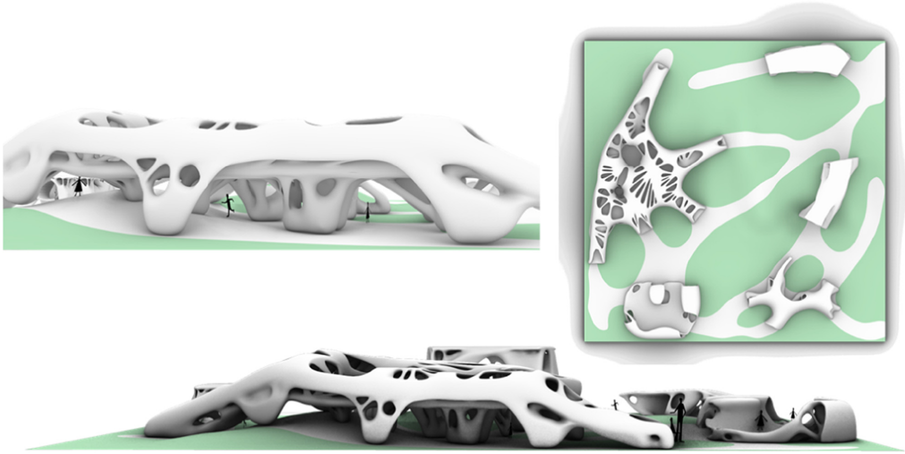

Fig. 8. Playground rendering. Detailed. (Upper left) top view (Top right). The overall renderings (Bottom)

Fig. 9. Whole playground rendering.

5.2 Applications in Interaction Design

Here we propose several interactive applications based on the generated playground equipment. The illumination lights connected to the sensors can be placed in playgrounds and facilities. A series of actions such as running, touching and sound of children will trigger different lighting effects. This can turn playground facilities into public art at night. At the same time, different lighting interaction mechanisms bring more different kinds of games to children (Fig. 10).

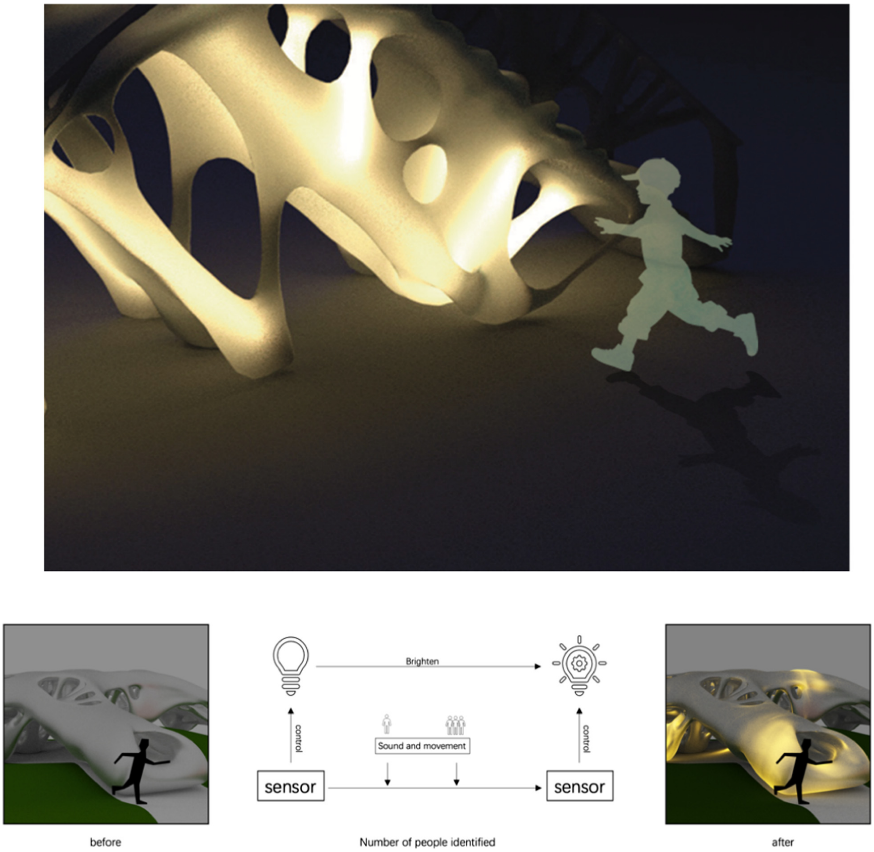

Fig. 10. Conceptual design of interactive function design that can sense different human actions.

The method we introduced is in not only applied in the generation of playground facilities. It can also be applied to the development of other children's spaces. For example, in China, children's science and technology museums are mostly displayed on shelves and window displays, accompanied by caption in text and pictures. This mode is obscure and boring for children. Many Western science museums have developed some experiential games to replace words caption to help children understand scientific knowledge. We can combine projection to design exhibition halls with different themes, such as ocean, desert, space, etc. Children have an immersive experience in different spaces (Figs. 11 and 12).

Fig. 11. The combination of the facilities and the ocean theme projection can be used as a theme exhibition hall.

Fig. 12. Interior structure diagram of the theme exhibition hall

6 Conclusion

The design of children's playgrounds has undergone several changes in developed countries. There are also many studies on how to build a playground that is more conducive to the physical and mental development of children. However, design practices and methods are still insufficient for playgrounds in China that fully consider children's psychology and needs. We propose a new design method. The purpose is to provide a reference for those designers who want to develop non-standard playground facilities. This method uses bionic algorithms to generate a three-dimensional playground based on factors such as natural environment, terrain changes, and traffic flow in the layout configuration.

References

1. Unal, M.: The place and importance of playgrounds in child development. Inonu Univ. J. Fac. Educ. (INUJFE) **10**(2), 95–98 (2009)
2. Ingunn, F., Jostein, S.: The natural environment as a playground for children: landscape description and analyses of a natural playscape. Landsc. Urban Plan. **48**(1–2), 83–97 (2000)
3. Farley, T.A., Meriwether, R.A., Baker, E.T., Rice, J.C., Webber, L.S.: Where do the children play? The influence of playground equipment on physical activity of children in free play. J. Phys. Act Health **5**(2), 319–331 (2008)
4. Malone, K., Tranter, P.: Children's environmental learning and the use, design and management of schoolgrounds. Child. Youth Environ. **13**(2) (2003)
5. Senda, M.: Design of Children's Play Environments. McGraw-Hill, New York (1992)
6. Nakagaki, T., Yamada, H., Tóth, Á.: Maze-solving by an amoeboid organism. Nature **407**, 470 (2000)
7. Tero, A., et al.: Rules for biologically inspired adaptive network design. Science **439**(42), 439 (2010)
8. Xie, Y.M., Steven, G.P.: A simple evolutionary procedure for structural optimization. Comput. Struct. **49**(5), 885–896 (1993)
9. Chen, W., Shidujaman, M., Jin, J., Ahmed, S.U.: A methodological approach to create interactive art in artificial intelligence. In: Stephanidis, C., et al. (eds.) HCI International 2020 – Late Breaking Papers: Cognition, Learning and Games. HCII 2020. LNCS, vol. 12425, pp.13–31. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-60128-7_2