# Smart Cart Proposal

Siddharth Kurwa
Mechanical Engineering
University of Texas at Austin
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**Background**

In the 1930s, a supermarket owner named Sylvan Goldman recognized a critical problem to his business: shoppers only purchased as much as they could carry. To overcome this, Goldman designed and implemented a cart to enable people to carry more products through his stores. While consumers were initially reluctant to use the cart in Goldman's Humpty Dumpty supermarket chain, the shopping cart now pervades across most stores and is intrinsically tied to our modern shopping experience (Dunne, 2014).

Between 1937 and today, there have been modest updates to the shopping cart to optimize the design and reflect improvements in materials and manufacturing techniques. For example, modern cart cages are largely made of plastic rather than the spot-welded steel, rear walls are hinged to enable efficient stacking and storage, and product storage capacity has increased to 15,000 cubic inches to ensure that volume availability does not limit quantity of purchases (Crockett, 2016). To date, these improvements have been largely focused on mechanical design modifications, unreflective of current technology trends.

Today's growing sensor solutions, rising storage and data capacities, and increased accessibility of powerful controllers have propelled growth in "intelligent" and connected devices like smart home systems, autonomous vehicles, and health-monitoring wearables (Ahmed, n.d.). These technologies can be applied to the shopping cart to further refine the in-store consumer journey.

To that end, modern retailers are actively working on deploying these technologies to drive consumer retention and growth. For instance, FiveElements Robotics developed a robotic shopping cart called Dash in 2016 to follow users around a store, carry products, and handle the payment process. However, after partnering with Walmart and scheduling production for early 2017, the product has not yet demonstrated the reliability to justify implementation at scale (Ackerman, 2016). Part of the reason is that there are still open areas of research like indoor localization that need refinement before commercialization (Zafari et. al., 2018).

That said, there is tremendous opportunity in working on this technology. The smart cart is a progression of the shopping cart to further address consumer's latent needs. Consumers should no longer fret about strolling their cart or scanning their groceries, liberating the shopping experience. Beyond the grocery store, the smart cart's underlying technologies have the potential to affect human-robot interactions in several other environments including warehouses, homes, and hotels.

**Concept and Project Scope**

I envision a fully fleshed-out smart cart to be a motorized vehicle that offers storage volume, navigates around store obstacles (obstacle avoidance and path planning), follows the user around the store (indoor localization and target tracking), seamlessly scans items placed into the cart, and provides a payment terminal on the cart itself.

For the scope of this course, I plan to build a system with primary emphasis on the design and prototyping of the motorized system, secondary emphasis on obstacle avoidance and navigation control, and tertiary emphasis on indoor localization and target tracking. At this stage, I do not plan to work on the item scanner and payment terminal tasks of the cart. Further, industrial design and aesthetic will not be a priority in this functional prototype.

I propose that the minimum deliverable at the end of this course is a mobile robot that can carry a specified payload and reasonably sense and avoid obstacles in its path. Further the robot should demonstrate design intent and robustness that will allow it to serve as a platform for subsequent research on tasks involving indoor localization, item scanning, and payment handling.

**Project Management**

This section will address how the project is being time-budgeted and appropriately scheduled to meet the minimum deliverable by the end of the semester.

Figure 1, below, depicts a high-level Gantt chart that roughly outlines the order in which tasks will be completed. As shown below, several weeks have been allocated towards testing and tuning. I anticipate that there are several issues and considerations that I will uncover as I dive into this project. To manage effectively manage those before the deliverable date, I have allotted several weeks to hashing out the details of the project.

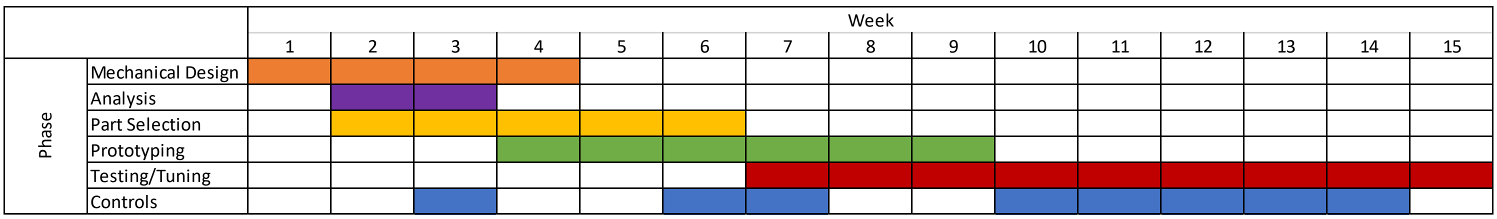


*Figure 1: Gantt chart.*

To break down the project into manageable chunks before the deliverable date, I have set several milestones that will ensure that the project is tracking to successful completion. Figure 2 describes these milestones and their intended completion dates.

| **Target Milestones** | |
|---|---|
| End of: | |
| Week 4 | CAD assembly completed. After this point, only tweaks and modifications should be necessary. |
| Week 6 | Electrical wiring/soldering/connectorizing should be complete. |
| Week 7 | Basic motor control functions should be complete and sensors should be individually function-checked. |
| Week 14 | Obstacle avoidance should be demonstrable and logical. |
| Week 15 | Prototype demonstration/presentation. |

*Figure 2: Milestone chart.*

To plan the low-level tasks that must be completed and the hours that I anticipate each task taking, I have assembled a list in Figure 3 with sporty estimates of time requirements. To account for probable aggressiveness in this timeline, I have multiplied my estimates by two to more conservatively estimate time requirements and provide buffer for surprise issues that may arise.

| High Level | Tasks | Time Allotment (hrs; no margin) | Time Allotment (hrs; conservative) | Fall 2018? | Status |
|---|---|---|---|---|---|
| Mechanical Design | Design storage compartment | 4 | 8 | Y | Not started |
| | Design wheel base | 7 | 14 | Y | Not started |
| | Design sensor mounting | 4 | 8 | Y | Not started |
| | Select/design power transmission mechanics | 8 | 16 | Y | Not started |
| | Design controls/power systems enclosure | 8 | 16 | Y | Not started |
| Analysis | Analyze payload capacity | 2 | 4 | Y | Not started |
| | Analyze electrical load requirements | 3 | 6 | Y | Not started |
| | Analyze mechanical power/torque distribution | 2 | 4 | Y | Not started |
| Part Selection | Select motors | 1 | 2 | Y | Not started |
| | Select electrical hardware (power supplies/circuit elements) | 5 | 10 | Y | Not started |
| | Select sensors for obstacle detection | 1 | 2 | Y | Not started |
| | Select sensors for target tracking | 5 | 10 | | Not started |
| Prototyping | Build storage compartment prototype | 5 | 10 | Y | Not started |
| | Build wheel base prototype | 3 | 6 | Y | Not started |
| | Build sensor mounting | 5 | 10 | Y | Not started |
| | Build controls/power systems enclosure | 5 | 10 | Y | Not started |
| | System integration and assembly | 8 | 16 | Y | Not started |
| Controls | Configure circuit with necessary elements | 2 | 4 | Y | Not started |
| | Check functionality of each sensor independently | 8 | 16 | Y | Not started |
| | Program basic motor control | 2 | 4 | Y | Not started |
| | Program obstacle avoidance decision tree | 16 | 32 | Y | Not started |
| | Program target tracking | 80 | 160 | | Not started |
| | Program simultaneous target tracking and obstacle avoidance with interrupt-based state machine architecture | 80 | 160 | | Not started |
| | Time Required (All Tasks) | 264 | 528 | | |
| | Time Required (Fall 2018 Tasks) | 99 | 198 | | |

*Figure 3: Low-level task list.*

**Material Requirements**

At this preliminary stage, it's difficult to project an exact Bill of Materials, but I have listed parts I am fairly certain that I will need in Figure 4. The calculations do not consider 3D printing or laser cutting costs which is assumed to be free through the Maker Studio.

At this time, I also do not have a dedicated space or funding for this project – something that I will focus on after review of this proposal.

| Part | Unit Price | Quantity | Price | Source | Purpose |
|---|---|---|---|---|---|
| Arduino Mega | $ 36.47 | 1 | $ 36.47 | Amazon | Controls |
| Ultrasonic sensor | $ 1.96 | 5 | $ 9.78 | Amazon | Controls |
| Plywood/acrylic sheet | $ 50.00 | All | $ 50.00 | Maker Studio | Electronics enclosure; basket |
| Wheel | $ 15.00 | 2 | $ 30.00 | Amazon | Wheel base |
| Spherical caster | $ 15.00 | 1 | $ 15.00 | Amazon | Wheel base |
| Encoder DC motor | $ 25.00 | 2 | $ 50.00 | Amazon | Power distribution; controls |
| 180 degree servomotor | $ 10.00 | 1 | $ 10.00 | Amazon | Controls |
| Wood studs | $ 50.00 | All | $ 50.00 | Home Depot | Mechanical frame |
| Wood screws | $ 12.00 | Pack | $ 12.00 | Amazon | Mechanical joining |
| Metric fasteners (M2.5/M3) | $ 17.00 | Pack | $ 17.00 | Amazon | Electronics mounting |
| | | Total: | $ 280.25 | | |

*Figure 4: Estimated parts list.*

**Proposed Credit**

The scope of this project will demand that I apply a skillset learned from several courses in my ME degree plan and beyond. From a mechanical standpoint, I expect to use Solidworks for CAD design which uses skills from ME 302, perform some static flexible load analysis which will use EM 319 Mechanics of Solids and ME 338 Machine Elements, and develop some gear reduction or power distribution method that draws from learning in ME 350R Robot Mechanism Design. Motor selection and electronic wiring will use skills from ME 340 Mechatronics and ME 340L. Sensor selection and motor control will involve skills from ME 344 Dynamic Systems and Controls and ME 144L. The obstacle avoidance and indoor localization tasks are largely out of the scope of coursework and will demand that I do some independent learning.

Because of the breadth of this project (design, analysis, prototyping, electronics, and software) and the depth in active research (obstacle avoidance and indoor localization), I believe that it warrants three credit hours as a ME 377K Projects in Mechanical Engineering course.

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