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VIRTUAL REALITY SUPPORTED DESIGN OF SMART GRASPER

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ABSTRACT

Smart material graspers have shown potential for different applications in terms of functionality and actuation, especially in handling arbitrary shapes, fragile objects and complex 3D geometries. However, to take these initial designs further towards real applications, the challenge remains to determine the optimal size, shape, and passive and smart material location. Virtual reality can be beneficial in the early concept generation as it can help visualize and understand the grasping process. The access to suitable hardware and the development of virtual reality (VR) software has resulted in increased use of this technology. The 3D visualization offered by VR especially in the early stages of the design process assists engineers in making appropriate and efficient decisions, and it can also support the interaction with the end user to iterate on potential design improvements.

The conceptual phase is often overlooked and rushed by the other departments involved in the design and development process although it is of great importance for successful outcome. It is important to make the most of it in order to assure quality result. In order to ensure short conceptual phase that will not reflect on the products' quality we propose introduction of the VR in the early stages of the design process.

In this paper we show how the use of VR can be beneficial in new product development. In this case we focus on the design of smart material grasper.

Keywords: virtual reality (VR), smart materials grasper, conceptual design phase, design process

1. INTRODUCTION

Object handling is one of the oldest and most common engineering tasks and has taken on different developments based on the industry it serves from robotics [1] and transport engineering [2], over manufacturing and assembly [3], to agriculture [4] and the bio-medical field [5]. Automation and robotics have introduced different shapes and functionalities of graspers, grippers and grabs, but mostly handling known objects in controlled environments. Handling objects with arbitrary shape in open environment still remains challenge up to this day.

Adaptability, flexibility, and modularity of smart structures offer solutions for autonomously grasping objects with arbitrary shape [6, 7]. Advancements in additive manufacturing offer designers the freedom in creating shapes with highly nonlinear characteristics and functionally graded materials [8, 9]. However, traditional design is constrained in the initial phase with the exiting and widely adopted tools, as it cannot fully show the creativity of the designer in terms of functionality of the design in real size in its foreseen environment.

Virtual reality (VR) can offer solution for this issue. VR is a technology that creates virtual environments entirely generated by a computer, replacing the user's perception of the surrounding environment with a virtual environment using HMDs, glasses and multi-display setups. Even though this technology exists for some time now and became widely available in the 2000s, the benefits have not been extensively implemented in the engineering design process. Recent studies presented a research agenda for VR in architecture, engineering and construction that systematically maps how VR technologies can be used, the potential benefits, prevalent issues, and a future research agenda [10]. In the past few years, VR has come back into the public's awareness with the release of a new generation of low-cost, high-quality VR products that can introduce ubiquities possibilities for designers in early stage design [11, 12]. Previous work on including augmented reality in the conceptual phase of the design process [13] showed potential to take it a step further and include VR and explore its benefits in the design process.

In this work we have introduced VR in the early design stage for smart material adaptive grasper. The goal is to visualize the grasper in terms of size and its environment, as well as choose the optimal grasper configuration based on size and shape. This paper shows a general design framework for grasper design that can be further tailored to different applications. Applications include transport of break bulk, warehouses, remote place exploration (space, deep sea, and extreme weather conditions), assembly lines in manufacturing, agriculture and others.

This paper is structures in five sections. The introduction is followed by the second section where the proposed methodology for smart grasper design is explained. The third section is dedicated to the parametric design, explaining the CAD modeling and the conceptual design and variations. The proposed grasper design is analyzed and tested through virtual prototyping in the fourth section. In the last section we present the advantages of the proposed methodology and give directions to further work.

2. METHODOLOGY

The engineering design nowadays heavily relays on 3D CAD modeling tools which have proven to be crucial in visualizing the designers' creativity. However, when the product changes shape and/or functionality over time, the standard 3D modeling tools cannot easily capture that realistically. This is when the VR technology can offer a solution, as it can be integrated in the early design stage and support the visualization of a design in real size and environment. Especially when the design is on the micro scale or the large-scale, then visualizing the design in its real size functioning in the expected real environment is a major challenge.

In this paper we propose a methodology that integrates VR in the design process (Fig. 1). The design process starts with the design problem definition phase, followed by the typical activities for the design clarification phase: brainstorming, list of the design requirements, additional research and embodiments of requirements with initial sketching. The phase of the parametric modeling is the phase in which the sketches take 3D shapes. In this phase we applied two methods. We used the engineering method for designing CAD models that can be visualized, analyzed, tested for functionality and afterwards produced. But in order to create more challenging designs we employed more creative techniques for the design of possible variations of the grasper. Since in the parametric modeling phase many different model and their variations have been created they are taken into the VR phase where they are evaluated according to their appearance in real size and functionality in simulated environment. This step is crucial in determining the most suitable design of the grasper.

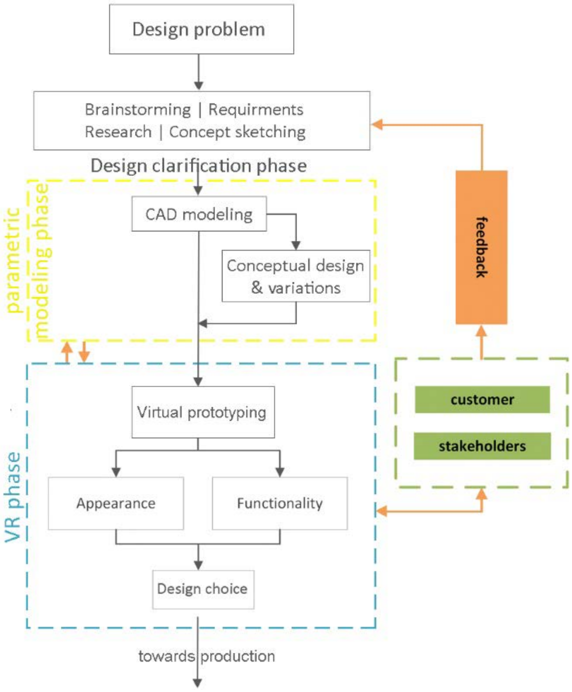


FIGURE 1. PROPOSED METHODOLOGY

Moreover this phase is used to better communicate the designs to the customer or the stakeholder offering them the possibility of co-designing. Their valuable feedback is used for the next iteration of the design improvement. This framework can be beneficial for multiple applications. In this work we show the benefit of applying this framework for smart grasper design.

3. PARAMETRIC MODELING PHASE

In this work we propose a methodology for development smart grasper. The main idea for this grasper is to be flexible in order to adapt to different tasks and environments. In order to achieve that we propose grasper with modular design. The modularity is achieved by multiplication of the initial segment in various arrangements. The idea is not to have one definite shape of the grasper but rather elements in our case segments that assembled together give the final shape of the grasper. This means that the user can create grasper tailored to its specific needs. In the following section the design of the segment and the overall design of the grasper is explained.

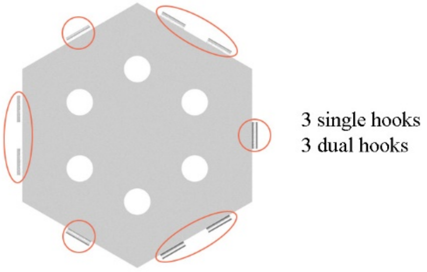


FIGURE 2. DESIGN OF THE INITIAL SEGMENT

In Figure 2 the design of the initial segment is presented. The segment is hexagonal in shape which makes it versatile and easy to adaptation for different applications. The segment has three singular hooks and three dual hooks allowing additional segments to be add in every direction achieving various combinations in the assembling process. Length of each side is 50 mm, and the angle between is 120°.

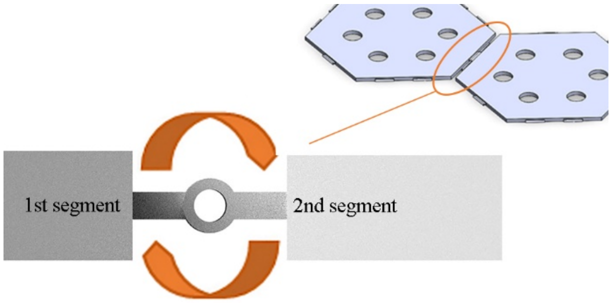


FIGURE 3. ALLOWED MOVEMENT OF TWO COUPLED SEGMENTS

The segment is designed DS Solidworks, which ensures precise dimensioning, assembly and later preparation for production. The functionality and intersection of the assembled segments is tested on various assembly design. Various assembly designs implies graspers with different number of segments, their arrangement and positioning. First we analyzed the allowed movement of two coupled segments. As presented in Figure 3, the segments can move freely in both directions around the coupling elements. The two segments can rotate around the coupling element almost in 360° having in account their thickness.

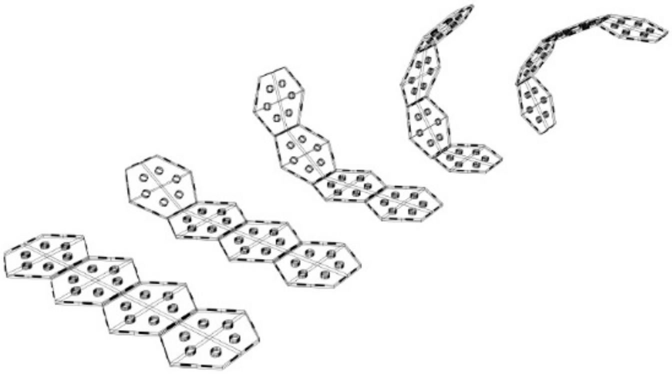


FIGURE 4. POSITIONING STEPS OF ONE GRASPER

In Figure 4 positioning steps of one grasper consisted of four segments are presented. This is only one example where the grasper moves from completely flat position to grasping position. The rotation of the segments gets more complex with every new segment added to the assembly (Fig. 5). But at the same time the number of possible designs of the grasper rises.

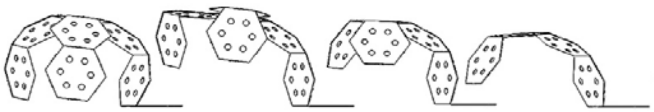
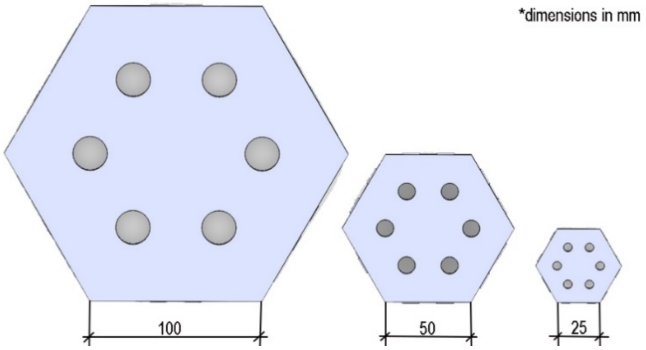


FIGURE 5. DIFFERENT POSITIONING OF ONE GRASPER

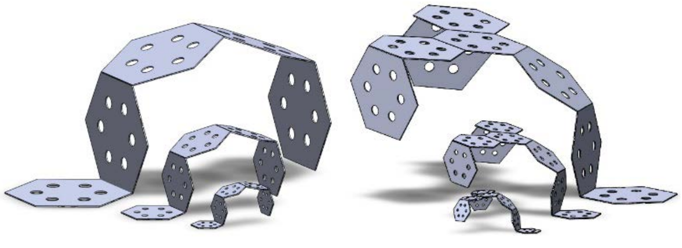
After conducting analysis of functionality of the grasper on different tasks and environments, it was inevitable to explore the option of implementing different sizes of the initial segment. This way we can offer grasper for different tasks and applications, by still maintaining the simplicity of using only one segment geometry. In the case of large size grasper it will be inefficient using small segments. This is why we created one smaller and one bigger option form the initial one, so show the possibilities. However the range of scaling up and down is not a limiting factor in this design stage. The larger segment presented in Figure 6a is with side length of 100 mm. The smaller segment presented in Figure 6c is with side length of 25 mm.



a) b) c)

FIGURE 6 (a-c). THREE SIZES OF THE INITIAL SEGMENT

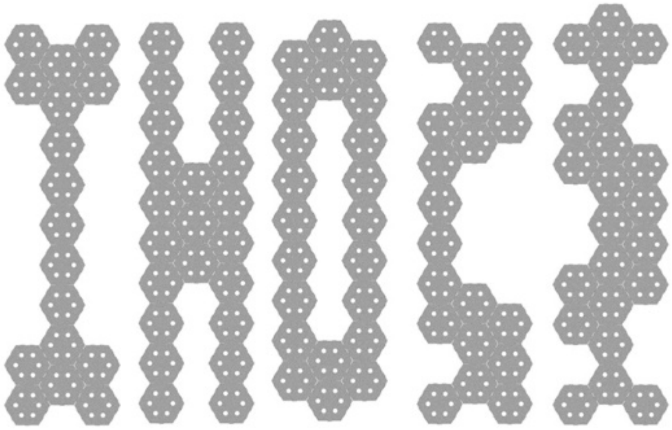
In Figure 7 assembled grasper of different sizes are presented. Different sizes are suitable for different applications. Each one of the graspers is constituted of same size segments. Segments are connected through their hooks, allowing each one of them to rotate round the coupling achieving the desired position.



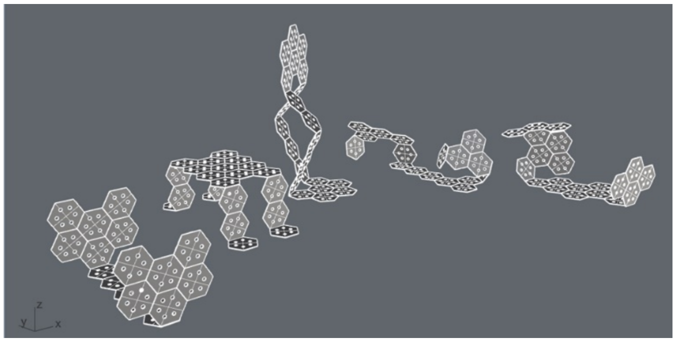
a) b)

FIGURE 7 (a, b). DIFFERENT SEGMENTS SIZES ASSEMBLED INTO GRASPERS

After the design of the segment was verified and its shape along with overall design of the positioning of the segments was approved we began the phase of conceptual design. Here, we explored different scenarios and possible application of the grasper. In this phase we used parametric modeling in the Rhinoceros and Grasshopper. This combination of these two software's allows more freely designing and exploration of the possible shapes of the grasper and coupling variations. In Figure 8 different arrangements of the segments are applied. The variations in the arrangement of the segments are numerous depending on the specific need of the grasper. Depending on the use of the grasper (grasp on the shape, transport from one place to another, release, reach out to another shape, etc.) it can be shaped differently (Fig. 8 b).



(a)



(b)

FIGURE 8. DIFFERENT ARRANGEMENT OF THE SEGMENTS RESULTING WITH DIFFERENT GRASPERS. (a) Flat positioning of the segments (b) Different shapes of the graspers from (a)

Assembling different size segments is beneficial for optimization of large scale graspers. Depending of the load or the object we need to handle, we can apply smaller or larger segments. It is important to note that the hooks on all three segments are the same size, allowing for coupling of segments of different sizes. In Figure 9 concepts of large scale graspers are presented. In the examples below we used all the three segment sizes with different arrangements. This allows for exploring functional grading of the grasper for tailoring local compliance. When more structural support is needed for object handling, then the density of the segments can decrease. Adaptation of complex geometry with arbitrary shape might require increase of density of segments to ensure contact between the grasper and the object.

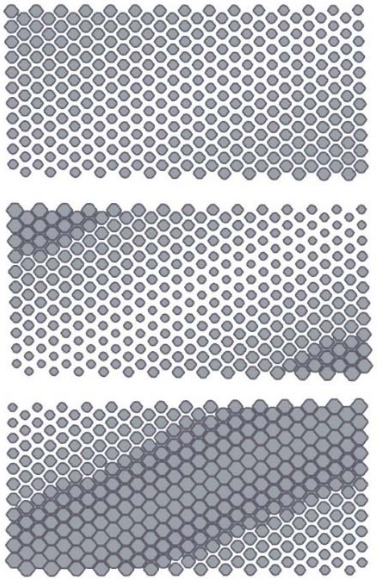


FIGURE 9. CONCEPTS OF LARGE SCALE GRASPERS

Also the possibility to vary the angle between the segments and change their initial positioning can be used to extend the possible different shapes. This is beneficial in the terms of widening the possible applications, as the deformation and relative movement can influence the functioning the grasper especially when the active material is taken in consideration. The limits of actuation strain might dictate the range of motion, so a 3D initial position, instead of a flat one, might solve the challenge. In Figure 10 examples of angles between adjacent segments is varied and flat large size grasper is transformed into complex shape. This example shows that the once definite design of the assembly can have different applications by changing the positioning of the segments.

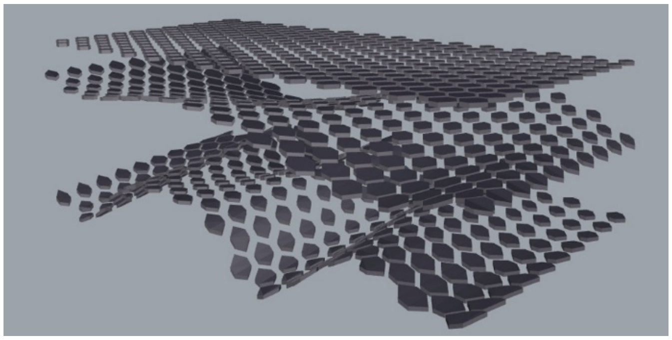
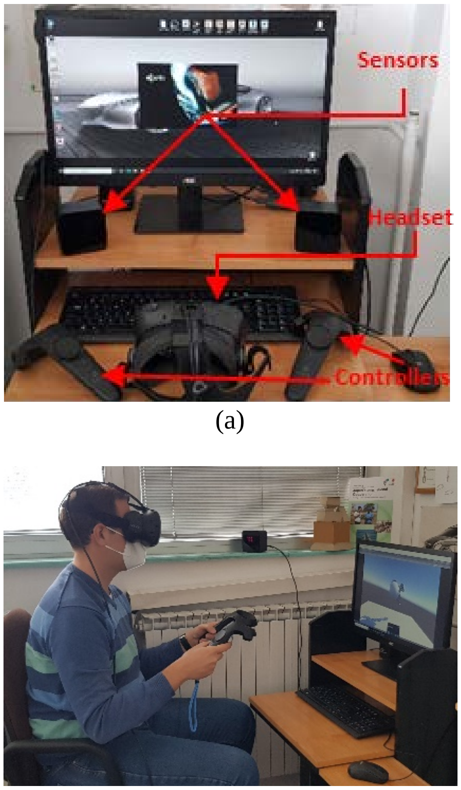


FIGURE 10. DIFFERENT ANGLES POSITIONING OF THE SEGMENTS WITHIN THE ASSEMBLY

4. VR PHASE

VR in the design process has the power to transform the way designers create, envision, and experience spaces, which translated to better design decisions and end results for clients. With this technology designers can immerse themselves completely into their design. This provides better understanding of the space, the visualization of the design in that space as well as the size, scale and orientation of the creation in real life use. Ultimately, VR assists in identifying key issues that had not been readily noted during the design process.

An additional feature of this technology in the design process is the collaboration possibilities. VR enables interactive collaboration between all involved parties in all stages of the development process of a product. Especially, the benefits are significant in the initial design process when collaboration between individuals or teams with different backgrounds is curtail. Time saving and avoiding errors in this stage is one more benefit provided using VR in the design process.



(a)

(b)

FIGURE 11. EQUIPMENT USED IN THIS PROJECT: HTC VIVE HEADSET AND UNITY. (a) Elements of HTC VIVE: headset, controllers and sensors. (b) Preview of model in VR.

For the purpose of the design process of a smart grasper, VR has been used to evaluate different designs in practical use. The goal is to visualize the grasper in terms of size and its environment, as well as choose the optimal grasper configuration based on size and shape. In order to visualize the design variants created with parametric modelling in VR, we have used the software package Unity which is a cross-platform game engine developed by Unity Technologies. This software enables users to create, design and modify a VR scene. Also, this software provides a preview of the result using a VR headset. In the design process of the smart grasper, we have used a HTC Vive VR headset (Fig. 11).

At the beginning we have created a project in Unity and added all necessary elements for appropriate preview of the scene in VR. The SteamVR Plugin was imported using Unity's asset store which enable the use of OpenVR SDK. Next, the scene was created as a simple plane and adding appropriate lights and SteamVR camera to the scene. In the next step we have imported various grasper designs as assets to the scene. In order to create an appropriate visualization of the grasper in real life use, simple 3D objects have been added to the scene – boxes and spheres. Various scene setups have been created using different grasper designs and sizes in order to visualize the grasper in terms of size and optimal configuration based on shape (Fig. 12).

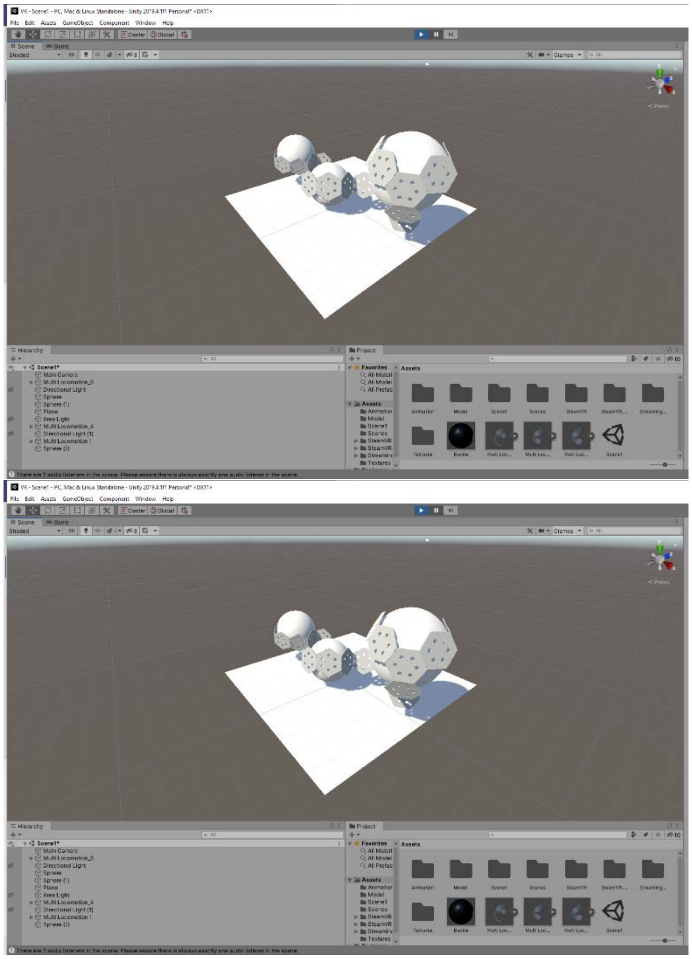


FIGURE 12. VISUALIZATION OF GRASPER IN VR

Previewing the scene in VR enables designers and all other involved parties to visualize the grasper in detail, from various angles and to visualize and inspect the grasper's functionality. Simply by putting the headset on we can provide the ability to fully show the creativity of the designer in terms of functionality of the design in real size in its foreseen environment (Fig. 13). The VR experience contributes to a better understanding of size and proportions, as the designs can be viewed in full scale as opposed to viewing small physical models or sketches or drawings. The collaborative design process including VR helped users by providing a method with which their ideas could be better formulated, analyzed, tested, and finally realized. One of the main challenges behind this method is that the number of HMDs limits the number of users, or even that only one user at a time is allowed in the environment.

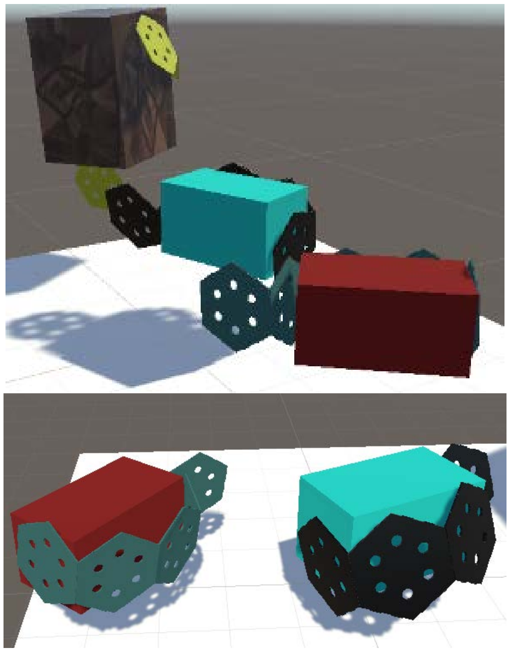


FIGURE 13. VISUALIZATION OF GRASPER IN REAL LIFE USE

5. CONCLUCSSIONS AND FUTURE WORK

In this work we presented methodology for implementation of VR in the conceptual design phase of smart grasper. It has been already established that the VR technology can serve as a great supporting tool for visualization and application. When designing a grasper with the intention to be self-actuated and to be able to conform to a complex 3D shape geometry, VR can bring the designer intro the end application and understand better local details in terms of size and density of segments to optimally complete the task. This can be beneficial for grasper in the micro scale designed to work in hard-accessible locations in the human body or large-scale graspers intended to work in harsh environmental condition handling break bulk objects. Using VR we can visualize the grasper in the environment it is intended to be used – inside a blood vessel of human body, or in a port using to attach a load to crane. VR will provide the designer with the ability to visualize and sense the use of the grasper in this conditions hence assessing the design, size and scale and other elements of the design.

The design framework based on modularity based on segments tied together, can be used for other applications as well that can benefit from segmented approach. Using different shape, size, material, density and configuration of segments provides limitless possibilities. Using parametric approach and VR technology the designers can offer application based optimal solutions. This framework can also be extremely helpful as communication tool opening the possibility to co-design with people outside from the design team such as customers and stakeholders.

Future work includes testing this framework in different applications. The goal is to include shape change over time analyses in the VR and optimize the grasper including actuation force and interaction with the object.

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