SHELFY

~ A Smart Automated Storage And Retrieval System

Team Details

- **Proposal Title**: Smart automated storage-retrieval system
- **Participated as: T**eam as Educational Institute
- **Hardware Resources Used**: SHAKTI Pinaka (E32-A35) on Artix7-35T
- **Registration Number: 8849173**
- **Contact details of SPOC:** Aditya Nirmale / 9769298001 / aditya.nirmale@learner.manipal.edu

Our Team

Name of Team Members	Email ID	Contact	Branch / Area of Specialization	Name of Institute
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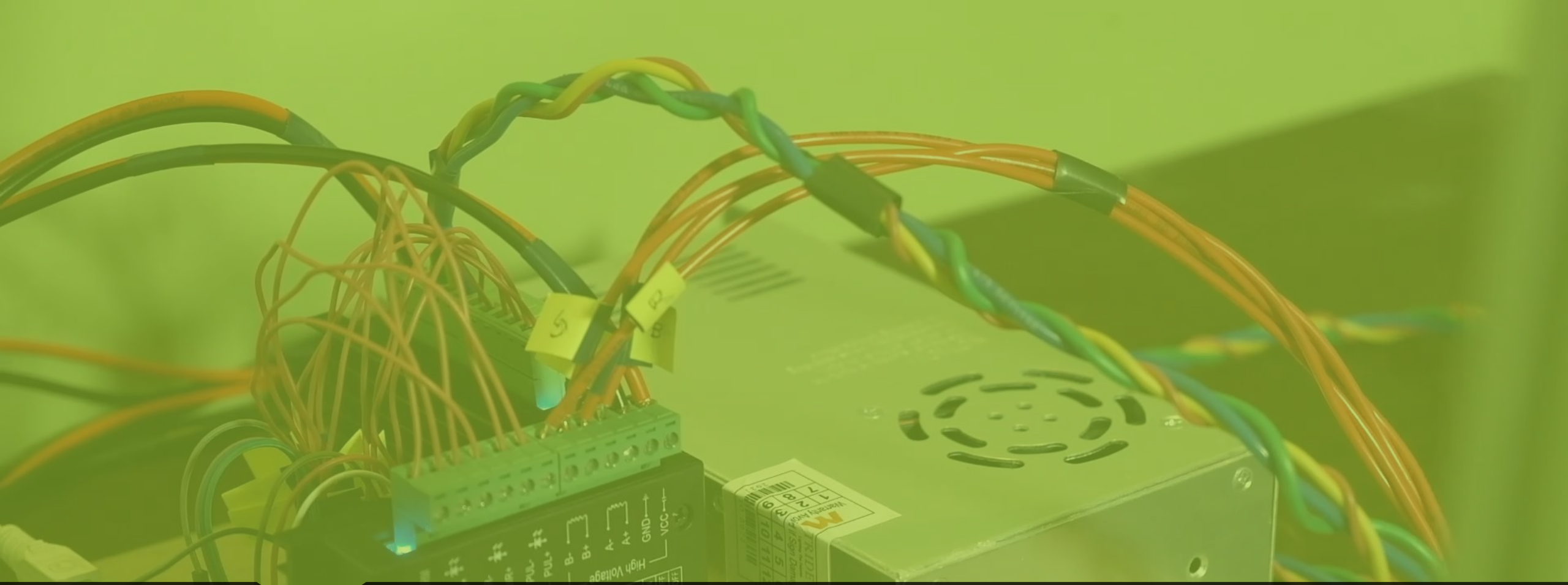
SHELFY

Shelfy aims to provide a more accessible and useful warehouse automation system that can manage inventory, storing and retrieving objects, all while being controlled remotely. This project is specifically targeted for the Indian market, where small scale warehouses are plagued with issues like non-standard stocking techniques, employee errors, and high cost of maintenance.

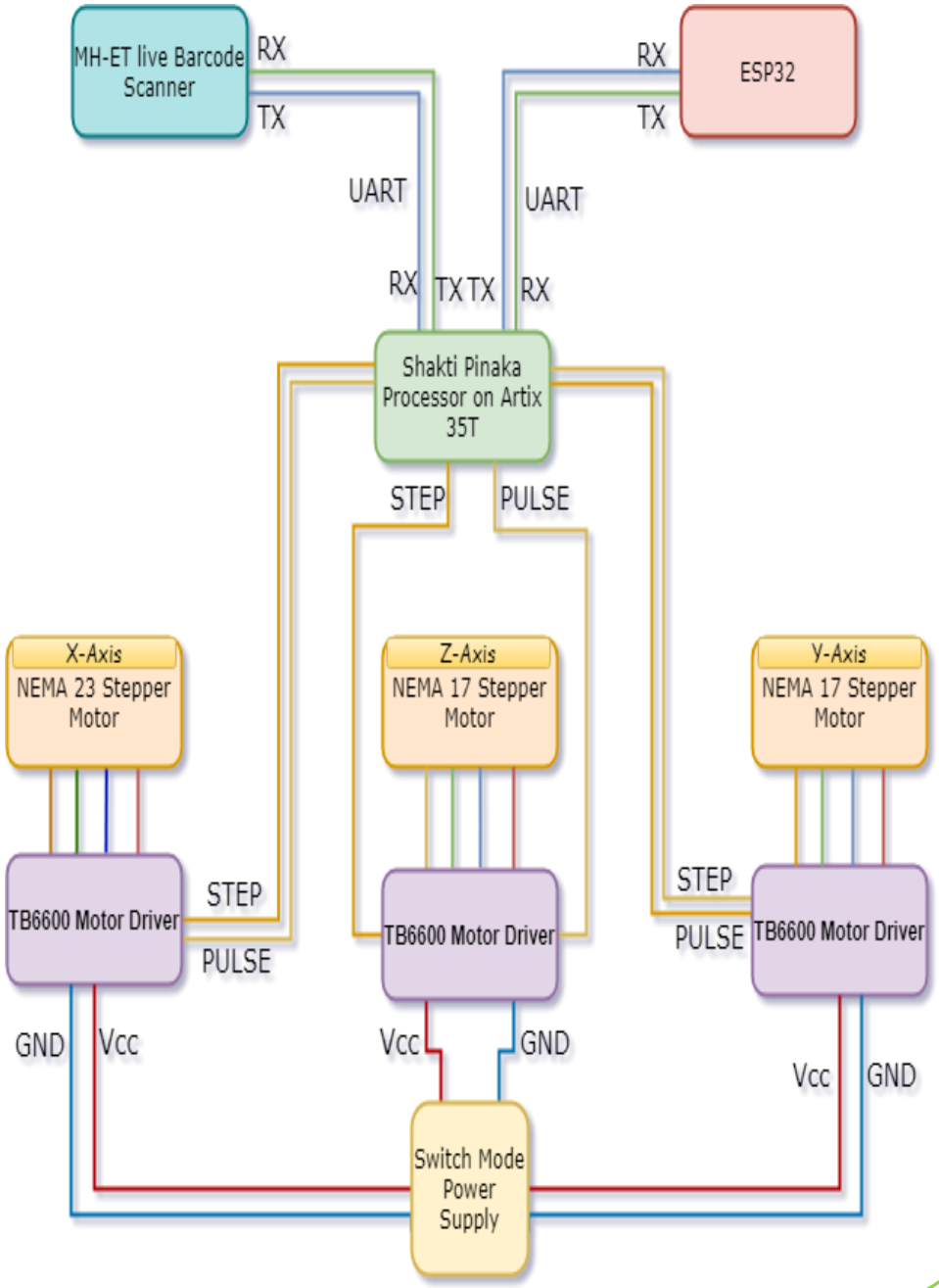
Shelfy is a modular, affordable and smart solution to resolve these issues and in turn enhances the supply chain while targeting the multi-billion-dollar warehousing industry.



Technical Details

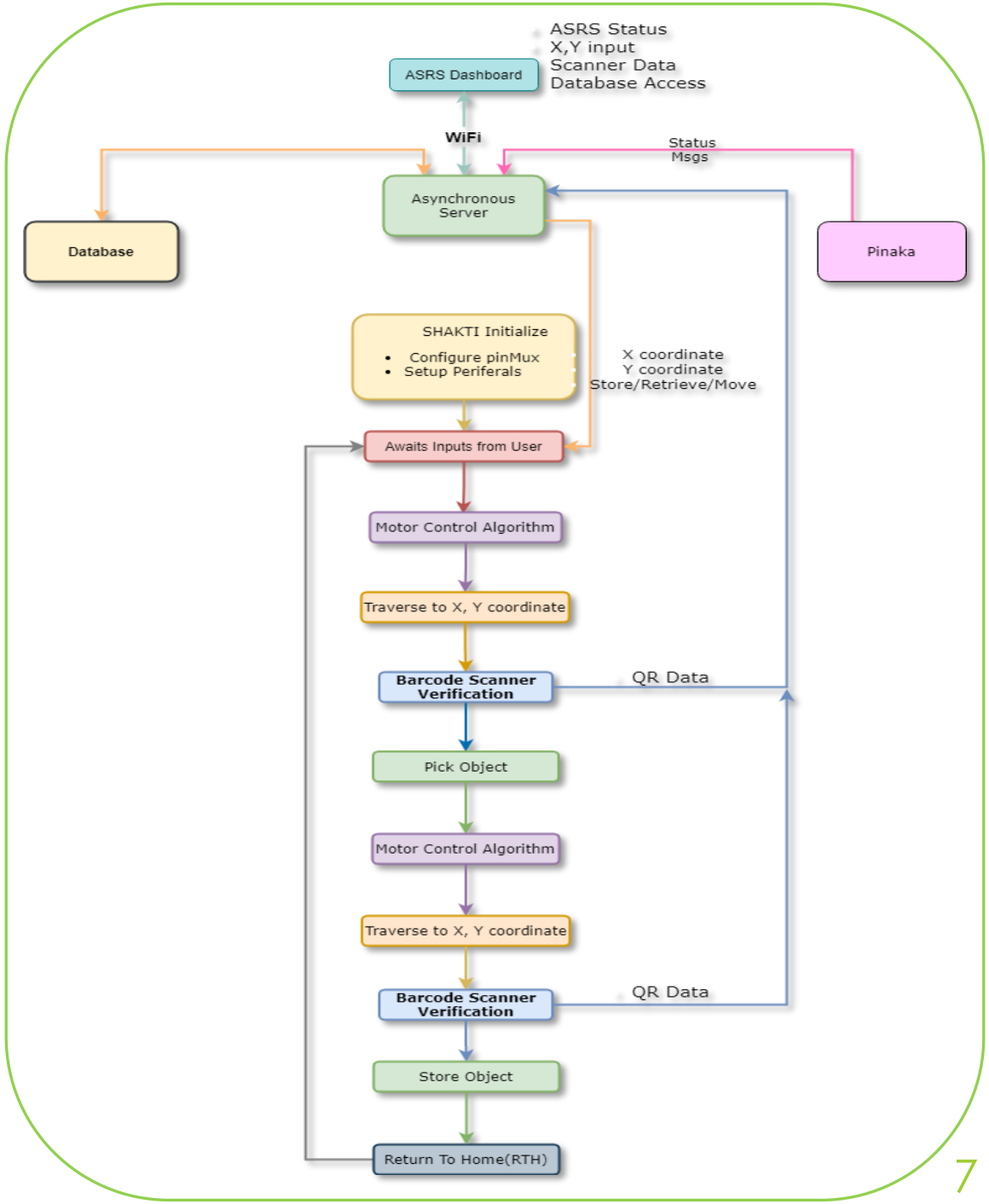
Electronics – Hardware

- Shakti Pinaka Processor on Artix 35T
  - Controls main electronics and communicates with the esp32
- ESP32 Wroom Devkit
  - Hosts the asynchronous web-server for low latency and easy implementation
- NEMA Motors with TB6600 Motor Drivers
  - All the motors are actuated using 2 GPIO pins each, namely pulse and directions
- MH-ET live barcode scanner
  - Scanner capable of scanning QR and Barcodes and communicating via UART



Electronics - Software

- Time.h ,Scanner.h, motor.h
  - For accurate time delays using the CLINT timer
  - Functions for communicating with the scanner
  - Functions for coordinated control
- Different routines for storing, retrieving and moving packages
- Status messages sent to server for monitoring shelfy
- Shakti-SDK on platform IO
  - Easy user interface and setup
- Blog Published on the Shakti Blog
  - Tutorial on simple web interface using esp8266



Shelfy - Dashboard

- ESP32 Devkit
  - Multiple libraries available to simplify development of web interface
- Asynchronous server hosted on esp32
  - Quick real time updates without and software on client end
- Database Hosted on Firebase
  - Efficient inventory management and tracking
- Website Features
  - Capability to Store, Retrieve and Move packages
  - Live Scanner data – inventory tracking and prevention of false storage and retrievals
  - Shelfy Status - For remote monitoring of system
  - Access to database for viewing inventory

View Stored Objects

Unique ID	Object	x-axis	y-axis	Stored On	Location ID	Stored
item_1	timing belt	1	1	Fri Jan 15 2021	LOC1	true
item_2	Barcode Scanner	1	2	Tue Sep 15 2020	LOC2	true
item_3	Gears	1	3	Tue Jul 21 2020	LOC3	true
item_4	Castor Wheel	1	4	Mon Apr 12 2021	LOC4	true
item_5		1	5	N/A	LOC5	false
item_6	Motor Drivers	2	1	Fri May 28 2021	LOC6	true
item_7	Wires	2	2	Thu Feb 20 2020	LOC7	true
item_8	Shrink Tubes	2	3	Mon Oct 19 2020	LOC8	true
item_9		2	4	N/A	LOC9	false
item_10	motor	2	5	Fri Dec 25 2020	LOC10	true
item_11	hex nuts	3	1	Sat Jun 19 2021	LOC11	true
item_12		3	2	N/A	LOC12	false
item_13	V Slot Rail	3	3	Sun Oct 04 2020	LOC13	true

Shelfy Dashboard

Store Object | Retrieve Object | Move Object | View Objects

Move Object

Enter object to move

Object Name

Co-ordinates to move to

X Axis

Y Axis

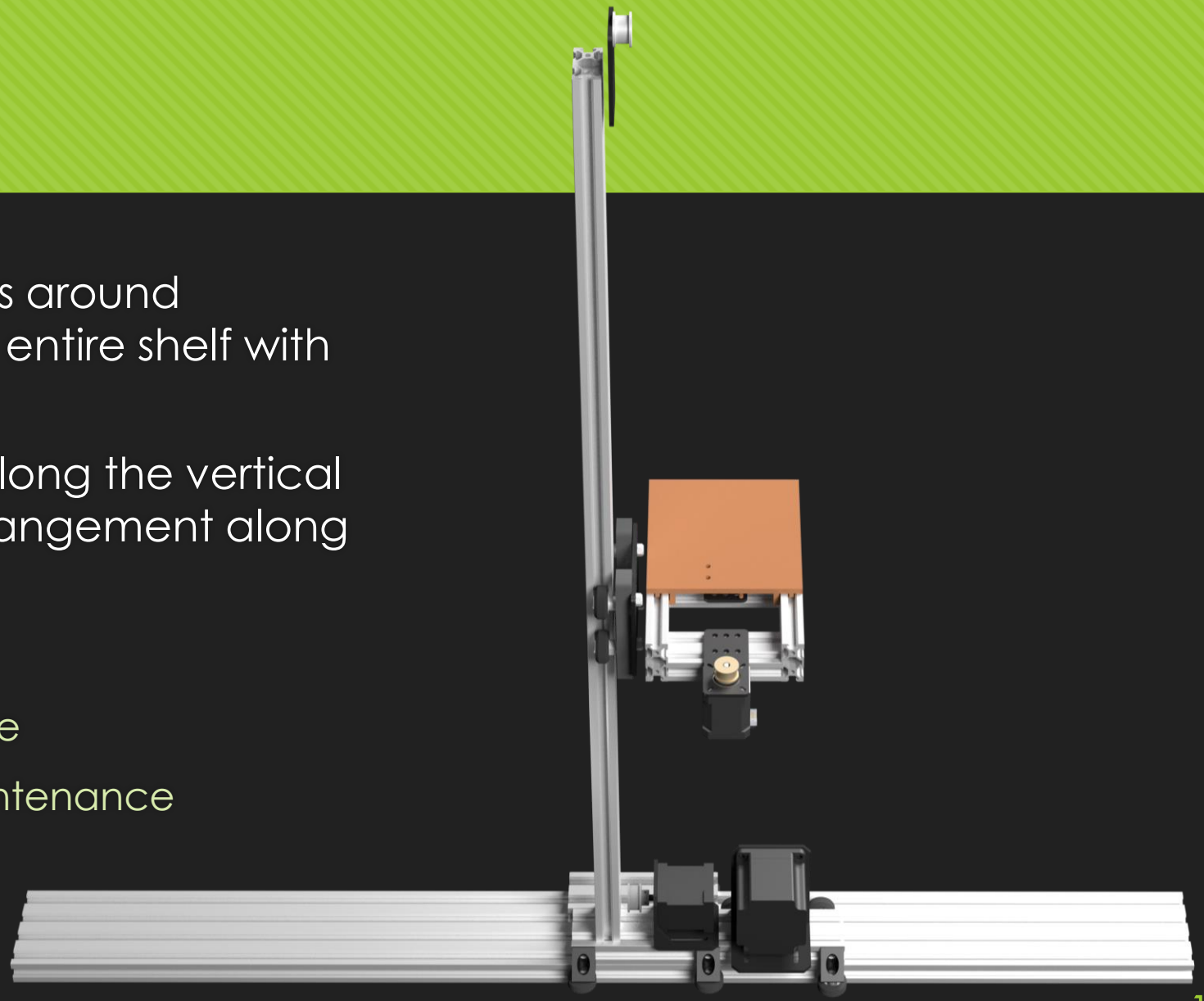
Move to Location

Shelfy Status:

initialization complete

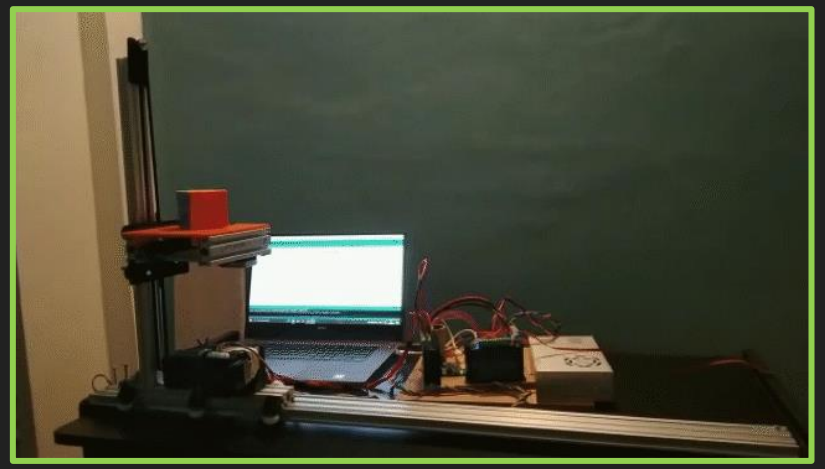
Mechanical

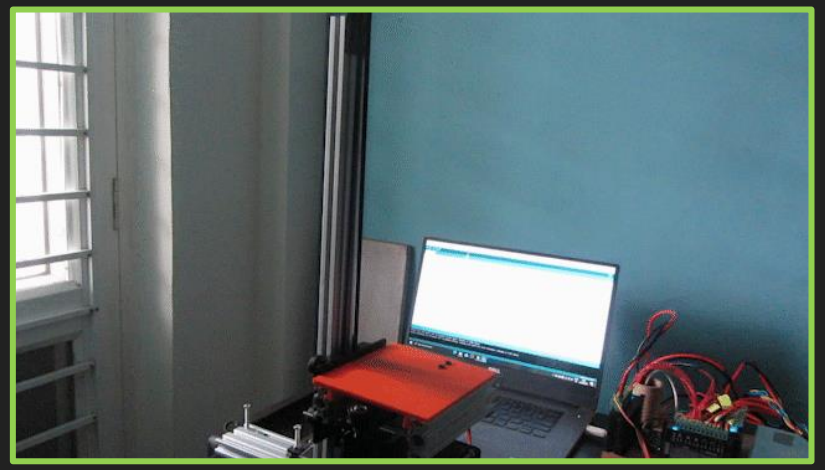
- The core concept of Shelfy revolves around a plotting mechanism to cover the entire shelf with ease
- The design is based on belt drive along the vertical axis in sync with a belt & pinion arrangement along the horizontal axis
- Belt based systems are
  - Easily scalable and adaptable
  - Lower cost of repair and maintenance
  - Reduced wear and tear
  - Cheaper to implement



Axes Mechanism

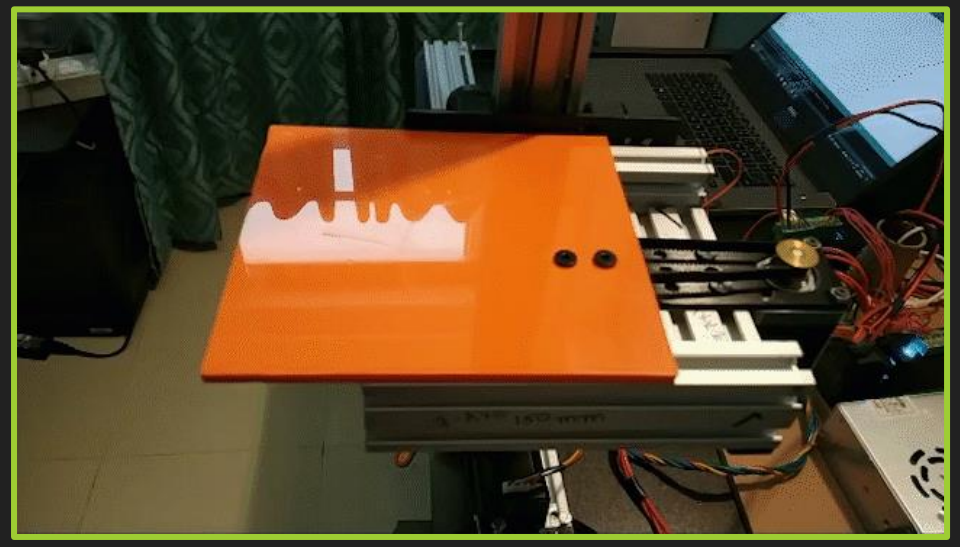
- Horizontal Axis - Belt & Pinion
  - 2060 V-slot Aluminum Extrusions
  - GT-2 Timing Belt and Pulley
  - NEMA-23 Stepper Motor
  - Gantry Plate mounted with Free V wheels
- Vertical Axis - Belt Drive
  - 2040 V-slot Aluminum Extrusions
  - GT-2 Timing belt and Pulley
  - Idler Pulley
  - NEMA-17 Stepper Motor
  - Gantry Plate mounted with Free V wheels
  - Custom 3D printed L-bracket to join two axes

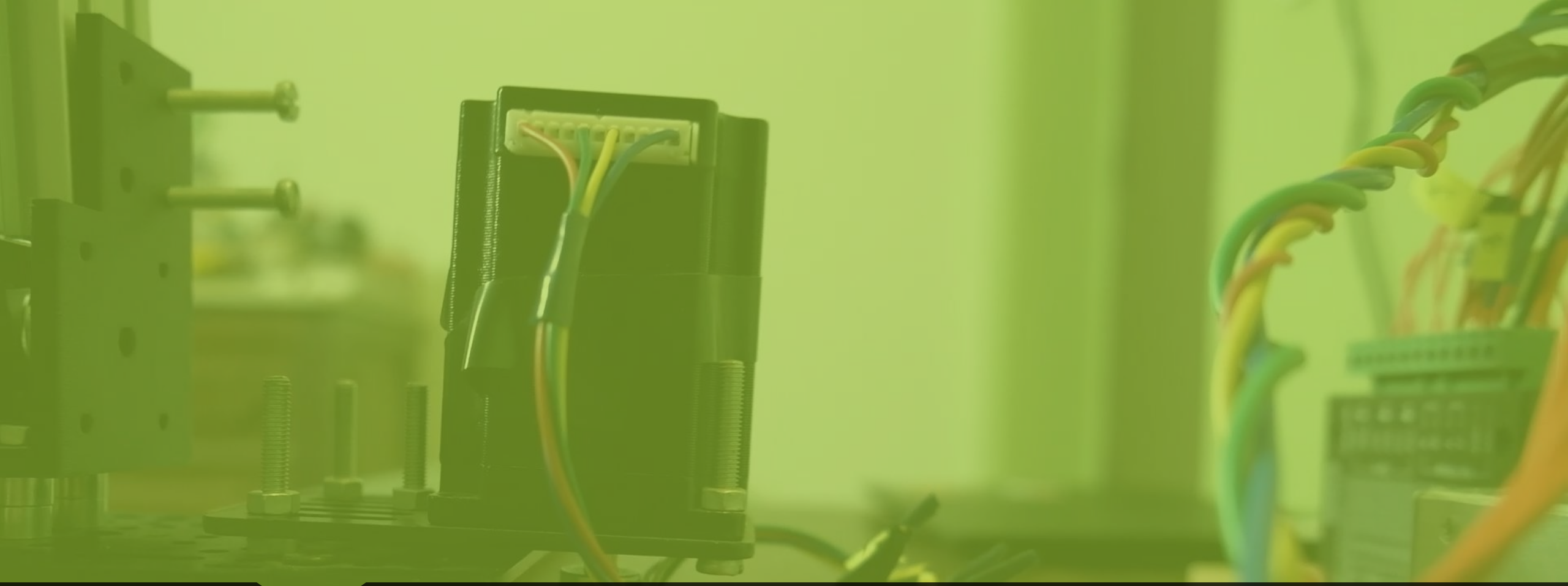




Axes Mechanism

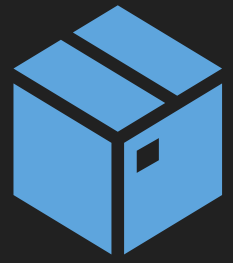
- Z-Axis/In plane Axis - Belt Drive
  - 2040 V-slot Aluminum Extrusions
  - GT-2 Timing Belt and Pulley
  - Idler Pulley
  - Custom 3D printed interactive plate
  - Nema-17 Stepper Motor





Deliverables during Competition

Deliverables at Semifinals Stage



- Storage and Retrieval mechanism for light weight cargo
  - Simple Tray mechanism with pallets to support a wide variety of cargo

- Robust control for accelerated and coordinated motion for X and Y axis
  - Efficient traversal throughout the shelf

- Server and Communication interface with Database Management
  - Remote operation and access to inventory from user friendly Shelfy dashboard

Deliverables at Semifinals Stage

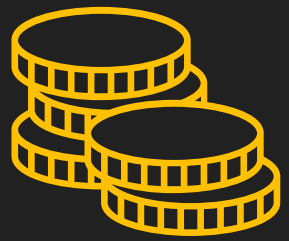
- Complete Prototype of Shelfy
  - Triple axis movement capabilities
  - Completely integrated shakti processor

- Business Model and Commercialization for Final product
  - For quick deployment of product on completion of development

- Inventory mapping and error prevention with barcode scanner
  - Real-time tracking for reduced storage and retrieval errors

Work in progress for finals

- Optimising the motor control algorithms and AI by rigorous testing
  - Increasing the efficiency and accuracy of motor algorithms
  - Implementing prominent AI based storing patterns

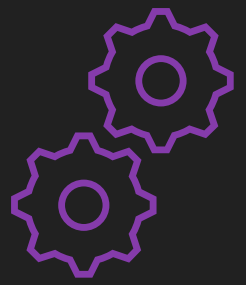


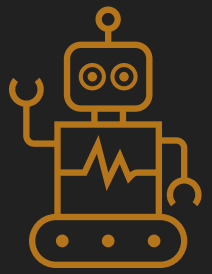
- Refining Business Model & Commercialization Plan
  - Incorporation of startup and laying down company road map
  - Detailed market survey and competitor cost comparisons

- Improved and optimized Shelfy Dashboard
  - Customization options and integration for automated orders.
  - Reduced latency and added user authorization features
  - Option for multiple shelfs

Deliverables at End of Finals

- True scale storage and retrieval system ready for deployment
  - Scalable and Modular, ready to be deployed in existing warehouses
  - High precision movement with payloads up to 50Kg

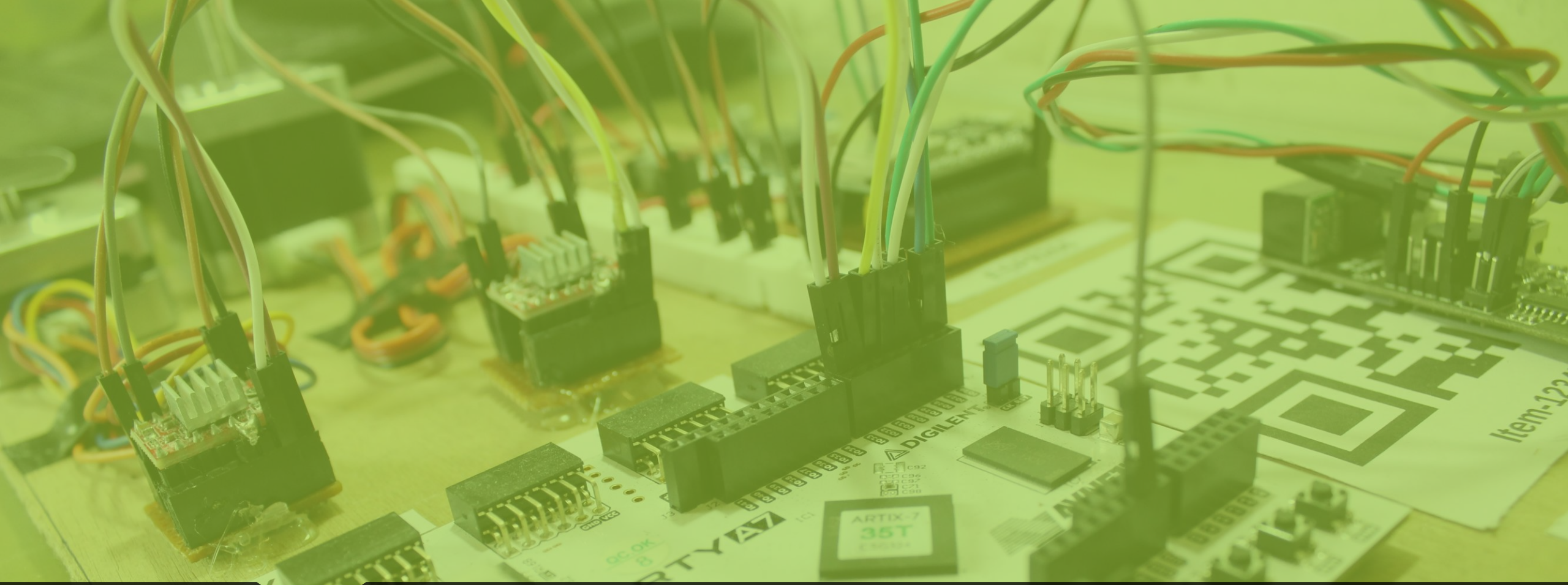




  - Integration with various autonomous robotic technologies
    - Collaborative robotics with wheeled robots, drones, autonomous conveyer belts and robotic arms
    - Offers a complete automated warehouse

- Automated data processing and AI based algorithms
  - Algorithms for perishability prevention, priority-based retrieval automated planogram and Inventory stocking

LIVE DEMO



Current Progress

Milestones Completed

Team has achieved and completed all the expected deliverables and developed a fully function prototype for Shelfy

- Fully functional mechanical prototype
  - A scalable dual axis mechanism based for traversing the entire shelf
  - Simple Tray mechanism to store and retrieve a wide variety of cargo

- A comprehensive business model and commercialization roadmap
  - Carried out a survey to analyze market potential
  - Analysis on production plan and go to market strategy

Milestones Completed

- Robust control algorithms
  - Coordinated and accelerated motion for efficient storage and retrieval
  - Optimized algorithms for inventory optimization and management

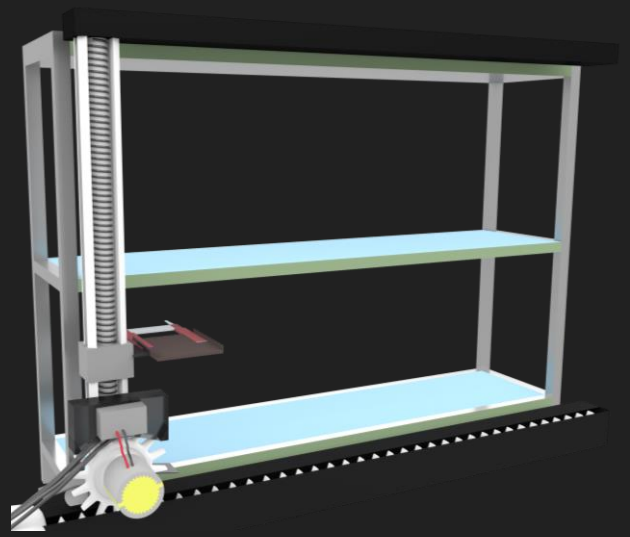
- Shelfy dashboard and database based on esp32
  - Remote control and fault detection for easy operability
  - Allows for easy inventory monitoring and tracking
  - Inventory database for management and tracking

- MH-ET Live QR code scanner
  - Inventory mapping
  - Eliminates chances of errors in storage and retrieval

Challenges Faced

- Initial esp8266 module was difficult to interface due to unavailability of libraries
- Due to unavailability of certain critical parts in India, mechanical components had to be 3D printed and redesigned after a performance review
- High torque stepper motors generate vibration and required a very secure and undisturbed platform for the mechanism to work perfectly
- Team split across 4 cities hence making complete integration a challenge

Deviation in Mechanical Design



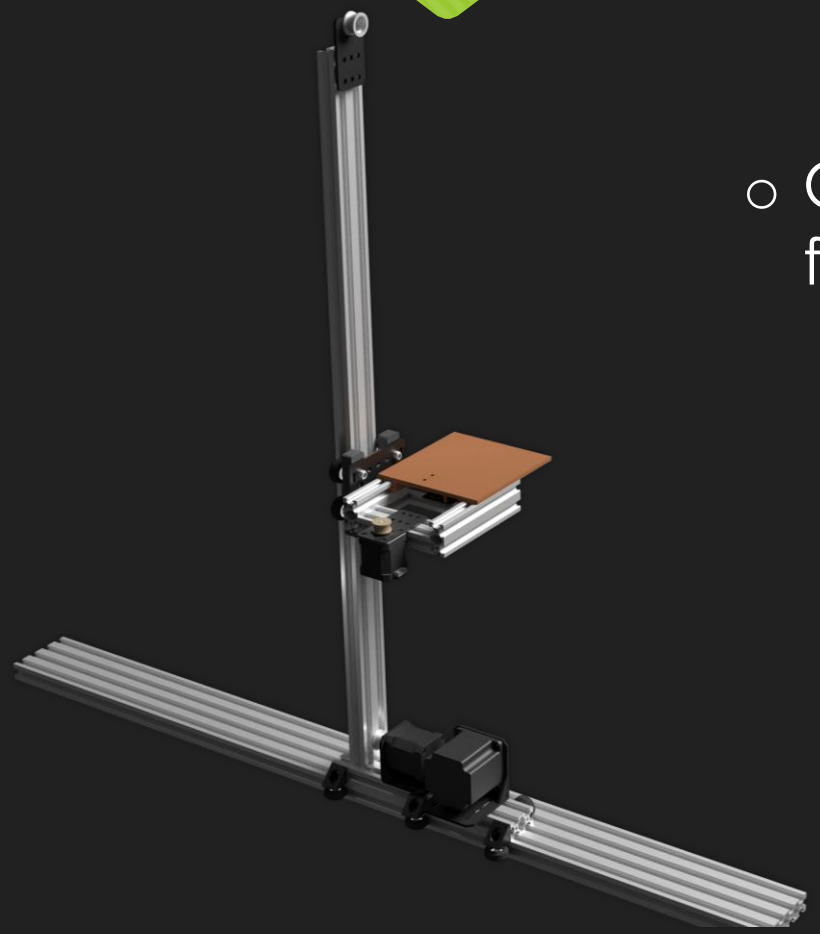
Shelfy 1.0: Initially proposed design

- Rack and pinion arrangement with a lead screw mechanism
  - Forklift like linear actuation for storage and retrieval
  - Complex and involved stabilizing mechanisms
  - Not scalable and greater wear and tear
  - High cost of development

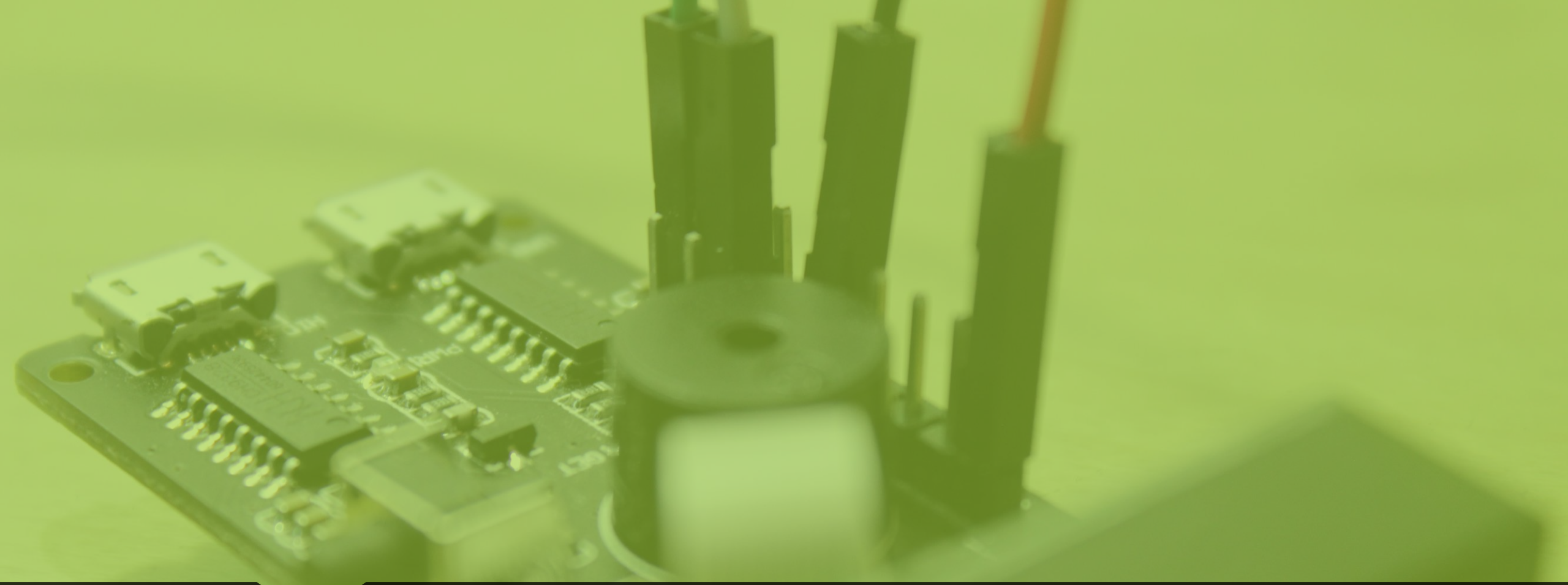
- V-Slot based design with belt drive actuation for both axis
  - Cheaper and easier to maintain while having scalable design
  - Uneven weight distribution induced toppling tendencies and sub-optimal motion
  - 3D printed L-bracket was unstable and caused Y-axis to tilt
  - Z-axis assembly would be hard to incorporate with this system

Shelfy 2.0 design at intermediate review

Shelfy 3.0 : Current Mechanical Design



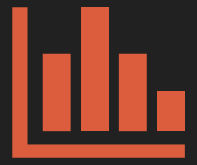
- Custom V-Slot gantry with retractable Z mechanism for compact form factor
  - Supported Y-axis for enhanced stability
  - Belt drive-based sliding tray mechanism for Z-axis actuation
  - Less dependency on 3D printed technologies
  - Optimized motor positioning and load bearing
  - Even weight distribution



Novelty And USP

Novelty of Shelfy

- Cost effective and Affordable
  - Indigenous Swadeshi processor
  - Standardized parts
  - Complete Installation Flexibility

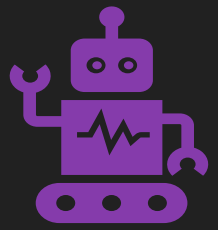


- Smart AI algorithms and Data analysis
  - Priority based storage and retrievals
  - Automated generation of storage maps
  - Automated Ordering

- Modular and Adaptable design compatible with existing solutions
  - No redesign required
  - Independent Operability

Novelty of Shelfy

- IoT capable and web interface
  - Simple GUI
  - Remote Access
  - Custom Routines



- Integration with companion robotic product
  - Complete Automation
  - Autonomous Ground Bots
  - Robotic Pick-n-Place Arms

- Targets Small Scale Indian warehouses
  - Unavailability of affordable solutions
  - Large market cap with high potential

Novelty Demonstrated at Semifinal Stage

Modular Design

Online database Software

Priority based Retrieval

Efficient Tracking using QR codes

Business Model

Market Survey

Production Plan

Go To Market Strategy

Business Viability

Business Model

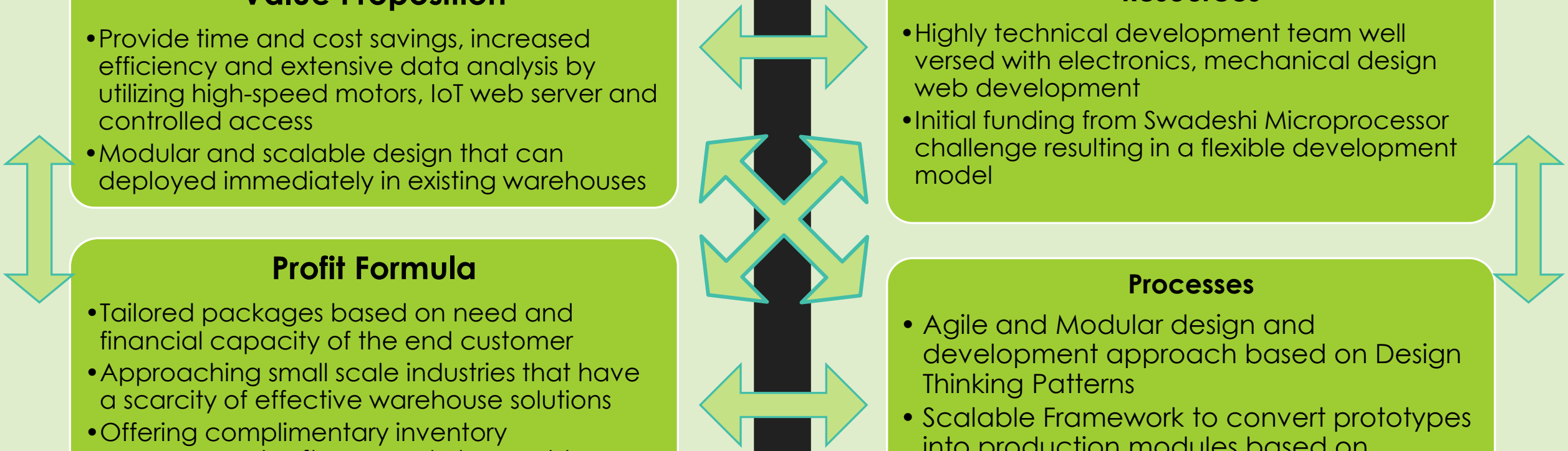
Priorities

Value Proposition

- Provide time and cost savings, increased efficiency and extensive data analysis by utilizing high-speed motors, IoT web server and controlled access
- Modular and scalable design that can deployed immediately in existing warehouses

Profit Formula

- Tailored packages based on need and financial capacity of the end customer
- Approaching small scale industries that have a scarcity of effective warehouse solutions
- Offering complimentary inventory management software and chargeable regular OTA after sales updates



Capabilities

Resources

- Highly technical development team well versed with electronics, mechanical design web development
- Initial funding from Swadeshi Microprocessor challenge resulting in a flexible development model

Processes

- Agile and Modular design and development approach based on Design Thinking Patterns
- Scalable Framework to convert prototypes into production modules based on customer requirements

Market survey

- 46 Participants
  - Warehousing service providers
  - Factory and Production Storage
  - Distribution Centers
  - 27 out 46 expressed need for an automation solution
- Main issues for not automating
  - High Initial Cost
  - Redesign of warehouse
  - Downtime for automation

Warehouse size : *50,000 square feet*
Problems faced : *Cutoff analysis inventory count*
Interested Features : *Faster Storage and Retrievals, health monitoring. Inventory Optimization and stock prediction*
Proposed Budget : *2 Crores*

~Rajnikant Surve,
VP Operation, Hikvision

Warehouse size : *20,000 square feet*
Problems faced : *Speed of picking*
Interested Features : *Faster Storage and Retrievals, Instant Inventory Updates, Optimized Storage*
Proposed Budget : *50 Lakhs*

~Sanjay Agrawal
Director SC Alstom Transport

Production Plan

In-house product development

- Robust, adaptable and scalable mechanical design capable of heavy payloads
- Full-Scale web server with smart algorithms and IoT management tools

Sourcing of components and Manufacturing

- Tie up with third party metal manufacturing and fabrication companies
- On site assembly of modular parts to match existing warehouse layout

Finished Product integration

- Integration with Shakti processor and webserver
- Control and AI algorithms adapted to customers' needs

After Sales Support

- Complementary Inventory Management software
- Nominal Charges for Regular OTA updates
- Inventory mapping for easy transition and implementation of shelfy

Go To Market Strategy

Potential Market	• Logistics companies like Mahindra Logistics, Gati etc. • Small to Medium scale warehouses – automobile service centers , grocery stores & small Indian websites with inventory of 100-200 items
Strategic Partnerships/ Channels	•Tie ups with Govt SME schemes for subsidized pricing •Collaborations with small scale manufactures to provide warehousing solution
Marketing & Distribution Channels	•Warehousing Expos and Exhibitions •B2B segment marketing via tenders, emails & calling •3rd Party Warehouse service providers •Direct B2B Sales
Promotional Offers	• Extended After Sales support with regular OTA updates • Installment payment options to provide relief for COVID-19 affected businesses

THANK YOU