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Design And Simulation Of Foldable Furniture In Ansys

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Abstract: This article focuses on creating space saving furniture using simulated designs in ANSYS that would aid in overcoming the concern of spacing of furniture in households as well as offices. The need of such product is increasing rapidly especially in overpopulated countries like India where space constraint is a major challenge when it comes to housing. Considering the ongoing pandemic situation, the design has high usability for work from home as well as work from office conditions. Also, the material suggested for the manufacturing of this design can be recycled thus reducing wastage and impact on the environment. The model of smart table has been tested and simulated in ANSYS under three different loading conditions. Results clearly indicate applicability of proposed design for both household as well as office applications.

Keywords: Design, Simulation, Kinematics, Mechanism, Modelling, ANSYS.

1 Introduction

As humans, we strive to get highest possible output with least possible input in various areas of life, and with the increasing population density in cities we are now trying to do the same with space [1]. People move to major cities to look for work and other opportunities due to which the average living space decreases and the cost of free space increases [2]. In major cities like New York, Beijing and Mumbai, the cost of living is high and one of the factors that affect the cost of living is the house rent. Furniture is an attribute important that takes up a major amount of space in a house [3]. Therefore, to own and enjoy the luxury of furniture in such conditions, we need space saving or foldable furniture [4]. During the covid-19 pandemic situation, a lot of firms have allowed their staff to work from home permanently creating a need of office furniture for home. With the help of space saving furniture, we will be able to convert the corner of a room into a mini office [5]. Therefore, there was an urgent need to design space saving furniture to overcome the above-mentioned problems.

In the past few decades, researchers have been showing keen interest in designing various mechanisms for smart furniture which can find best suitable applications according to present day needs [6]. For an instance, a study by Paris et al. [7] introduced different types of folding mechanisms and build a collection of these mechanisms in Simulink library. The study also highlighted the concept of foldschemes along with their classification. The designed Simulink library consists of the basic elements like foldfacet and foldvertex which can be used for designing a foldscheme and folding mechanisms enabling engineers to rapidly design well-suited folding mechanisms for specified applications. Further, Zirn & Ruther [8] developed a low cost electric drive add-on kit suitable for foldable scooters or light weight foldable bikes. The authors considered an ultra-light bike called "STRIDA" for adding the kit. The authors further developed a BLDC-Outrunner drive chain for the rear axis with a drive control mechanism. The study considered a simulink model of the proposed system for analysing the design and for calculating the range estimate of the add-on kit. The results indicate that the electrification can be realized by a 1.3-1.5 kg add-on kit that can be adapted for several folding scooters and bicycles.

Moreover, Rajan et al. [9] discussed the issue of space in small houses of middle-class families. The study discussed about the lifestyle, the type of furniture these families' uses and the need for improvement. The authors developed a model of smart dining table using SOLIDWORKS for better visualization. Further, the analysis of the product was done using ANSYS. Lastly the authors developed a prototype of the proposed system for validation. In addition, Varghese et al. [10] created a design methodology to achieve a reliable and most suitable solution for space management in houses of middle class families. A study has been conducted on different types of dining tables, raw material, types of hinges, folding mechanisms etc. Further, product design specification was generated based on Quality Function Deployment (QFD) technique and five different concepts were created through mind mapping technique. Validation of the selected concept was done by making a working prototype. The results indicate that the proposed concept was found to occupy just less than 25% of its deployed area.

Furthermore, Sonawne et al. [11] developed electronically supported space saving smart furniture using IR sensors for middle class households. The project was built using microcontroller PIC18F4550. PIC controller (PIC18F4550) has a RISC architecture that comes with some standard features such as on chip program ROM, data RAM, data EEPROM, timers, ADC, USTAR, and I/O port. The results indicate that the project developed was both space and time saving. Luo et al. [12] designed a new type of folding tables and chairs based on the planar linkage mechanism using 3D modelling software SOLIDWORKS and a dynamic analysing software ADAMS. Initially the study considered four kinematic linkage mechanisms to create a 2D drawing along with all the geometrical parameters. Further, a 3D model of proposed system was developed using CAD software. Lastly, the design has been imported to ADAMS for further optimization thus analysing its movement characteristics to get a more reasonable mechanism that can be put into actual usage. Lastly, Saul et al. [13] developed a software called SketchChair for building chairs of different designs with ease. The design was initially prepared using a 2D sketch-based interface and then the sheet materials were used for fabrication. The designs were further cut using a laser machine or a CNC milling machine for practical implementation.

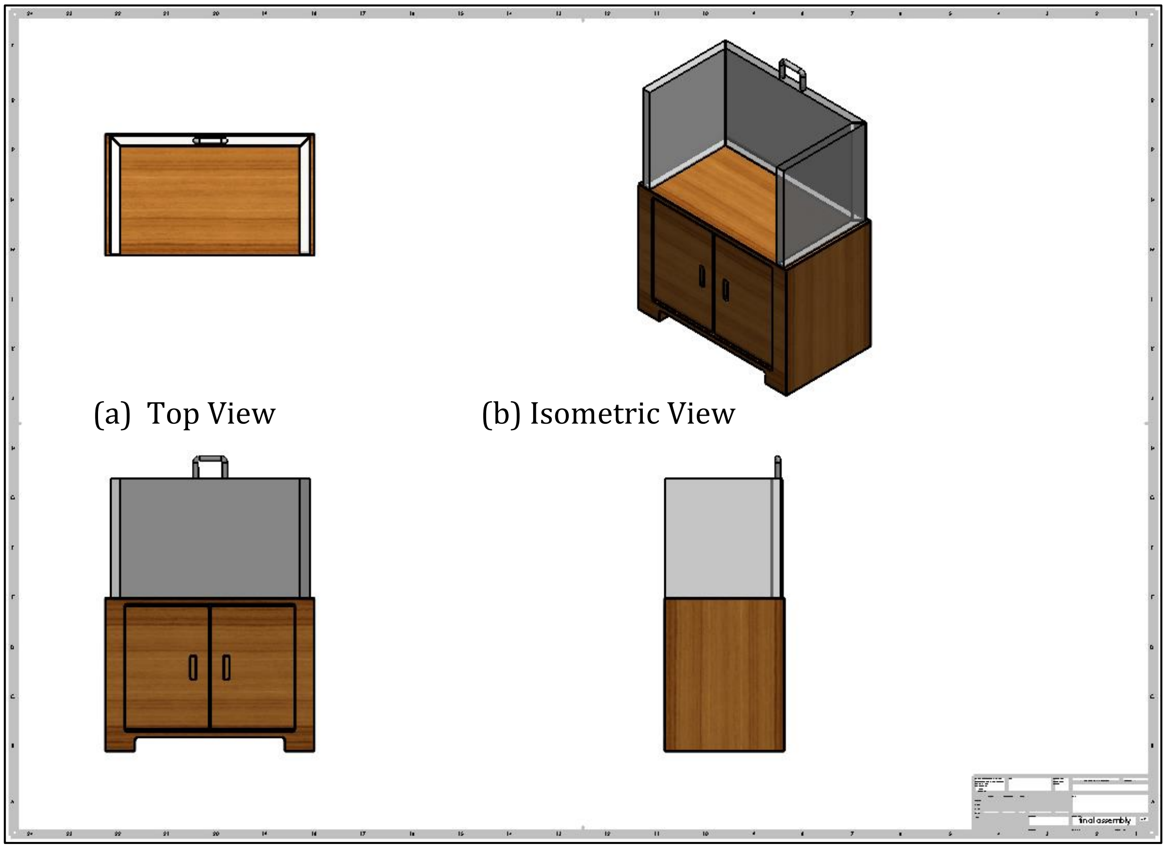
2 Model analysis and designing of foldable table

Generally, wood is considered to be a good material for furniture applications but there are also some other lighter materials like aluminium or carbon fibre which can provide better strength compared to wood. But these materials are expensive, requires costly equipment and skilled labour. Therefore, wood has been considered as the best choice for this study since it is durable, light weight, economical and most importantly recyclable. Hence in this study engineered wood has been proposed for building the desired model. The properties of engineered wood which makes it suitable for present application has been highlighted in Table 1.

Table 1. Properties of Engineered wood

Model type:	Linear Elastic Isotropic
Yield strength:	1.8e+07 N/m^2
Tensile strength:	1.8e+07 N/m^2
Compressive strength:	6.6e+06 N/m^2
Elastic modulus:	4e+09 N/m^2
Poisson's ratio:	0.25
Mass density:	750 kg/m^3
Shear modulus:	2.5e+10 N/m^2
Thermal expansion coefficient	12 /Kelvin

The model of the proposed system has been initially created in SOLIDWORKS. The different views of proposed system have been shown with the help of Figure 1.



(a) Top View (b) Isometric View

(c) Front View (d) Side View

Figure 1. Model of proposed system along with different views created in SOLIDWORKS

The foldable table has been designed in such a way that it can be operated in three different modes for better usage and applicability. In the first mode table has been provided with closed partitions and therefore the whole top area can be used as a table-top. In the second mode table partitions are open which allows for a separate workspace. Lastly, in the third mode the whole area beneath the table top is a storage area with multiple drawers to store files as well a stool or a small chair.

3 Load analysis of the proposed system

Since, the smart table can be used for a variety of applications therefore it has to be tested for different loading conditions. The load has been varied in following three ranges i.e. low (50-70 kg), medium (80-120 kg) and high (above 120 kg).

3.1 Stress, Strain and displacement analysis for 70 kg load

Initially, a total load of 70 kg (700N) was applied on the top of the table. The stress, strain and displacement plots obtained were shown in Figures 2, 3 & 4 respectively. The minimum and maximum stress obtained was 6.131e-02N/m^2 and 9.858e+05N/m^2 respectively. Further, maximum stress was generated at the edges of the table top whereas maximum displacement of 0.3221 mm was seen at the centre of the table top. It has been observed that there is a significant difference between yield stress i.e. 1.8e+07 N/m^2 and maximum stress, therefore it can be concluded that the design is safe for loads up to 70kg. This is the maximum ideal load case for both office and home conditions.

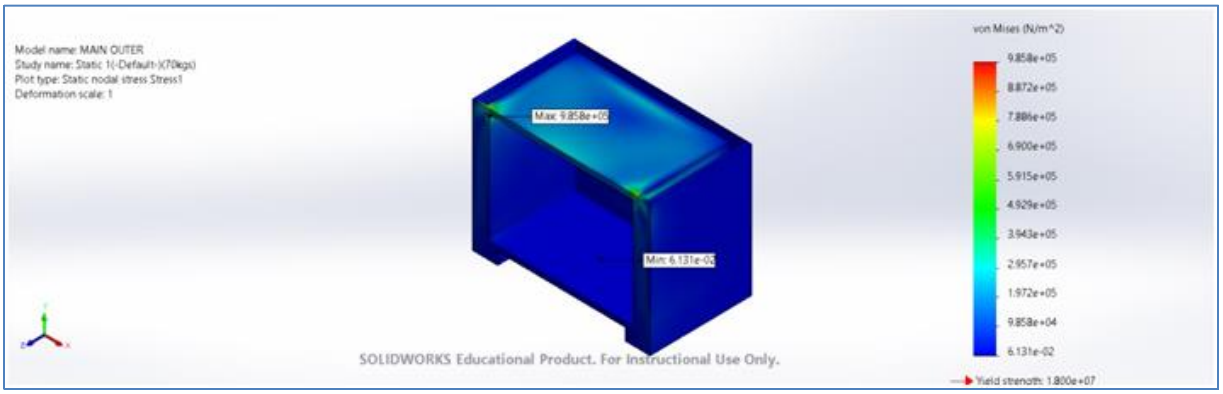


Figure 2. Stresses induced in the system for payload of 70kg

Figure 3. Strain induced in the system for payload of 70kg

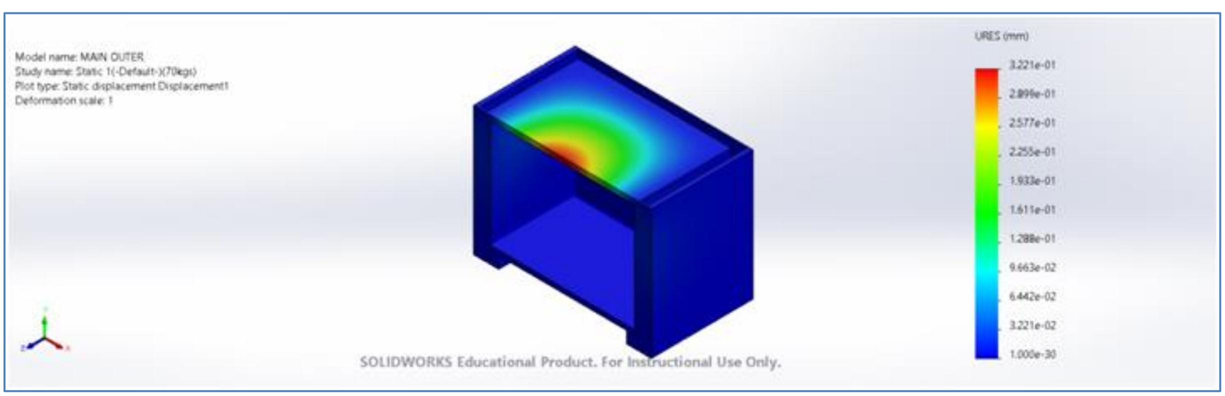


Figure 4. Displacement obtained in the system for payload of 70kg

3.2 Stress, Strain and displacement analysis for 120 kg load

Further, a load of 120kg (1200N) was applied on the top of the table. The stress, strain and displacement plots obtained were shown in the Figures 5, 6 & 7 respectively. The minimum and the maximum stress obtained were 1.068e-01N/m^2 and 1.587e+06N/m^2 respectively. Again, maximum stress was generated at the edges of the table top. Moreover, maximum displacement of 0.5181mm was observed at the centre of the table top. Still, there is a significant difference between yield stress i.e. 1.8e+07 N/m^2 and the maximum stress, therefore the design is still safe for loads up to 120kg. Generally, loading is not so high for household as well as office purpose.

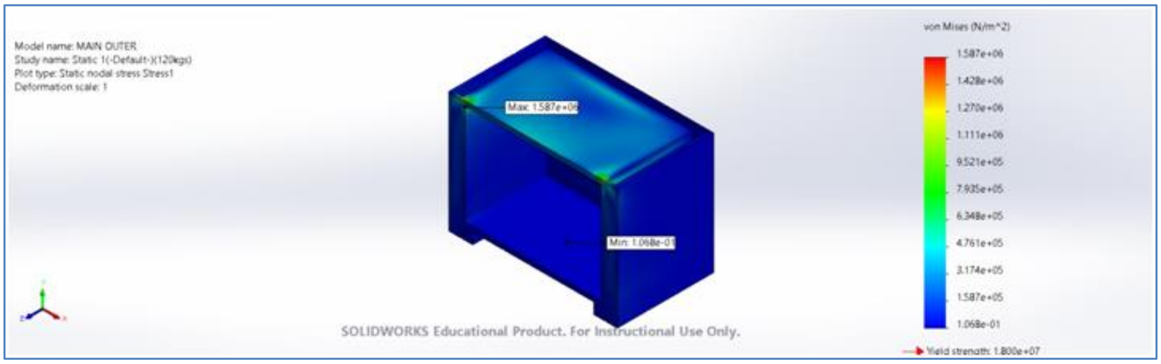


Figure 5. Stresses induced in the system for payload of 120kg

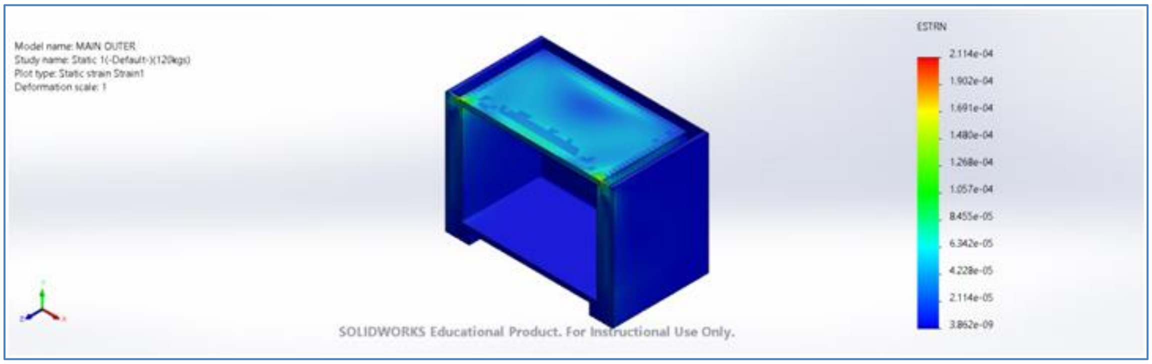


Figure 6. Strain induced in the system for payload of 120kg

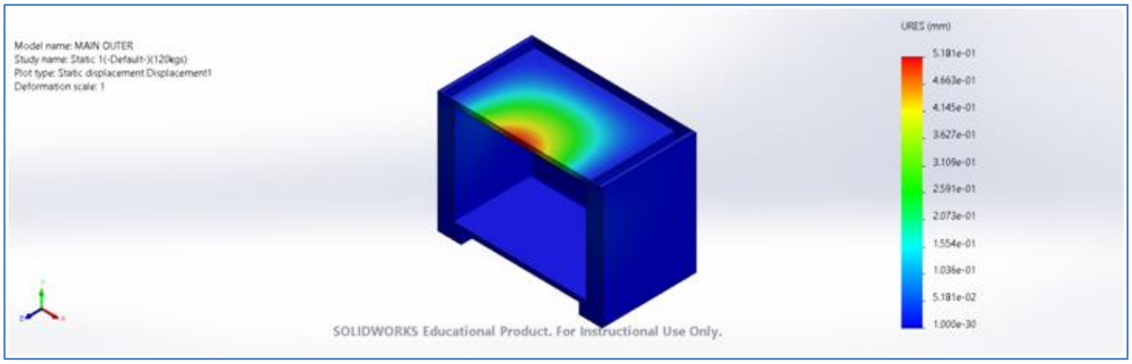


Figure 7. Displacement obtained in the system for payload of 120kg

3.3 Stress, Strain and displacement analysis for 150 kg load

Finally, a total load of 150kg (1500N) was applied on the top of the table. The stress, strain and displacement plots obtained were shown in Figures 8, 9 & 10 respectively. The minimum stress and maximum stress induced was 1.285e-01N/m^2 and 1.948e+06N/m^2 respectively. Again, maximum stress was generated at the edges of the table top. Maximum displacement of 0.6358mm was obtained at the centre of the table top. Still, there is a significant difference between yield stress i.e. 1.8e+07 N/m^2 and maximum stress, therefore the design is also durable for loads up to 150kg which is a rare loading condition for both office and home environments.

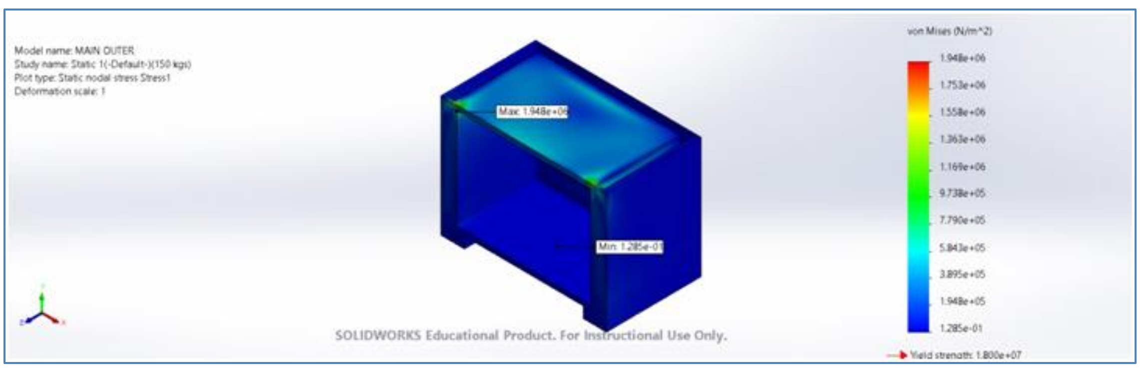


Figure 8. Stresses induced in the system for payload of 150kg

Figure 9. Strain induced in the system for payload of 150kg

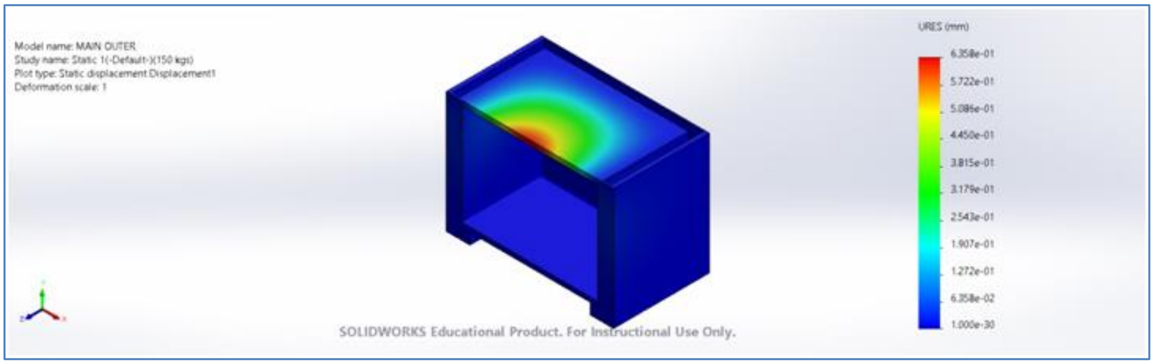


Figure 10. Displacement obtained in the system for payload of 150kg

4. Result & Comparison

The results obtained after stress, strain and displacement analysis of the proposed system for a load of 70kg, 120kg and 150kg are shown with the help of Table 2, 3 & 4 respectively. It is clear from the design analysis that the proposed system can withstand a load within range of 70-150 kg with very high factor of safety. Hence, the product is safe to use even for high loads in an office or housing environment.

Table 2. Stress, Strain and displacement obtained in the system for payload 70kg

Name	**Type**	**Minimum stress**	**Maximum stress**
Stress1	VON: von mises Stress	6.131e-02N/m^2 Node: 45347	9.858e+05N/m^2 Node: 75290
Name	**Type**	**Minimum strain**	**Maximum strain**
Strain1	ESTRN: Equivalent Strain	3.659e-09 Element: 46093	1.313e-04 Element: 14560
Name	**Type**	**Minimum displacement**	**Maximum displacement**
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1	3.221e-01mm Node: 1465

Table 3. Stress, Strain and displacement obtained in the system for payload 120kg

Name	**Type**	**Minimum stress**	**Maximum stress**
Stress1	VON: von mises Stress	1.068e-01N/m^2 Node: 45356	1.587e+06N/m^2 Node: 75290
Name	**Type**	**Minimum strain**	**Maximum strain**

Strain1	ESTRN: Equivalent Strain	3.862e-09 Element: 11871	2.114e-04 Element: 14560
Name	**Type**	**Minimum displacement**	**Maximum displacement**
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1	5.181e-01mm Node: 1465

Table 4. Stress, Strain and displacement obtained in the system for payload 150kg

Name	**Type**	**Minimum stress**	**Maximum stress**
Stress1	VON: von mises Stress	1.285e-01N/m^2 Node: 45356	1.948e+06N/m^2 Node: 75290
Name	**Type**	**Minimum strain**	**Maximum strain**
Strain1	ESTRN: Equivalent Strain	0.000e+00mm Node: 1	6.358e-01mm Node: 1465
Name	**Type**	**Minimum displacement**	**Maximum displacement**
Displacement1	URES: Resultant Displacement	3.866e-09 Element: 35449	2.594e-04 Element: 14560

5. Conclusion

The research objective of designing a foldable table for adequate household applications has been successfully achieved. The stress, strain and displacement analysis of the proposed design in ANSYS clearly indicates that the design is safe for a load upto 150kgs. The maximum stresses induced in the system for a load of 70kg, 120kg and 150kg were 9.858e+05N/m^2, 1.587e+06N/m^2 and 1.948e+06N/m^2 respectively which is well within the yield stress limit. Additionally, the product is economical and eco-friendly as product has a moderate price and can be made by recycling waste wood. The product can be effectively used as a safety measure against the pandemic. Further, due to its structural strength, durability and multipurpose functionality, it is applicable for both household and office applications. It can be used as an isolated workstation in an office or a simple table or cabinet for household purposes. As an extension for future work, the whole unit could also be designed in such a way that it can be folded into a small structure and therefore can be easily kept anywhere thereby taking less space. Further, 3D printing technique can also be used for additive manufacturing of the proposed system.

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