Product: ParkED
Team: Back Benchers

Abstract

The project revolves around the idea of improving the conventional bench in the parks, by making it capable of moving into a specific place or a predefined space, and it will also have extra features that will be useful to both the owners and its users. The main outcome of the product would be to get the bench from other places into a designated position specified by a user, which could be used to arrange multiple benches in a specific layout for a given position. The bench will also be equipped with sensors to help with navigation, for safety purposes and also for data collection. If the core features could be implemented successfully in the given time and budget, we would like to add some other useful functionality to the bench such as the capability of self-charging at nearby specialized charging dock or the bench could be equipped with charging ports so that the users could charge their electronic devices.

1. Pitch

"ParkED" is a bench robot product with an autonomous positioning and navigation system. The intention is to help improve employee well-being by reducing the time spent on moving the benches which is a boring and repetitive task. As shown by reports (Wilson"), musculoskeletal disorders and back injuries are extremely widespread in the people who handle heavy loads on a regular basis. Accidentally dropping the load could also result in damaged bench. Our product will prove to be a game changer for the employees as it let humans avoid the harmful work and let them focus their time and energy on more strategic and motivating tasks. Besides that, the park management staff is still able to stay involved in a way that is not as risky. The built-in settings provide a complete range of bench positioning options for the upcoming event whether it is festivals, concerts, sporting events or fairs. The benches could be equipped with commercial grade phone charging stations. As stated by a researcher (Robin), charging port has become one of the most important public amenities and it can effectively reduce outdoor stress. The benches may be equipped with solar panels that gather energy for its travelling and charging power consumption and which would allow them to produce less greenhouse gases and contribute less to global warming.

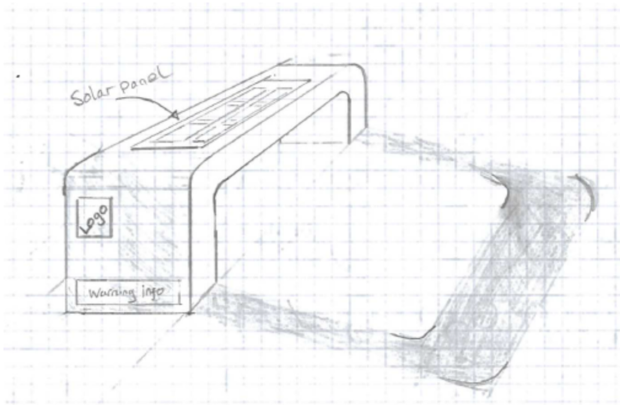

Figure 1. Figure showing a proposed form for the bench to take. The solar panel depicted is an optional addition and would not necessarily be in the final product.

2. The team

Abdul has prior experience with hobby electronics and full-stack web-development. He wishes to make himself useful in both the software and hardware parts of the project, and wants to play an integrating role between different sub-teams. Because of this, he might struggle with information-overload and keeping up with things happening across the sub-teams. However, he feels determined and ready to take-on the challenge. As the team leader, he aims at keeping the team morale high utilizing his positive-outlook and determination throughout the course of the project.

Muiz have a lot of experience with Lego EV3, but he would love to learn more about robotics hardware especially Arduino and Raspberry Pi. He have done a lot of programming using various programming language and frameworks and he is willing to learn different useful technology for the project to be successful. However, he specifically mentioned that he might be burned out if he works too much on the project which did not yield a lot of progress, at the early stages of development. Therefore he prefers following an evenly distributed plan and milestones to prevent burning out.

Jack comes from a background in hardware and software development, with an avid interest in engineering robots. With a practical mind and the programming experience to compliment, he will likely take great pride in working on the prototype. Jack also has done much technical drawing which may prove useful when it comes to the UI or Robot designs. While great with technical skills. Jack can often find communication and time management difficult (like keeping on topic). Fortunately though, when it comes to things he is passionate about, productivity spikes.

Suvi has previous experience mainly in software and web development. Despite the lack of previous experience in hardware they are very keen to learn more about it, and so would like to work on the hardware side of the project. They would also like to work on the application UI. They may struggle a bit with stress and time management, though having a clear project plan and timeline helps with both. They would like the work to be spread evenly throughout the semester, with some flexibility so people can work less on this project when they have a lot of work in other courses.

Rory is a programmer who responds well to practical, creative challenges. He is particularly interested in the navigation software of the system but he is a curious man who would find work on any part of the project engaging. He understands that the workload is enormous and is determined to work consistently across the whole semester in order to remain healthy. He recognises that this relies on communication and support throughout the team and will take care to promote and sustain this.

Emily has experience with algorithms and data structures, statistical analysis as well and some web development. As a result she would prefer to work on the software side of the project. She has an interest in ethical matters would enjoy researching the ethical implications of the project. She might struggle with stress over the course of the project. To avoid this she is going to work on time management and improving her team-work skills. She would like an even spread of work across the semester, with some contingency so that less work can be done when there is coursework out in other subjects.

Ziqian has experience with software engineering. He had his own projects, coded mostly in Java and Python and is glad to learn other programming skills. As a computer science student he finds himself overwhelmed most of the time and he will try to avoid by maintaining a healthy work-life balance. He would prefer an evenly spaced distribution of workload across the semester.

Youwei is a Computer Science and Electronics student, and has experience with both software and hardware. He has a number of personal projects both in software and hardware. For software project, he has Library management system(Java code), memory recycling and knapsack problem(Python code), Heuristics for the Travelling Salesman Problem(Python code). For hardware project, he has CPU simulation(Verilog code), branch prediction simulation(c++ code), MIPS Processor Simulator(c code). He will utilize his broad set of skills he has gained from his degree so far and will help the team with both software and hardware aspects of the project.

3. Users

3.1. Park Managers

Interaction Experience A core user of this system will either be an individual or a small team of park managers. Their primary use will be assigning the bench positions to gather around spaces for events or to meet increased demand. This system intends to relieve labour from these sorts of tasks and so it is important that this is very easy and quick to use.

Conflict Park managers/Event organisers are not necessarily technical jobs; a system requiring technical expertise would result in resistance from our core users and limit the extent to which our aims or labour relief are reached. The accessibility of this system is crucial.

3.2. Park/Event Goers

Parks are typically public spaces which cater to diverse communities. Parks are visited by all ages with a range of needs.

Interaction Experience The bench will be directly engaged with by park goers who sit on the bench. The bench should be comfortable and feel welcome and safe for all members of society.

Conflict There is a potential point of tension between our aims for Park Managers and Park Goers as a bench that moves really quickly, for example, would be efficient and allow for more events to be catered for but would make for a less safe or comfortable park experience. It is important to balance both of these in our system's design.

Park goers should feel sure that their loved ones/pets are not being put in danger by the benches. Work should be done to ensure that park goers feel safe in the presence of the system.

Benches are relied upon by many groups, for example, people with mobility issues, or that suffer from fatigue. A safe and comfortable park going experience may depend on their knowledge of a static bench's location on which they can rest. Replacing all benches in the park with ParkED benches would take away this certainty making for an experience which goes against our values. We should stress a balance between static and mobile benches in parks to ensure this doesn't happen.

One way we hope to improve the comfort of the park experience is collecting data on the popularity of certain bench positions by recording when and where a bench is sat on with weight sensors and passing that information to the Park Managers. This could inform future positions of benches. The collection of such data must be handled very sensitively as this might make park goers uncomfortable. Research into the ethical issues raised by this must be done to ensure that this feature is handled appropriately.

3.3. Maintenance Workers

The system will be maintained by people. We aim, first of all, to create a robust system that would not require frequent repairs in order to reduce the workload of our maintenance workers. Similarly, the tracks, being the only moving parts in the system, are likely to be the most prone to failure; to create an easier maintenance experience the tracks should be easily removable/replaceable.

3.4. Performers

It is likely that these benches will have an impact on the careers of street performers. This impact might be positive, attracting larger audiences and incomes. There is the possibility, however, that these benches negatively affect the industry creating a less obtainable barrier for entry. Any system that intervenes in an established career requires sensitivity and communication. Though the way the benches are used is in the hands of the park manager, it is important that we are aware of the implications that the technology might have on all stakeholders. For this reason, research, for example, interviews with street performers, is important.

4. Impact

4.1. Deployment of the system

We expect our customers to be park owners, such as city councils and private businesses. The benches will be sold to the customers as one-off products. We will also be providing maintenance and customer support; whether this will be included in the price of the bench or provided as a separate service is yet to be decided.

Optionally we could rely on advertising revenue to finance our business, in which case we could provide the benches for free or for a much smaller fee. Adverts would be shown on screens on the sides of the benches. However, more research is needed in order to determine whether this is a viable business model.

4.2. Social impact

While our customers are park owners, the end users of our product will be people visiting the parks, and they will also be the ones most affected by our system. The benches will affect the experience of all park goers: people who want to sit on a bench, people who are walking or cycling through a park, children running around and so on.

Positive impact In the best case scenario, our benches would make parks a more attractive place to visit, and people would spend more time in parks. Benches would be easy to find, and they would be located in the places where they are needed the most. This could also improve accessibility, providing seating for people with fatigue or mobility issues.

Negative impact There are also potential negative impacts that we need to consider. If our benches are not programmed well or something goes wrong, they could run into pedestrians, pets or children. This would also make people less inclined to spend time in parks, as people would likely feel unsafe or uncomfortable around these benches. Our system could also cause accessibility issues, especially if our benches are the only seating available in a park. People with certain conditions may need to be able to reliably find seating when they need it, and benches that move around might make that more difficult.

5. Outcomes

Although the project has been proposed as a system comprising of a set of benches, our primary goal is to construct only one bench initially, satisfying all of the outcomes mentioned in the following subsections. The constructed bench will be a sized-down version of the life-sized bench. All of the testing will be carried out indoors which means we might have to emulate some of the outdoor conditions.
The following subsections outline the outcomes which have been planned to be achieved iteratively. The outcomes marked as *optional* will be decided later in the course of the project based on available resources.

5.1. Mobile Bench

The bench should be able to move from one location to another utilizing the on-board hardware which includes but is not limited to motors, motor-drivers, controllers, and a computer. There will be a battery powering all these components.
ideally, the bench should be able to:

1. Drive forward and backwards.
2. Steer in a specified direction.

This partially fulfills the requirement of mobile benches, see more in section 5.4 and 5.5.

5.2. Application software to control the benches

There should be a software application intended for the primary user(3.1) that:

1. Provides an interface to the user.
2. Shows a map representation of the operable area of the system. The will reflect the current position of the benches and their occupancy status in real time.
3. The user should be able to send commands to the bench to make it move in the specified direction. This will replicate the behavior of a *remote-controlled* vehicle. This fulfills the requirements of mobile benches.
4. When the autonomous navigation (section 5.5) is implemented, the user should be able to select the point on the map they wish to send a particular bench to, and the bench should start navigating to the given destination.

This software should be user-friendly to a level where our identified primary user in *section 3.1* can use it with no more than **2 hours** training. The software will ideally be in the form of a web-app which seems ideal for our primary user who will likely use it on a desktop in their office. A web-app offers cross-device compatibility which increases its usability.

5.3. Energy requirements and the charging mechanism

Our goal is to make the system as environmentally-friendly as possible. The first priority would be to charge the bench's on-board battery by adding solar panels to the bench. However, we need to draw on existing research done(Dewi et al., 2020) in this area.
Regardless of that, there will have to be charging stations/points around the navigable space. An autonomous docking system is also part of the goals which utilizes the autonomous navigation capability of the benches to connect them with the power supply when they are in the right area. In order to achieve this, we have to draw on the research done(Cassinis et al.) in this area. At the moment, we are considering getting electrical outlets from lamp-posts in the park.
This maximises the utility of the system for the primary user who does not have to invest physical labour into recharging the battery of the bench(es).

5.4. Safety features

The bench should be equipped with sensors capable of detecting stationary and non-stationary obstacles (including pedestrians and pets) - regardless of whether they have been mapped into the system - in its nearby surrounding. When it encounters an obstacle, it should modify its trajectory and travel around the detected obstacle. An example of such a sensor would be ultra-sonic sensor(Burnett).
If the bench engages its safety mechanism and plans an alternate route when an object of certain minimum height is within certain minimum detection radius from the bench, the outcome will be considered satisfied.
The bench should also be equipped with lights which changes colour when the bench is moving. This would enable pedestrians to notice it from a distance - especially at night. It should also be equipped with small speaker that would *beep* when the bench is in motion to cater to people with disabilities.
Such features are meant to prevent any negative impacts on - and maximise the positive experience of - the indirect users of the system (3.2, 3.4).
A productionised version of the bench would have to be weather-proof, so we will research how this might be achieved.
Lastly, the system has to prevent unauthorised access. One of the scenarios where unauthorized access can be catastrophic is when a hacker overrides the safety features on the benches make them crash into pedestrians or other vehicles. Therefore, a clear security policy and thorough analysis of system security is required before prototype is pitched to the investors.

5.5. Autonomous navigation

The bench should be capable of autonomous navigation. To make a decision about a particular stack of technology for autonomous navigation, further research has to be carried out. Popular approaches used these days include SLAM using set of cameras or 360 Lidar(Balasuriya et al., 2016), GPS positioning with sensors to avoid obstacles(Moeller, Spring 2020), or combination of Lidar- or camera-based SLAM and GPS(Deng et al., 2018).
However, since the system prototype will be demonstrated indoors, which makes using GPS in the prototype unfeasible. If our research indicates GPS as a viable option for a life-scale model, then the prototype will use an overhead video feed publishing x,y coordinates of the robot thus emulating a GPS system.
When fully implemented, the robot should be able to navigate from position A to B on a nearly optimal path without human intervention while avoiding all mapped and non-mapped obstacles. As long as the bench ends up *reasonably close, ideally the distance equal to 1.5 x width of the bench,* to point B, this outcome will be considered satisfied.

5.6. Bench usage statistics

We have established that the system will be aware of the occupancy status of a bench for safety reasons, as it would be bad if the bench moved while occupied. The system should also store this data. This should help the administrator to send the bench to area with higher demand, and at the same time identifying which particular benches to be moved thus having the positive impact on the experience of secondary users of the system (sections 3.2, 3.4). Optionally, the system can make such recommendations utilizing the stored data making the job of primary user easier.

5.7. Security and Protection from vandalism

The bench requires to be lightweight in order to be energy-efficient. However, this makes it less prone to theft and vandalism. Therefore, the system should be able to send a critical alert to the system administrator in situations which include but is not limited to:

1. The bench being displaced when its supposed to stay stationary.
2. The bench is toppled-over.
3. Excessive amount of pressure has been applied to the bench.
4. The bench leaves the Geo-fence of the system's operable area

There should also be a recovery mechanism which would help the bench localise itself again after corrective measures have been taken
We are also considering making use of speakers to sound an

alarm when the bench is being vandalised. However, some research into the ethical implications of this is required.

5.8. (optional) Improved accuracy and precision in autonomous navigation

Building further on section 5.5, we aim to make the system precise and accurate enough to be used reliably for benches to be able to navigate through tight spaces, operate in all weather conditions, and work under dense tree canopies. This outcome will be considered satisfied when is the bench is moving from position A to B and stops within 0.1 x width of the bench distance from B.

5.9. (optional) Other value-added features

We expect the system to be highly expensive to the potential customers compared to a set of ordinary public benches. In order to make the project cost effective, we expect to have digital screens or canvas-based advertisement boards somewhere on the bench. This will enable the system owner to have a substantial revenue stream, and will help them in recovering the initial investment relatively quickly. However, the decision between the two proposed approaches relies on further research on how energy-efficient the system is and how environmentally-friendly its power sources can be.
The benches can also be equipped with sensors that would collect data on the environment at a micro-level and the system can store this data to be used by local-councils and the MET department.
If the system proves to be energy efficient and capable of producing renewable energy, this opens the room for utilization for electricity generated beyond the requirement. The bench in such case can be equipped with charging ports which the users can utilize to charge their electronic devices. This will aid in making the experience of park-goers better, and can attract additional population segments into the park who wish to work on their devices from there.

6. Tasks

Below we have outlined the main project areas and subsystems. These tasks are summarised in a gantt chart (3) which includes expected timescales and effort for each section. We aim to have all tasks finished with 1-2 weeks to spare as a contingency in case things take longer than expected.

6.1. Project Management.

This task group lists the nontechnical tasks involved in the project. This area requires organisation, researching, writing and marketing skills.

1. Schedule the project and iteratively tune the schedule as we go.
2. Research marketing and commercialisation of the bench.
3. Research the Ethical Implications of the robot.

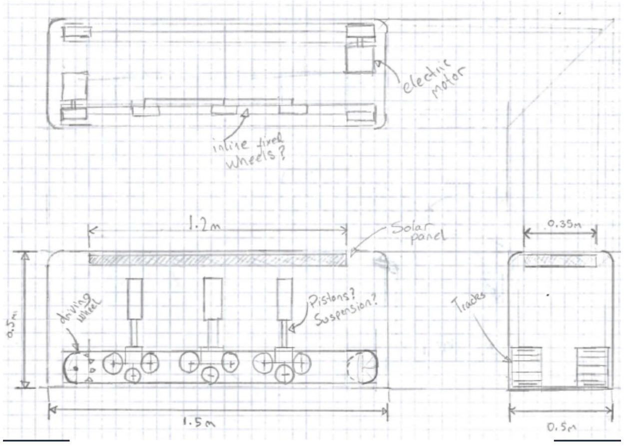

Figure 2. Figure showing the tracks' mechanism and how it fits in with the broader bench design.

4. Write project reports and give project demos.
5. Present the project on industry day.
6. Budget the Project. This is heavily dependent on the research and design of the bench (tasks 6.2, 6.3, 6.6).

6.2. Bench Building.

This area involves all aspect of physically building our model bench. It is very hardware centered. It is also dependent on obtaining the physical parts we need.

1. Build the basic bench structure. This will be a scale model for practical reasons such as testing in the lab.
2. Research the necessary safety features (lights, alarm, weight sensors).
3. Add the safety features to the structure.
4. Research the necessary security measures (accelerometer, gps-based alarm).
5. Add the security features to the bench.
6. Research and report weatherproofing measures.

6.3. Bench Motion.

This area involves controlling the motion of the bench. This will require hardware skills, technical robotics skills, research as well as some software implementation.

1. Enable the bench to perform simple motion.
2. Research collision detection and navigation methods.
3. Add the needed navigational sensors to the bench (gps, accelerometer, Lidar).
4. Implement basic navigation with collision avoidance.

5. Combine localised collision avoidance with larger routes planned by system.
6. Test the bench's navigating along a route.

6.4. Central Path-Finding System

This area involves identifying the ideal path a bench should take between two points through the park. This path will then be given to the bench which will try to traverse it, while avoiding unexpected obstacles as explained in 6.3. This will require algorithmic research and software skills.

1. Research how best to create and store a map of park and valid paths.
2. Implement the map creation.
3. Research algorithms for path-finding.
4. Implement a chosen algorithm for path-finding.
5. Test finding paths between coordinates.

6.5. Application.

This subsystem enables users to easily access the functionality of the system, combining all the features together. It will also involve enabling the front-end and back-end to communicate. This will require software skills, likely to include app or web development.

1. Create the user interface of the application for bench owners.
2. Integrate the user interface with the wider bench system. This is dependent on the central system being built and on being able to communicate with the benches (tasks 6.4, and 6.3), but can be built somewhat in tandem.

6.6. Bench power.

This area identifies how the bench will be powered. It will require lots of research and analytical skills. It is dependent on the design of the bench and the components used.

1. Determine how much power will be required. This task is dependent on the mechanisms of motion being determined as these will influence how much power is needed (task 6.2 and 6.3).
2. Research the best way to supply the power.
3. Integrate power generation/charging facilities in the robot.

Work Distribution and Mechanisms:

The team agreed to use MS-Teams as our method of communication. We will have channels for each area and subsystem as needed. We also plan to use GitHub as our code repository.

Areas have been assigned to team members as explained below, in accordance with their interests and skills outlined in section 2. We want to balance using our existing skills for efficiency with developing new skills in areas of interest.

Bench building: Youwei, Abdul, Suvi, Jack

Bench Motion: Rory, Abdul, Jack, Suvi, Youwei

Central Path-Finding System: Rory, Emily, Abdul, Ziqian

Software Application: Emily, Ziqian, Suvi, Muiz

Bench Power: Jack, Abdul

Project Management: Whole Team

Milestones for Demo Days:

The gantt chart (see fig.3) gives an indication of what tasks we would like to complete by each demo day.

Milestone 1: We hope to have a basic bench structure which is capable of basic motion by demo 1. We also would like to have a mock up of the user interface. By then we would also like to have a method for storing a map of the park in our system. We will have begun research on path-finding algorithms, navigation and safety features.

Milestone 2: We aim to have completed thorough ethical research and market research for the project by demo day 2. We would like the bench structure to include safety features and navigation sensors. We hope that the bench will be able to detect and avoid collisions while moving. We hope to have implemented a path-finding algorithm to determine how a bench should travel through the park. By this point we will also have a better understanding of how much power the bench will require so we can start researching methods of powering the robot.

Milestone 3: By the final demo day we want our scale model robot to be equipped with safety and security measures. We will have researched relevant waterproofing. The bench will be able to navigate along paths given to it by the central system while avoiding collisions. All of this functionality will be integrated with the Application and User Interface. We will have a concrete plan and implementation of how the bench will be powered.

7. Risks

7.1. Limited experience in Autonomous Navigation.

The team lacks experience with the proposed technology stacks for autonomous navigation (see section 5.5), and our plan is mostly based on our initial research on the subject. Figuring out how to navigate may prove costly in terms of time and money. However, the abundance of research papers on the subject suggest that the realization of the proposed outcome is achievable.
As a contingency plan, we can rely on the manual control of the benches by the system-operator. This will still

achieve the goal of eliminating any physical human labour to displace the benches.

7.2. Bench disrupting park use.

Considering the width of an average walkway in a public space, the proposed accuracy might result in the bench stop in the middle of the walkway when its supposed to stop just outside it. This is likely to cause inconvenience to the pedestrians.
If we fail to achieve the proposed outcome in section 5.8, we have to rely on some technique to highlight no-stop areas for the bench. This might mean more labour hours will be required during the initial mapping of the navigable space.

7.3. Proposed docking mechanism fails to be implemented

We understand that it is essential for the automated docking mechanism for charging (section 5.3) to work flawlessly in the system to fully eliminate the needs of human labour except the primary system operator (3.1). However, we also expect it to be the hardest core outcome to achieve as it highly depends on the realization of the optional outcome of increased accuracy in navigation(section 5.8).
In order to prevent this from happening the decision of choosing the technology stack for autonomous navigation is highly crucial, and thus we have allocated a week to carry out the proper research for this (see 3). As a contingency plan, we also hope to continue the development of the system even if the risk is realized; however, this requires human labour to plug the benches in once they are near their charging stations.

7.4. Identifying and scheduling charging of all benches

There is a risk that the bench will stop at somewhere when it runs out of battery if it is too far from an available charging station. This may cause the bench become a barrier that block people's road and the bench will not be able to provide services to user without enough electricity.

The way to reduce impact is if the bench moves to the nearest charge station well before running out of battery. Alternatively all benches could be scheduled to charge at times to ensure they're not using a station a different bench needs.

As a contingency, benches could send a help signal and location information to the park manager. Manager will find the bench and help it charge once they receive the help signal.

7.5. Blind-spots when navigating

There are some transparent items that LiDAR can not detect such as resident's windows. Bench will collide with resident's windows and this will cause property damage.The way to reduce impact could be to install ultrasonic sensors on bench so that bench can detect transparent items.

7.6. Team Conflicts

Over the course of the project there might be some disagreements between the team. Ideally they will be short-lived and resolved either democratically or through mutual understanding. However, we can not ignore the possibility of such conflicts halting the progress on the project as several tasks require a set of other tasks to be completed first (see fig.3).
The mitigation strategy we have to adapt from the beginning would be to be exercise patience and practice being good listeners at an individual level. At the team level we have to stay a bit flexible and leave some room for changes down the line.

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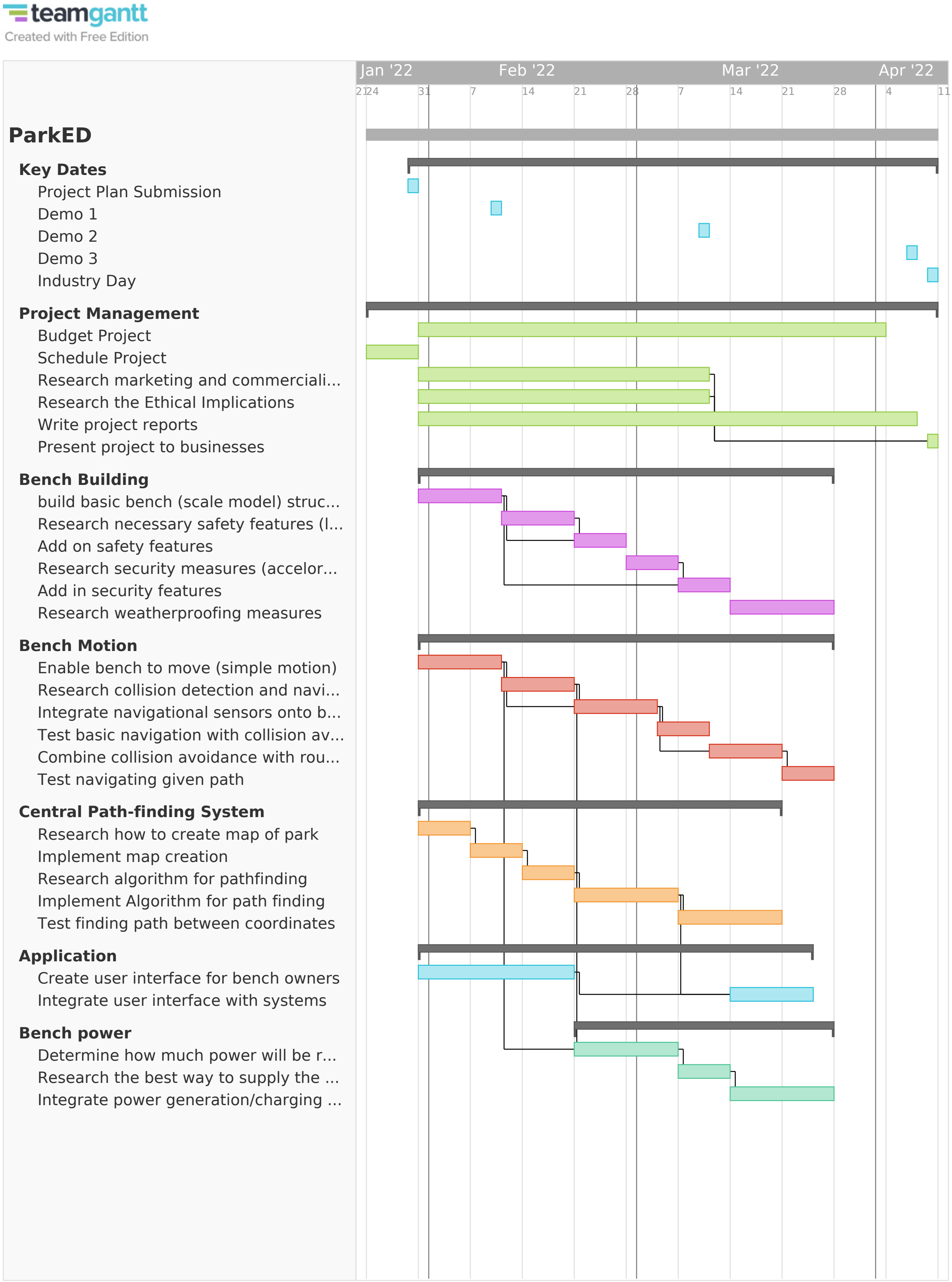

Figure 3. Gantt chart giving time estimates for each task. Shows dependencies between tasks.