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# A new design mobile cabin hospital based on the Hoberman sphere

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**Abstract.** Mobile cabin hospitals have been established in many countries and regions to cope with the spread of the new crown epidemic. The feasibility and convenience of the model are analyzed in the context of practical situations. This paper examines and exploits the collapsibility and convenience of Hoberman spheres, their principles and methods of movement, and the dynamics of the scissor structure, which is the basic unit of movement of Hoberman spheres. The effect of changes in angle as well as the length of the scissor-like structure leading to the size of the sphere is analyzed. It was also studied and analyzed through specific model designs, what materials are more suitable for the lining material. The resulting design for the individual wards of the mobile cabin hospital was constructed from half of the Hoberman spherical shell and covered with protective material inside. The final optimization of the combination makes it innovative. The design objectives were simple, easy to install and transport, and reusable.

**Keywords:** mobile cabin hospital, Hoberman spheres, scissor-like structure.

## 1. Introduction

At present, COVID-19 is still spread all over the world, and it may still break out in China from time to time. In China, mobile cabin hospitals have played an important role in the fight against the epidemic. Although the Mobile cabin hospitals as shown in Figure 1 are advanced and excellent, there are still some spaces to improve. The innovative foldable structure can be used for this purpose. It has two stable forms: unfolded and folded forms. In the unfolded state, the structure services in working mode; in the folded state, the structure is compacted, and suitable for storage and transportation. Foldable structures were initially used in the furniture industry but now extended to industrial design even aerospace structures. Urban space is becoming more crowded and people's pursuing customization. Foldable structures are efficient in utilizing space and can be expanded or contracted according to different requirements. Foldable structures can balance people's growing needs with scarce urban space resources and bring about a change in the traditional construction industry[1]. Chuck Hoberman’s sphere is a mechanism composed of rigid linkages which can be expanded in a spherically symmetric manner as shown in Figure 2.

If it makes a big enough Hoberman sphere for private patient clink, it will reduce virus transmission between patients. The key points to build the mobile cabin hospital are faster and safe enough. Hoberman sphere has a changeable appearance, and it can use electricity to change its form easily. As one of the

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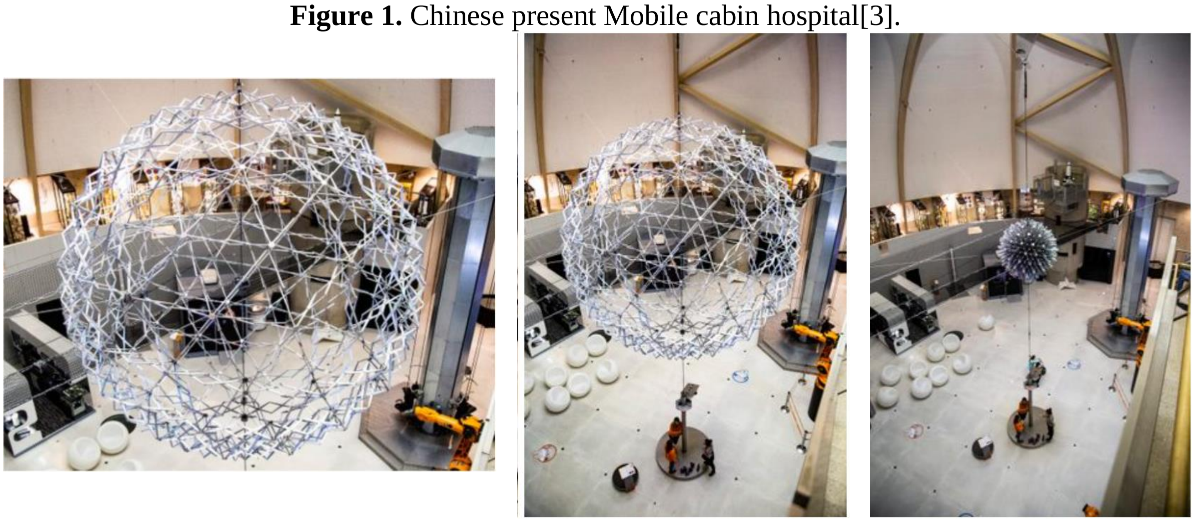
most iconic toys in the 90s, the Hoberman sphere also has many applications. As shown in Figure 2, which means the process of volume change through A to C, a giant Hoberman sphere, manifests itself in a psycho-hypnotic way. the world's largest Hoberman sphere was hung from the ceiling of the AHHAA Science Canter in Tartu, Estonia, which can be expanded and contracted in a hypnotic display of biomimicry.[2]. As shown in Figure 3, a pneumatic device, a foldable structure, is used as a facility for disease control. To hold the Hoberman sphere in place, a simple but long-proven reliable connection method, the Janney Coupler was used. As shown in Figure 4, it has been used for train carriage links for hundreds of years.

Conventional construction process on site can be affected by bad weather, shortage of materials, tedious work, and other factors. The foldable structure is integral, based on a structural mechanism, which is highly prefabricated. The folding structure is a highly prefabricated unfolded pattern that can be erected on-site by simply assembling the folding mechanism is the heart of the structure, which can significantly reduce construction time and increase efficiency. when building temporary or emergency sites. There is a wide range of uses and many innovations in everyday life.


**Figure 1.** Chinese present Mobile cabin hospital[3].



(a) (b) (c)

**Figure 2.** Use for hypnotic of biomimicry[4] (a-c Hoberman ball from open to normal size).

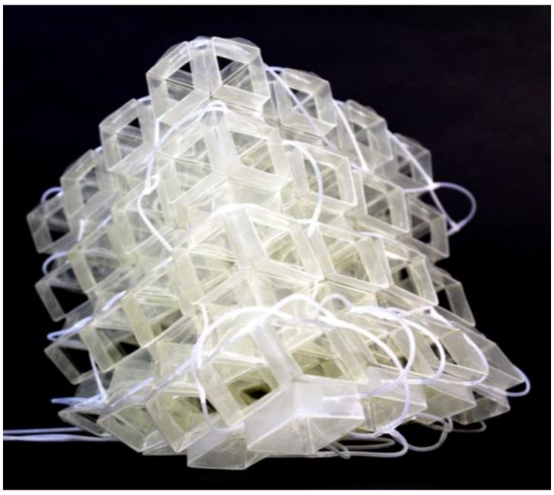


**Figure 3.** Medical tools that fold into the body[5].

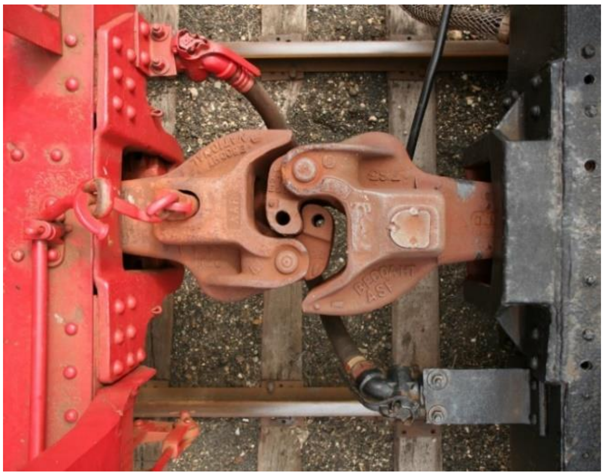


**Figure 4.** Janney Coupler [6].

## 2. Design method

### *2.1. The Hoberman sphere overview*

The Hoberman sphere is known as an 'unfolding structure', or it is a contracted and expanded split structure. There is no clear distinction between an unfolded and unfordable structure, as the structure is not folded, which means it is a transient and temporary structure. The concept of dynamics in architecture is linked to its own origins and the evolution of humans living in nomadic civilizations[7], a dynamic that led to the development of shelters that could be easily assembled and disassembled. The concept of movable and portable elements now exists as the underlying principle of a study called "dynamics". The term "kinetic architecture" was introduced by William Zuk and Roger H. Clark in the early seventies, when the problem of the dynamic spatial design was explored in mechanical systems[8]. The evolution of dynamical architectures is intrinsically linked to advances in translational geometry, which have enabled the design and construction of more complex dynamical systems. Bionics, which is related to the study of dynamics, is the science of analyzing the behavior of biological mechanisms found in nature. Kinetic structures are based on certain biological principles, such as dynamics and adaptability, which are present in all living organisms. It is applied to structures allowing constant flexibility and adaptation of form in response to different spatial or functional demands.

Hoberman sphere has good foldability and convenience. This characteristic can be used in building the clink. It usually has six great circles and each connection joint links with four scissors-like structures. In this case, it only takes a small force to change its volume. In a traditional Mobile cabin hospital, the spacing between patients is relatively small and there are no private spaces for each patient, and re-infection is prone to occur. If it needs to make an isolated observation point in a certain place, the traditional way of installation is usually to use many steel boards to assemble a small emergency hunt. If the Hoberman sphere can be used to establish the clink, it will be more humanized. It consists of steel bars, in that case, it can use this small single clink until it has been damaged. The Hoberman Sphere is called an “Unfolding Structure” or it is a split structure that can be contracted and expanded[9].

The Hoberman sphere consists of a number of cells, each consisting of four scissor-like structures and two connectors. Figure 5. control folded and unfolded. For a long time, the most common approach to expanding a Hoberman sphere was to stretch its two outermost connecting blocks. However, after repeat stretching and observation, it was found that the distance between the two symmetrical connecting blocks of the Hoberman sphere varies with its volume. When the Hoberman sphere is contracted with a red block on the outside, it is symmetrical inside and also has an identical red block. But when it is

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unfolded, the two red blocks are very close. When the two adjacent red blocks (Figure 6.) are squeezed together, they can form a semicircle. Therefore, only the two adjacent red blocks need to be fixed. Of course, to facilitate it can simply attach four pairs of connecting blocks. To prevent the individual room and avoid direct transmission, a hemisphere fabric made of the same material as the protective medical garment was attached to the connecting block of the Hoberman sphere inner test.

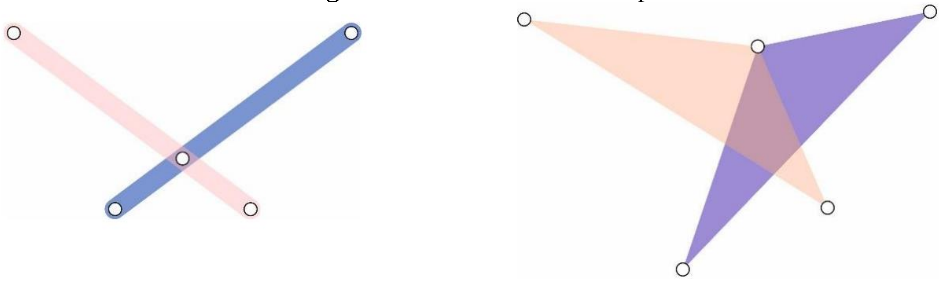

**Figure 5.** Conventional and angulated scissor-like elements.

**Figure 6.** Two very close together blocks[10].

*2.2. Sphere lining material*

When too soft a material is attached to the inner test of the Hoberman sphere, the wrinkle pattern of the fold is not readily visible, and it is easy to misjudge the movement. Using a moderately hard plastic bag makes it easier to handle and attach to the inside of the Hoberman sphere.

There are two possible solutions to this problem.

(1) The traditional Chinese official's hat style: The top of it is made of six pieces of fabric together. More cumbersome to operate and poorly sealed. This is not very practicable and the work is more tedious.

(2) Bathing cap style: cut out the shape according to the instructions. Attach it to the red link block from top to bottom. Easy to fix but not easy to measure its size.

If using the paste, the contact area is too small, difficult to handle, unstable, and not long-lasting. If attaching it to the red block with a seam, just like large parasols are used in our life the umbrella canopy is opened and attached to the bone with cords. This method is more difficult to handle than gluing, but it holds firmly and is less likely to fall off during activities.

When the Hoberman sphere is slowly folded, the lining at each connecting block is folded in a swivel and folds like a flower petal. The lining surface is well squeezed between the gaps of the scissors-like element.

If one use other means between the scissor-mounted structures of the Hoberman ball, this leads to several problems occurring. If a hard material is used for the connection (e.g., a hard plastic sheet) it goes back to causing, after shrinking, a lack of good volume reduction, making transport and storage less convenient. The Al Bayt Stadium for the 2022 World Cup, for example, has a collapsible roof for

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its stadium. It is made of a soft material, which ensures easy storage and aesthetics when shrinking, but also softness when unfolding.

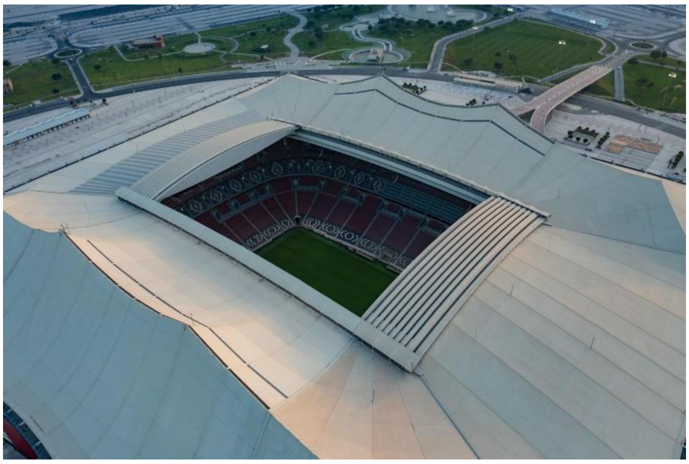

**Figure 7.** Al Bayt Stadium[11].

## 3. Result

### *3.1. Change in sphere volume as a result of sphere angle*

Foldable structures are a type of dynamic design, whose working mechanism is based on geometric principles. that the structure unfolds to go from a contracted state to a fully expanded state that is stable for the duration of the structure. The mechanism is based on its geometry design. It is often unstable in its transition state that must be supported by external mechanical forces to ensure correct unfolding direction and safeness. This structure is also called an axial fold structure, the most common folding structure. This structure has an option. The midpoint is the axis of the fold, and the unfolding and contraction are based on this axis. The midpoint is chosen as the axis of folding, and the unfolding and contraction are conducted around this axis and located on the tangent of the axis on which the midpoint is located. The X-shaped scissor joint is often seen[12].

If datum the angle of the scissor-like structure (Figure 7.), it can be found that the variation in angle is responsible for the size of the Hoberman sphere volume (Figure 8.).

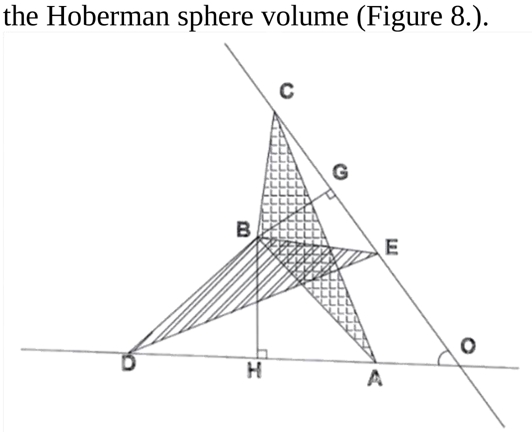


**Figure 8.** Analysis of the angular relationship of the scissor-like structure.

AB is equal to DB、BE is equal to BC、 ∠ABC is equal to∠DBE、So ΔABC is similar to ΔDBE assumptions α=∠DOC、ε=∠GEA、γ=∠AEB、σ=∠BEH、δ=∠GBH can be easily obtained that α=π-δ(in quadrilateral BCOH).

$$\delta=\varepsilon+\gamma+\sigma=\delta-\gamma/2+\gamma+\delta-\gamma/2=\beta$$
$$\alpha=\pi-\delta$$

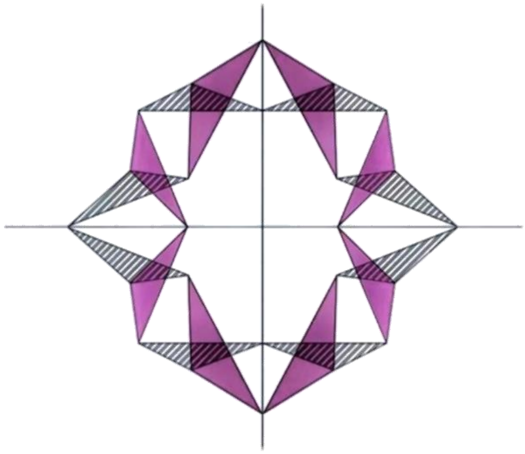

**Figure 9.** Hoberman sphere cross-section consisting of many scissor-mounted structures.

Choosing two pairs in order to form a loop, a Hoberman sphere-like plan is formed by joining multiple scissor-like structures together in a circle. A smaller γ leads to a smaller δ and finally a smaller α. This is how a change in the angle of the Hoberman sphere leads to a change in its size.

We can analyze the change in volume of the sphere by looking at the change in angle of the scissor-like structure in the Hoberman sphere. Take Figure 7 as an example, when the α is equal to 60 degrees. After measuring the model, it can be obtained that its radius is 15 cm. So, it is easy to obtain a volume of 7.067$dm^3$. Using the same measurement method, multiple sets of data can be obtained for changes in volume due to angle. (As shown in Figure 10) The x-axis is the angle of α and the y-axis is the volume of the sphere.

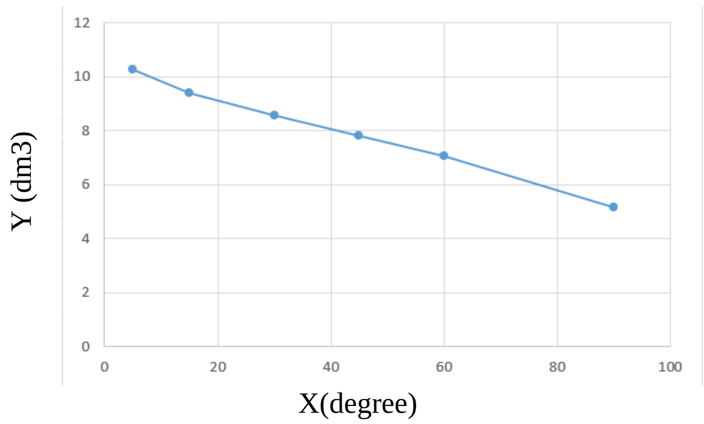


**Figure 10.** Change in cabin volume due to α.

### 3.2. *The model of mobile hospital cabin*

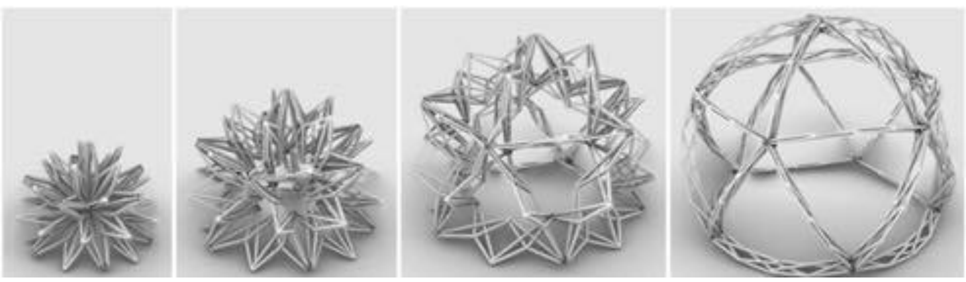

**Figure 11.** The Changing shape of the Hoberman sphere[13].

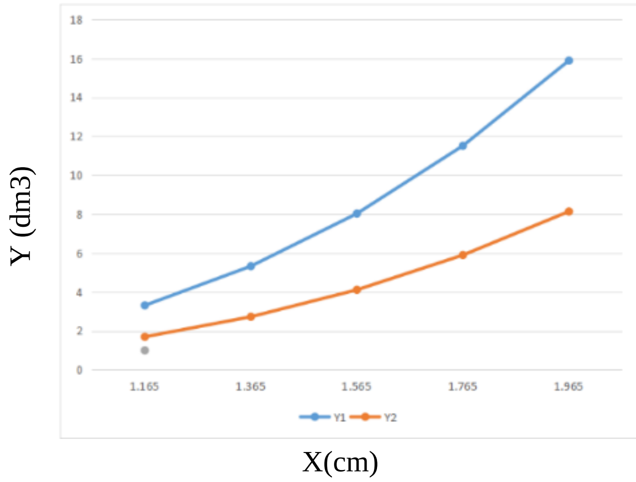


**Figure 12.** Clinic volumes data analysis.

As the volume of a ball $4/3\pi R^3$ the volume of Hemisphere is $2/3\pi R^3$. It can be seen from Figure 10; the volume can change due to changes in angle.

Five sets of radius data were chosen at random for comparison. (Figure 11.) The x-axis is the radius of the hemisphere that can be practically applied and the y-axis is the volume. The blue line is the volume after expansion and the orange line is the volume after contraction. which can be easily obtained by controlling the value of the radius. The five sets of data show that a small change in radius results in an exponential increase in the volume of the clinic.

After measuring the volume of the Hoberman ball when tightened is 64/125 of that when unfolded. So, if the radius of the ball is about 1.165m, the area when tightened is about 2.727; And the volume is 5.958m3 when unfolded, 3.051m; and it should be sufficient to put down the bed.

The shape of the Hoberman sphere and the properties of the motion can be made practical. Secondly, Volume measurement by change of angle got the reason for the Hoberman sphere to undergo a specific homogeneous deformation is obtained. By analysing the angular changes in the scissor-like structure of the Hoberman sphere, the reasons for the change in volume of the Hoberman sphere would be decided. Next, the usability of the cabin is modelled and evaluated for its application in actual situations. The specific material of the lining of the cabin and the method of fixing it to the sphere shell are then analysed through several experiments.

## 4. Conclusion

By using the foldability of the scissor-suited structure and the combination with lightweight, soft materials. The theoretical construction of a foldable and easily movable mobile cabin hospital with a Hoberman ball as its main body was demonstrated by the production of a practical model. A variety of epidemic diseases are staggering at the moment, and the new crown epidemic has not seen any abatement. In some areas, mobile cabin hospitals have been set up on a temporary basis to focus on patients with serious illnesses. This is a more carbon-free and environmentally friendly option than the traditional mobile cabin hospital, which uses less material. At the same time, it can be reused many times.

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