

Development And Production Of Board Game Components Using Additive Manufacturing Technologies

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Abstract— The aim of the thesis is to develop an innovative product and prototype for a social game using additive manufacturing. The focus is on correcting the negative aspects observed in the design of competitive games. The product is constructed based on basic design principles and is based on strategic games. The basic idea is a modular way of executing a game board, which contributes to various combinations of assembly and the possibilities of developing the game. Some components are constructed in the Solidworks programme, while they are designed through the application of a 3D printing device based on technologies: FDM and stereolithography. The final part was found to create new optimal solutions for the detailed analysis and innovation of existing products. It shows the importance of striving for better solutions and focusing on progress.

Keywords— additive manufacturing, design, modularity, social game

I. INTRODUCTION

The main purpose of the social game is not learning or improving health, but achieving stronger human relationships. Social development is the main principle of play, and understanding how social play enhances interpersonal relationships is essential. [1] Market research has established itself through the continued existence of numerous social games. Their careful examination identified individual advantages and disadvantages. The shortcomings identified were used as inspiration for the improvement and development of a new product.

The disadvantages of the existing games are:

1. High retail price
2. Insufficient number of components
3. Difficult production of complicated parts
4. Incomprehensible instructions
5. A complicated way of playing
6. Parts of low quality

When developing a new game, many advantages of existing market games were utilised: They have:

1. Multiplayer
2. Player competition
3. Modular connection of board parts
4. The variety of pieces and elements
5. Combining pieces on the board
6. Colouring figures and boards

Looking at all the facts, the basic segments of the new game were decided. Insuring sturdier parts of the pieces and made of plastic for durability. Parts with smaller

dimensions that take up less space. Making parts 3D printing, allowing to make large drives. The simplicity of the moulds of the parts for easier and cheaper production. Availability of high quality instructions and play options for all ages. The combination of different stacking positions with the characteristics of the individual pieces. This allows for a greater number of different strategies and game variations.

II. PRODUCT CONSTRUCTION

A. Size

The product components are manufactured in different sizes, depending on the purpose of their use. The boards are manufactured in the dimensions 150 x 150 x 10 mm. They are large enough so that a mini version of the main game can be played on each board. On the top of the board, the protrusions are made to serve the figures. The formation was chosen to ensure stability so that no breakages can occur. They are small so that they do not take up too much space and can be transmitted without interference.

The figures are 40 mm high and 15 mm wide. The small dimensions allow a large number of pieces to be placed on the board. In this way, more combinations are possible. The comparison of the board size with the figures is shown in Fig. 1. [11]

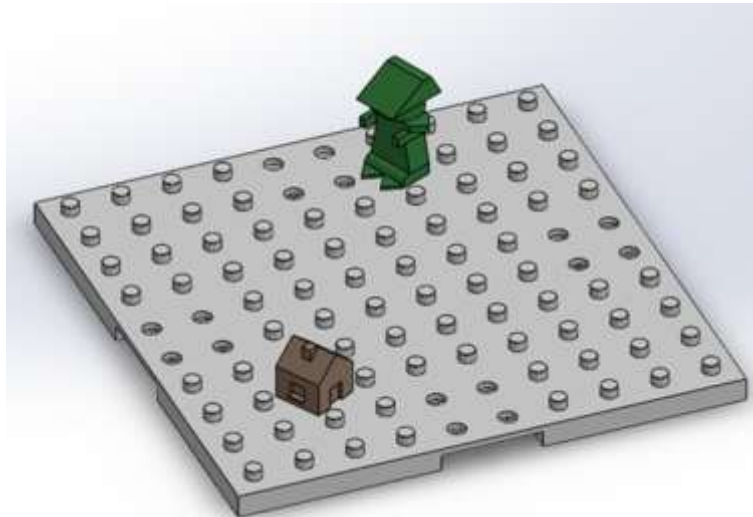


Fig. 1 Comparison of board and figure size [11]

B. Shape

Studying the relationship between a product's aesthetic appearance and its technical functionality is a classic dilemma in product development. If the user's shape preferences are expressed as a mathematical function of design variables, they can be analysed in the same way as technical characteristics.[2]

The components are developed from a combination of basic geometric shapes such as triangles, squares and circles. Simple shapes do not complicate the appearance of the parts and make them easy to produce. Selected shapes are joined together, creating a new, more complex geometry shown in Fig. 2. [11]

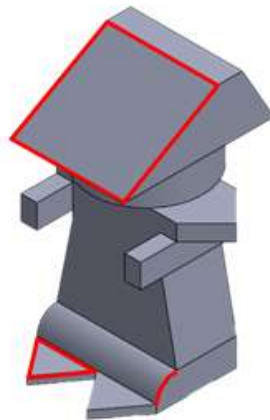


Fig. 2 Merging basic shapes into complex geometry of figures [11]

C. Color

The colours of the components are limited to the availability of the colour technology. Different colours are selected depending on the intended use of the component and are shown on Fig. 3. Figures used by the players are coloured in four colours: red, blue, yellow and green. Different colours are provided for four players for identification. The boards and couplings are kept in neutral colours so that the figures stand out better. The cottages and towers are a darker and lighter shade of grey, while the treasure chest is a golden hue. The aim was to create the luxurious appearance of a treasure chest and emphasise the importance of its position for the outcome of the game. [11]

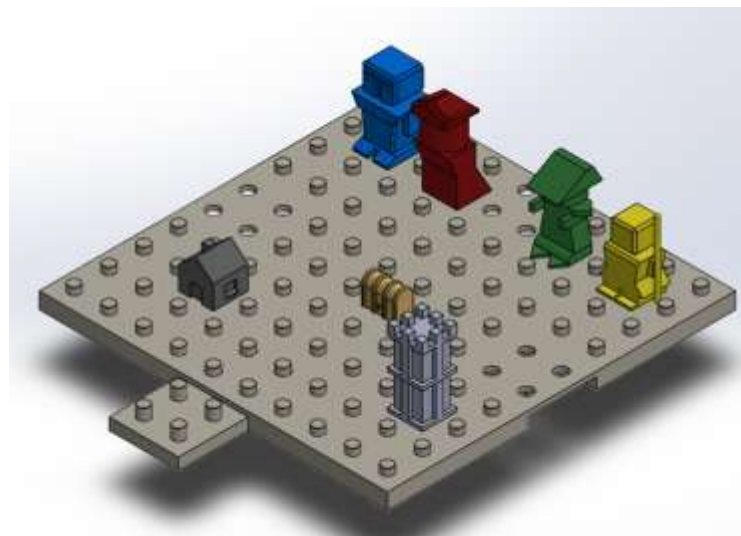


Fig. 3 Game components in selected colours [11]

D. Ornament

The use of ornaments, in addition to enhancing aesthetic value, contributes to the activation of various psychological processes such as perception, creativity, identity, and recognisability. Through visual aspects, ornament enriches experience, encourages emotional connection, and fosters a deeper understanding and appreciation of the design. [3]

Various ornaments have been added to enhance the aesthetic value of individual elements. They contribute to the design and increase the appeal for use by the consumer. Excessive use of ornamentation has the opposite effect, and detracts from the aesthetic qualities of the product. Their use is conditioned by a characteristic function, application and type of product. It is necessary to consider on which surfaces the ornaments should be applied and which shape should be chosen.

The position and shape of the ornaments should be determined at the initial stage of the product design. This ensures that time is not wasted during construction. Also so that no subsequent changes are made during development that increase the overall cost of the product. [4]

With the aim of achieving a simple design, a large number of ornaments on the components were omitted. The ornaments were placed to emphasise the theme of the game and the world of the characters that the players control. The front of the treasure chest, features a key ornament of the key was shown on Fig. 4. There are supports on the sides of the tower. A spear has been depicted in the hand of a figure. On the cottage, windows, doors and a chimney have been added to complete its appearance. [11]



Fig. 4 Ornament on a figure [11]

III. BASIC COMPONENTS OF THE PRODUCT

A board game consists of various components such as boards, connectors, figures and other elements. The individual components of the product are described below.

A. Game board and connector

The board (Fig. 5) is the main component of the product and accommodates other components on it. The boards can be combined into different shapes. The dimensions of the boards are 150x150x10 mm with 84 protrusions on the upper surface, which other components sit on. The connection of the boards is realised by couplings that prevent them from separating during use. The connections are simple in design and easy to handle. The same colours as the boards, so they are not too conspicuous. [11]



Fig. 5 Game board and connector [11]

B. Figures

The figures shown in **Error! Reference source not found.**Fig. 6 are the basic drivers of the game. The design of the figures is aimed at pursuing a strategic game. The clothing of the figures is orientated towards this characteristic period. A total of 10 figures are provided. The whole and even number is chosen to quantify the figures according to their strength (1 leader, 2 arrows, 3 spears and 4 knights). The spear holds a lance in his hand, the knight is the tallest figure and wears a helmet on his head, the archer is inspired by Robin Hood while the leader wears a crown ornament on his head.[11]

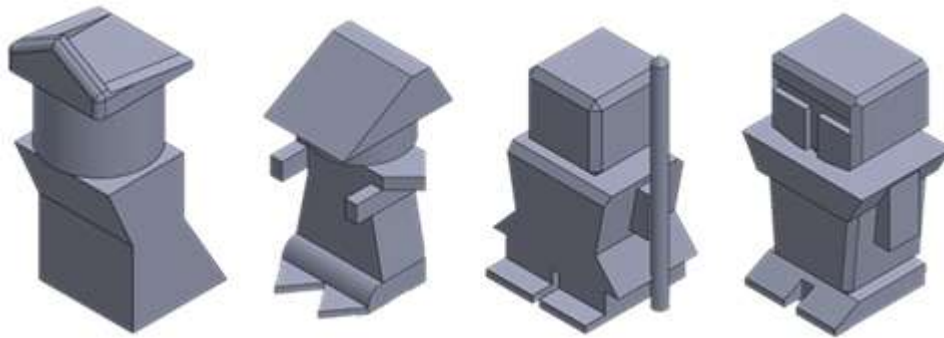


Fig. 6 Figures: leader, archer, spear, knight [11]

C. Other elements of the setting

A treasure chest (Fig. 7) represents the goal the players are vying for because it means victory. Such a shape of the figure is chosen because the chest generally represents a version for lost treasures. The colour of the chest was chosen because gold stands out even more. [11]

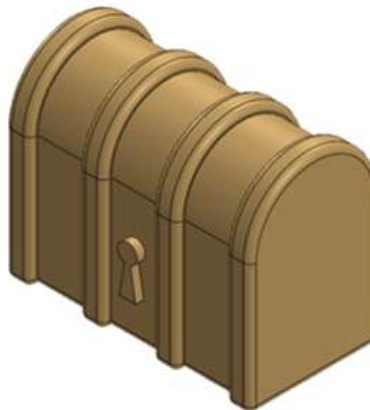


Fig. 7 Figures: leader, archer, spear, knight [11]

The walls and towers of the fort (Fig. 8) are hidden mild to make it more difficult for the players to find a treasure chest. The walls consist of many small pieces that can be lined up in the desired shape. They can also be placed on top of each other to increase the height of the fort. The towers traditionally indicate the edges of the fort. [11]

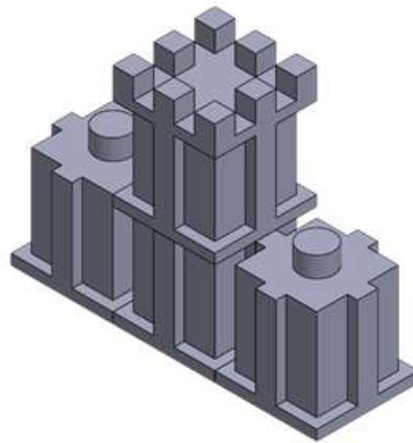


Fig. 8 Walls and towers [11]

Small houses have been made for the last figure (Fig. 9). The main function of the little house is to complicate the game and give a more realistic impression. The little house is designed according to a traditional pattern consisting of a cube and a three-sided prism. The ornaments of windows, doors and chimneys have been added for better recognisability. [11]

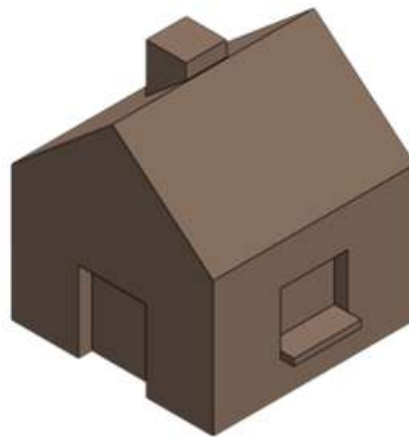


Fig. 9 Figure: little house [11]

IV. PRODUCTION OF THE PRODUCT PROTOTYPE

All components of the social games are manufactured using additive 3D printing technologies. This technology was chosen due to its numerous advantages over conventional methods [5]:

- Creation of complex shapes
- Constant modification of the product
- Reduction of time for a new design
- Low costs for the manufacture of products
- Reduction of assembly errors
- Low investment costs
- Effective utilisation of materials

Before the advent of additive technologies, there were many limitations in designing complex geometric shapes with the conventional technologies available at the time. Additive technologies contributed to greater design innovation by making it possible to create products without shape limitations. A three-dimensional model is made before the final product is manufactured. In this way, many changes can be made until the desired look is achieved without incurring production costs.

Additive manufacturing enables the creation of products that would be unfeasible with conventional technologies. Its flexibility allows for greater efficiency and optimisation of production processes. It adapts to dynamic market demands by enabling the design of individualised products. [6]

The great possibilities of additive manufacturing, the ease of use and the low financial investment have contributed to the increasing use of this technology. It is used by consumers and individual industrial designers to produce prototypes or finished products.

Prototyping enables the realization of the product and comparison with the virtual idea. When testing real products, errors that were not foreseen during development can be identified. The product is produced again by modifying and optimising the model. Additive technology enables quick changes and low costs for the reproduction of individual components.

The process of producing a test series is described below and shown in **Error! Reference source not found.** Printers were selected that matched the price/quality ratio. The parts are produced on two types of printers.

The boards and couplings are produced using a 3D printer that works on the principle of FDM technology (Fused Deposition Modelling).

The devices based on FDM technology work according to the principles of the NC machining centre with three axes. The nozzle is controlled by a computer via three axes. The polymer material in the form of a wire passes through the nozzle and reaches the temperature of the molten material. When the material exits the nozzle, it is in a dripping state and is placed at the points defined in the programme. In contact with the air temperature, the material changes to a solid state. The material is extruded in a thin layer at the designated points, giving it a three-dimensional shape. The characteristic advantages of FDM technology are its ease of use, low investment and maintenance costs, small dimensions, and the fact that no laser, ventilation or cooling is required.[7]

FDM technology has several limitations, including long production times and frequent issues with extruder jamming and calibration. Printed parts often exhibit poor interlayer adhesion, compromising mechanical strength. Additionally, surface porosity increases moisture absorption, which accelerates material ageing and reduces overall part performance.[8]

The figures are produced on a 3D printer that works on the principle of masked stereolithography.

Conventional photolithographic processes with UV polymerisation based on stereolithography. The products manufactured using this process were produced by layer-by-layer polymerisation of polymer droplets with a low nitrogen content. In this process, photopolymers based on acrylic, vinyl or epoxy resins are processed. The dimensions and moulds are transferred directly from the 3D computer model of the product to a stereolithography device. Systems are used to solidify photopolymer materials using laser scanning. The advantages can be seen in the high resolution of the parts obtained.[7]

Disadvantages of stereolithography include: volume shrinkage of final product, UV sensitivity, brittleness and short shelf life of the resin. Also production speed depends on laser movement and model size.[9]

It took a few minutes to calibrate the two printers before starting work.

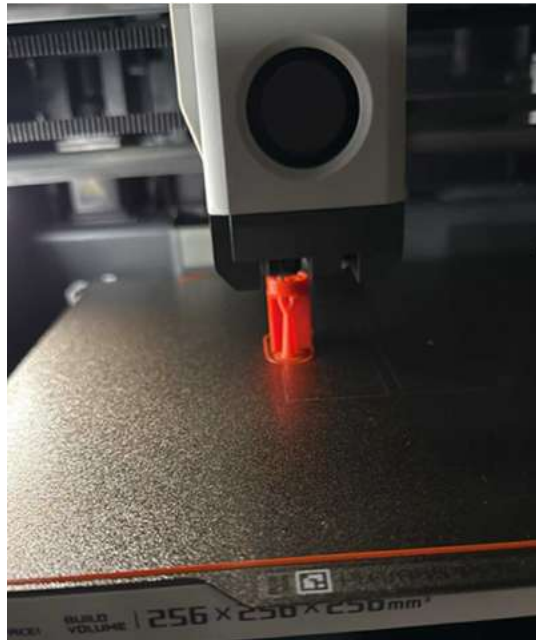


Fig. 10 Figure printing process [11]

Due to the amount of material, it took about 10 hours to make the boards. Completion also included separating the supports from the board material. Due to the smaller size and the number of details, it took about half an hour to make the connectors. Once the joints were made, they did not require any further processing. Although the figures are the smallest components, they have the most complex geometry compared to the board and coupling. The figure printing technology was chosen for the best quality performance. A single figure was produced for half an hour. After production, it was necessary to separate the carrier material from each figure.

V. PRODUCT ASSEMBLY

Once production is complete, the resulting components must be combined into a single product. Assembling is more than just putting parts together. It is the final and most critical stage of the production process. At this stage, all individual components are combined into a complete and functional product.[10] Timely planning of the assembly process is essential to ensure efficiency, achieve product quality, and minimise errors. Since the components are independent, they do not need to be additionally connected. The only thing that needs to be done is to join the components together in a very simple way. The connection (Fig. 11) is made using connectors that connect the boards in different configurations.

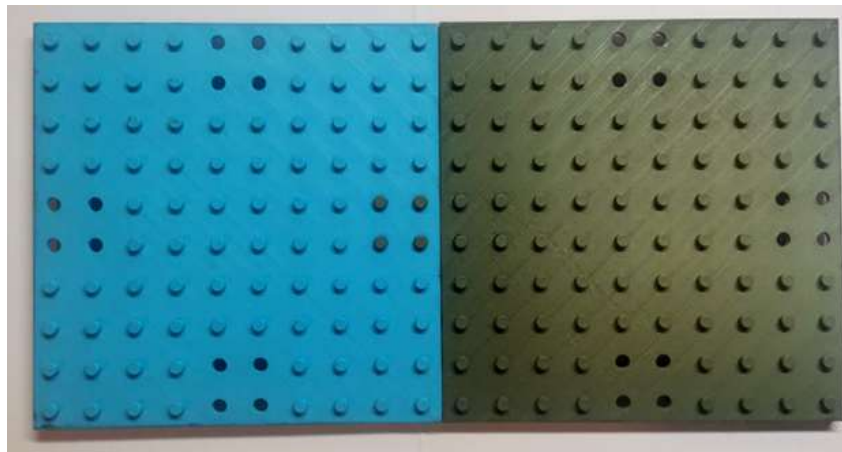


Fig. 11 Connecting boards [11]

VI. SOCIAL GAME RULES

A. Game preparation

Preparation begins by arranging the individual boards as agreed and connecting the couplings to form one large board. Each player chooses one of four colours: red, blue, yellow or green. The player should then pair all the figures with the same colour. Each player places four figures on their part of the board, at least one of which must be a "leader" figure. The tiles on which the figures are placed by the players are chosen independently of each other, on the condition that there are no towers or treasures on the board.

B. The course of the game

The game begins with the youngest player and continues towards the clock. The player whose turn it is rolls the dice and moves the chosen piece as many spaces as the dice show. The player can then choose between two options:

- Roll a dice to move another piece
- Roll a dice to attack (the piece is in the area of the opponent's piece/towers)

The result of the battle depends on whether the figure remains in position (winning the battle) or leaves the game (losing the battle).

If the dice shows the number 6 and the "leader" player is in the game, an exception can be made. In this case, a player can bring a figure that is no longer in the game into play.

After a dice roll, the player ends the turn twice and the game continues with the next player in a row.

C. Ending the game

The player wins if he is the first to bring a chest to his "Leader" figure. If a player collects a chest with his "Leader" figure, he automatically wins the game.

VII. CONCLUSIONS

The number of games on the market is constantly increasing, making it more and more difficult to maintain originality. There are many games with similar strategies and players often get bored quickly. This article was about developing a game that can be constantly optimised without reaching the final version where there is no more room for progress.

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