

CONCEPTUAL DESIGN DOCUMENT



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ABSTRACT

In this document the proposed stair climbing system and its components will be described in detail, and an explanation for each component's inclusion will be provided. Such explanation will be supplemented with the list of design requirements derived from the problem statement, and how each component/design feature directly contributes to fulfilling the requirements and solving the problem presented.

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1.0 PROBLEM STATEMENT

Transporting heavy furniture up and down the stairs is difficult and potentially dangerous.

2.0 REQUIREMENTS

In this section, the requirements will be laid out in the following categories: Functional, Sizing, and Safety.

2.1 FUNCTIONAL

To achieve the goal set by the problem statement, the requirements of function are as follows:

2.1.1 - The system shall transport furniture repeatedly up and down one floor within a residential building.

2.1.2 - The system shall accommodate up to a 4-seater sofa.

2.1.3 - The system shall accommodate up to a 5-shelf bookshelf.

2.1.4 - The system shall be reusable.

2.2 SIZING

To ensure that the system is of a proper size that is capable of being transported and capable of fitting within the stairwells it operates in, the requirements of interface are as follows:

2.2.1 - The system shall fit within a standard stairway according to Section R311.7.1 of the 2021 International Residential Code (IRC).

2.2.2 - The system shall be transportable in the back of an average American pickup truck in addition to the transported furniture.

2.3 SAFETY

To ensure that the system is overall safe, and does not endanger the operator or environment, the requirements of safety are as follows:

2.3.1 - The system shall cause less injury and strain than an average moving job.

2.3.2 - The system shall not destructively alter the environment.

2.3.3 - The system shall not damage the furniture.

3.0 SYSTEM OVERVIEW

In this section the system will be shown, and the operation will be described in detail.

3.1 SYSTEM COMPONENTS

In this section the system's components will be described in detail, with an explanation of how each requirement is met through the design's features.

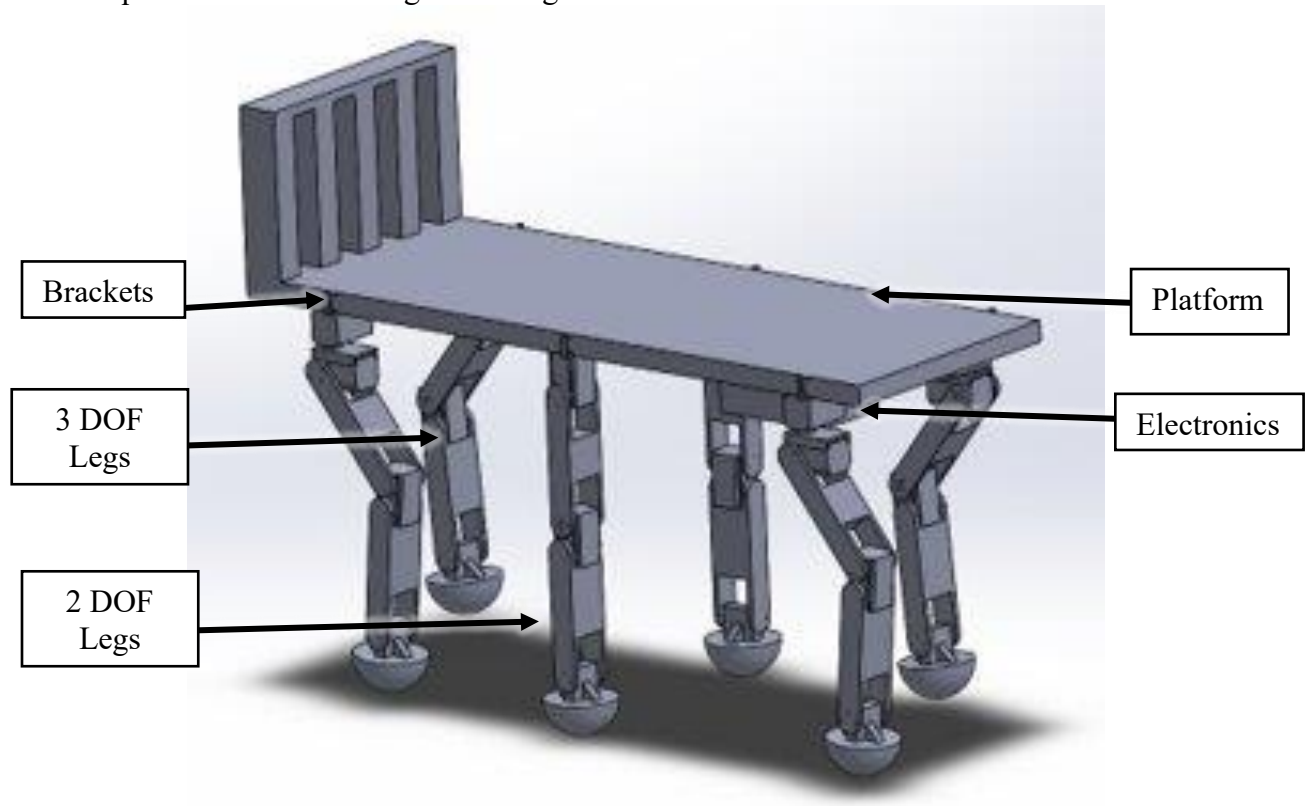


Figure 3.1: Complete Drawing

3.1.1 Platform

In the figure below, the dimensions of the platform are shown.

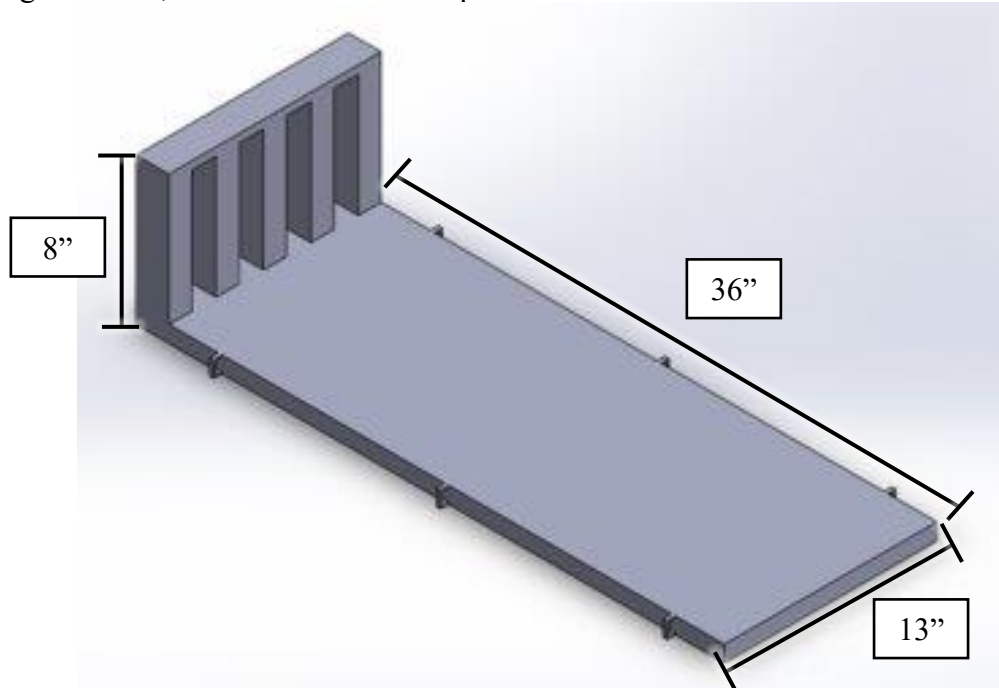


Figure 3.2: Platform Drawing

To accommodate its payload [2.1.2, 2.1.3] as well as fit into a standard residential stairwell [2.2.1] or pickup truck bed [2.2.2], the system is sized to be 25" at full scale, allowing for an inch of space between the system and the stairs' thinnest point, the rails.

3.1.2 Brackets

In the figure below, the dimensions of the bracket are shown.

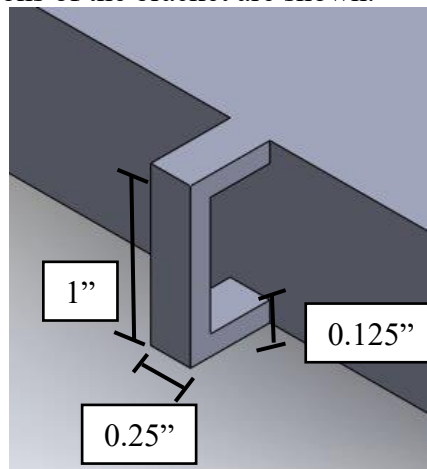


Figure 3.3: Bracket Drawing

To prevent the payload from slipping, thus damaging the furniture as well as the surrounding environment [2.3.2, 2.3.3], brackets are located along the edge of the platform to allow for straps to be applied to the payload.

3.1.3 Legs

In the figure below, the dimensions of the robotic leg are shown.

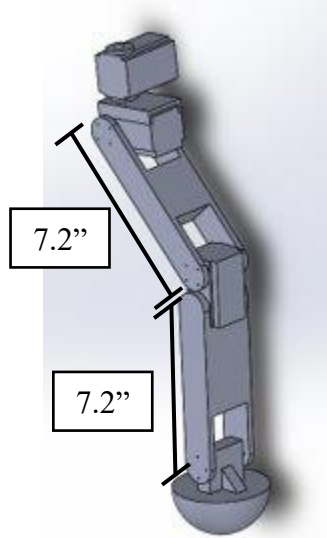


Figure 3.4: Robotic Leg Drawing

In order to ascend the stairs [2.1.1] without modifying the surrounding environment [2.3.2], the system will utilize a set of legs for locomotion. The front and back pairs of legs each have 3 degrees of freedom, with a 2 degree of freedom shoulder as well as a 1 degree of freedom elbow provide the majority of the force required to ascend the stairs. Providing stability [2.3.2, 2.3.3] rather than climbing force, the pair of central legs have 2 degrees of freedom each, with a 1 degree of freedom shoulder and elbow. Additionally, to prevent damage to the stairwell flooring [2.3.2] each leg has a semicircular rubber foot.

3.1.4 Electronics

In the figure below, the dimensions of the electronics bay are shown.

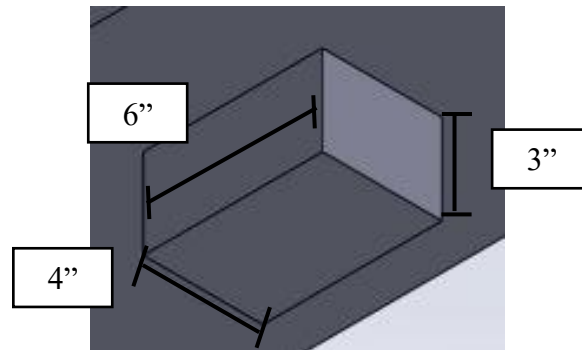


Figure 3.5: Electronics Bay Drawing

In order for the system to be reusable [2.1.4], the system will have a rechargeable battery. In order to reduce the strain and injury to a person [2.3.1], the system will be remotely controlled. In order to ascend the stairs [2.1.1], the system will have an encoder to detect the depth of each step and the height of the next step.

3.2 CONCEPT OF OPERATIONS

The standard practice for operating the device is as follows: First, the user will load the payload furniture onto the platform and then apply securing straps through the side brackets. Next, use the remote control to command the device to begin walking up the set of stairs. Once the device reaches the top of the stairs, undo the straps and remove the furniture from the platform.

3.2.1 Process Flowchart

The following flowchart describes the process that the system will follow in order to achieve the problem statement.

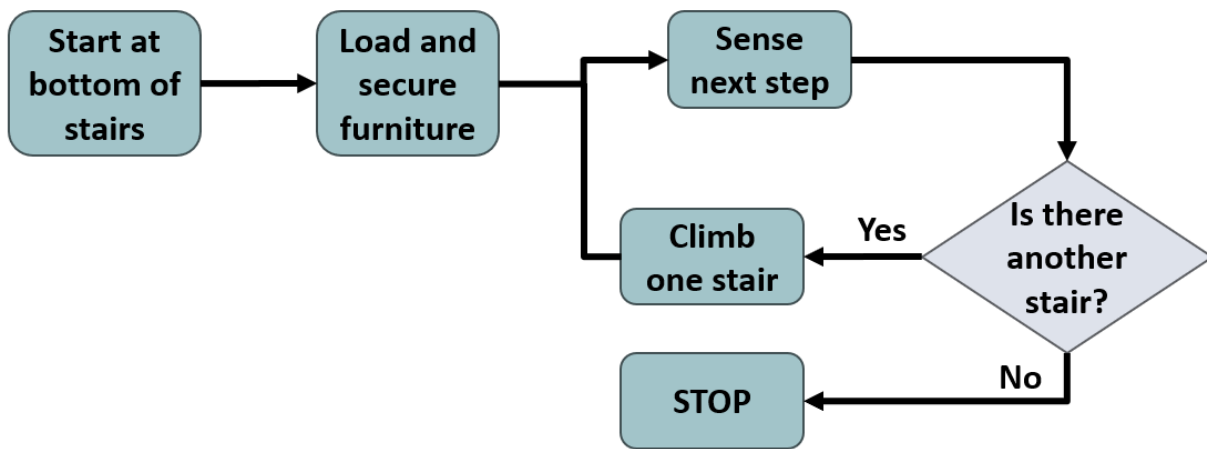


Figure 3.6: Process Flowchart

3.2.2 Hardware Block Diagram

The following block diagram describes the connections and relationships between the various components.

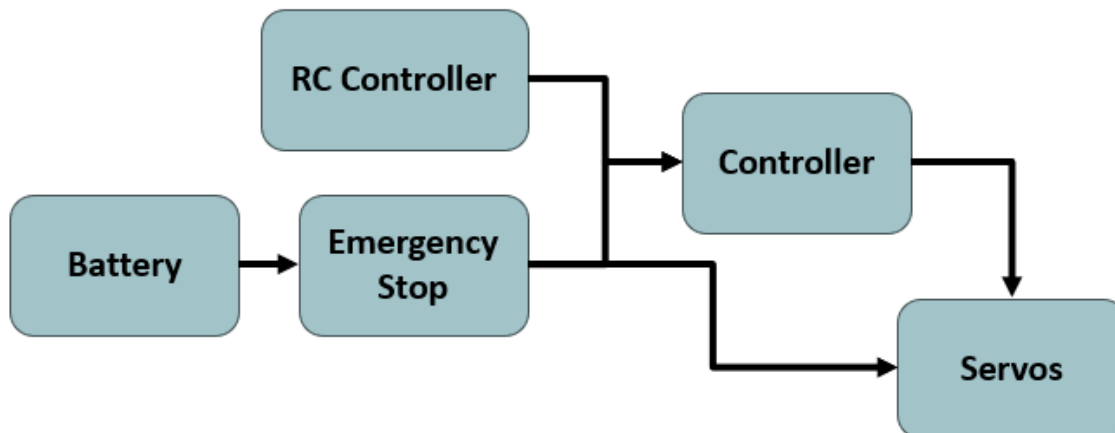


Figure 3.7: Hardware Block Diagram

4.0 CONCLUSION

Through the above features, the system can reliably and safely transport its intended loads up and down a flight of stairs without endangering the operator and while reducing the overall strain on the operator compared to manually moving the payload up the stairs.

5.0 APPENDIX

Below is the appendix, including the requirements verification matrix and the decision matrix created for the project.

5.1 APPENDIX A – REQUIREMENTS VERIFICATION MATRIX






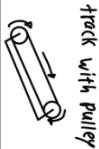


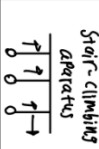




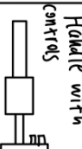
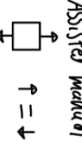
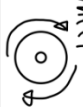


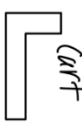

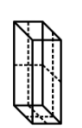
No.	Requirement	Verification Description	T	A	O	R
1	2.1.1	Test load and trial	X			
2	2.1.2	Measurement/Trial	X			
3	2.1.3	Measurement/Trial	X			
4	2.1.4	Repeated Trials	X		X	
5	2.2.1	Measurement and Comparison	X			X
6	2.2.2	Measurement and Comparison	X			X
7	2.3.1	Trial, followed by Analysis and Comparison	X	X	X	X
8	2.3.2	Trial and Observation	X		X	
9	2.3.3	Trial and Observation	X		X	

T – Test and Measurement; **A** – Analysis and Simulation;
O – Observation and Inspection; **R** – Reference and Datasheet
(*Requirements verification matrix. | download table - researchgate*) [1]

5.2 APPENDIX B – DECISION MATRIX

Criteria	Climbing Ability	Time to climb 1 flight (higher = faster)	Simplicity (higher = simpler)	Part Count (higher = lower #)	Stability	Adaptability	Operator Effort (higher = less effort)	Safety	Score	Best?
Weight	10	2	5	4	10	6	5	10	Score	Best?
Lobed Camshafts	7	3	7	8	8	4	10	7	367	
6 Legs, 2 2DOF and 4 3DOF	9	8	1	3	10	10	10	10	433	Best!
2 Legs with "Tail" pushing non powered front	8	6	6	5	7	8	10	9	400	
Centipede On Tracks	8	8	4	4	9	7	8	10	404	
Powered Treads + Trirheel and Cage + Assisted Lifting	8	8	7	4	9	7	7	10	414	
Autonomous Robot Legs (2 DOF)	9	8	3	4	8	9	10	10	421	
Legs Driven By Camshaft	8	4	3	4	9	6	10	10	395	

5.3 APPENDIX C – MORPHOLOGICAL CHART

Mobility (un-powered)	wheel with treads		tri-star wheel		sled											
Mobility (powered)	insect legs		treads		track with pulley		hind legs		"strand beest"		stair-climbing apparatus		geared tri-wheel		rotating platform	
Operation	Autonomous operation via software		R.C.		cabled pendant		Handle with controls		Assisted module							
Stability system	controls/ software		flywheel		Linear actuators		counterweight									
Payload system	Cart		Platform struts													

6.0 REFERENCES

“Requirements verification matrix. | download table - researchgate,” ResearchGate, https://www.researchgate.net/figure/Requirements-Verification-Matrix_tbl1_269163835 (accessed Sep. 28, 2023).

[1]