Product: ClYDe

Team: Cloud 9

Abstract

ClYDe is a system that sanitises desk tops and other flat surfaces in high-traffic spaces, like libraries and offices. A successful project will include several milestones. The first is designing a tool capable of dispensing an alcohol-based disinfectant and wiping the flat surfaces. Next we must construct a robot capable of reaching several different desk heights, while maintaining enough reach to cover a desk top. Another milestone is the robot mapping out indoor spaces, performing efficient route planning and navigating to assigned desks. The robot needs arm movement in order to perform the cleaning operation and obstacle avoidance to reach its destination without collision, as well as placing itself close enough to the desk to ensure it can be cleaned properly. We will use image processing to determine if a desk is able to be cleaned, and if not mark it as such. Additionally the system will communicate with a companion app that can display information and issue commands.

1. Goal description

The problem that our group found is that public spaces with frequently used desks can be a health risk and need to be frequently sanitised, especially during a pandemic. The solution we provide is that we will design a robot that drives around an indoor space, sanitising desktops.

1.1. Relevance of the system

In the current Covid-19 pandemic situation, sanitation in public places is more important than ever. It has also highlighted the fact that critical and highly congested spaces, like libraries, can pose a serious health risk. Nevertheless, these spaces are highly valuable for people. Taking the example of a library, visitors often take their belongings with them when they leave a desk, but not wipe down the surface. Our project, ClYDe, serves as a table cleaning robot which will create safer public spaces due to the less exposure for cleaners and visitors. With a robot doing the monotonous and repetitive task of cleaning hundreds of desks, cleaners will be freed up to do more demanding tasks. Although the robot will be designed with the intention that this robot is not only meant to be used during the COVID 19 pandemic. It will bring health benefits in reducing disease spread in general, which can be beneficial for those with pre-existing conditions susceptible to different diseases, a fact that has been highlighted extensively in the past year. Outside a pandemic situation, it can also help prevent the spread during flu season every year. Additionally, the grim fact is that pandemics are likely to become more common, as more diseases are expected to make the leaps from animals to humans.(Gill, 2020) Everyone has been affected by the pandemic, and any tools to help deal with future ones will be valuable.

Apart from the health benefits, this robot will bring financial benefits as well. The global cleaning robot market size is projected to reach $6.2 billion by the end of 2025, as per the report released by Million Insights, Inc, but this number was only $2.5 billion in 2018(mil, 2020). which indicates that there is a huge potential in the market. According to the Spending Review 2020 (SR20) released by the British government, the authorities have spent almost 38 billion pounds on funding for public services, and far more in total, in 2020-21 to help tackle the pandemic(Treasury, 2020). Additionally, a certain amount of money will be saved with the help of the cleaning robot. Even in the normal time, libraries and some other public spaces have spent large amounts of money on cleaning. The average base salary for a cleaner is £9.19 per hour in the United Kingdom(indeed, 2021). Taking eight hours in a day and five days in a week as an example, the cost for a single cleaner will be £19,115.2. ClYDe can help reduce this, funnelling more money into making public spaces better.

A mobile desk-sanitising robot is also an innovative solution. After some investigation on the Internet, most cleaning robots are limited to the household floor cleaning type, including vacuuming, sweeping and mopping. An example of this is the Roomba, manufactured by the iRobot Corporation(Ackerman, 2015).According to Million Insights the current cleaning robot type most institutions are developing robots that can clean one of the following: floors, pools, windows and lawns, with few focusing on other areas(mil, 2020). This means that there are not many projects that perform table cleaning. This means ClYDe should be able to establish itself in the market.

More detailed descriptions of the robot functionality are included in the following section.

1.2. High-level description

System functionality

The actual robot is fundamentally split into three groups of functionality: space movement, vision and sanitising. The robot will have a solid base capable of movement and ensuring balance, a long arm with a sanitising tool, and a camera placed high to be able to detect when a desk is cluttered and the QR codes that will be on each desk. The system will include an internal floor plan where desks are marked, and will navigate between them to sanitise them one by one. Sanitising will be done by the robot positioning itself close to the desk, and reach up with its long arm. Computer vision will be used to determine the size and shape of the desktop, and the robot will move its arm over the surface. Meanwhile the cleaning implement will make sure sanitiser is dispensed and wiped off. A pathfinding algorithm will be employed to find a good route. Along the way it will avoid obstacles using its sensors, for example LIDAR. A user will be able to interface with the robot through a mobile app, capable of displaying information about the route of the robot, marking a desk for cleaning, and sending commands. When its battery is low, the robot will return to a specified location.

Primary Use Case: Robot moving to and sanitising a desk
Actors: User, Clyde (our robot)
Triggers: User uses the app to request cleaning
Preconditions: User can log into the app
Risk: Robot gets stuck on the way. (see 2.4.5)

Main success scenario: Robot(Base with arm) moves towards specified desk. Identifies desks using QR codes placed on each one. Look at desktop and decide whether it is able to clean it, i.e if it has obstructions. Sanitize desk with disinfectant. Mark desk as cleaned and move on.

Alternative: Desk is cluttered. If obstructions are found on desk, move on to another desk marked for cleaning and send message to the app that there is something left on the desk which shouldn't be there.
Failure: Robot gets stuck, and the task will time out and the robot will try to move to another desk.

2. Task planning

2.1. Milestones

Basic functionality
This milestone represents progress into the basic functionality of the system. This includes having first drafts of the robot design, sanitation tool design and basic movement controls. While not completely quantifiable, this milestone provides a baseline for the rest. This should be completed by demo 1, on the 3rd of February.

Navigating to a desk
The system should be able to navigate from its starting position to an assigned desk, while avoiding obstacles along the way. To test this we would place the robot some distance away from the desk it seeks to clean, and place several physical obstacles along the way. Some obstacles could also be moving. The robot should be able to navigate this environment without getting stuck or bumping into obstacles. Physical and simulated tests for this would be very similar. We expect to have this finished by demo 2, on the 3rd of March.

Environment representation and pathfinding
The robot should have an internal software representation of its environment, including desks it needs to visit and how far they are from each other. The map could also represent permanent obstacles like walls or other features the robot cannot pass through. It should be able to plan out a route to visit all the desks it needs, and return to its starting location. Visited desks should be marked as clean. We expect to have this finished by demo 2, on the 3rd of March.

Image Processing
The robot will use a camera in order to detect a QR code on the desk it will clean as well as to try and detect any obstructions on the desk such as laptops or books. This image processing can be developed completely independently from other milestones as the camera input can easily be created for testing purposes. The QR code of the desk will relay information to the robot such as the ID of the desk as well as it's dimensions in order to allow the robot to verify it is in the correct location. This QR code may also be used by the robot to position itself appropriately in front of the desk. Testing should be straight forward, as images of desks can be fed to the image algorithm to see if it can detect obstructions and QR codes. Through this testing we can calculate the accuracy of the algorithm and decide whether it is acceptable. The image processing should be completed by demo 2, on the 3rd of March. Once the image processing has been completed, it can easily be plugged into the robot as the output will be simple information (list of information from the QR code and a Boolean value representing whether an obstruction has been found).

Disinfecting Desk
The system should be able to disinfect a desk that is within our size constraints. This means that the robot arm should be able to apply enough disinfectant to cover the desk surface, while keeping the rest of the robot balanced. In a physical test, the robot arm would be held at the height of the base next to a desk marked with a QR code, and we would assess how much of the surface it is able to cover, and that appropriate amounts of disinfectant are dispensed. A simulator test would be similar, to the extent that the simulation software can handle 'fluid'. The robot should also mark a cluttered desk as so. This is a complex operation, and we expect to have it completed by demo 3, on the 17th of March.

Working phone application
Here, the robot will be able to communicate information with the phone application, such as planned route, messy desks, and what desks have been cleaned. The application should be able to display the information in a useful way to the user. This can be tested in several ways, depending on how sophisticated the simulation software is. If true communication is not possible, one could first confirm that the robot's software is sending the correct messages to the correct places. Then a faked message could be sent to the app to see that it handles incoming data correctly. This method could be flipped to test the communication the other way. We expect this to be completed by demo 3, on the 17th of March.

Fully functional robot
This is the system when it is completed, in essence putting

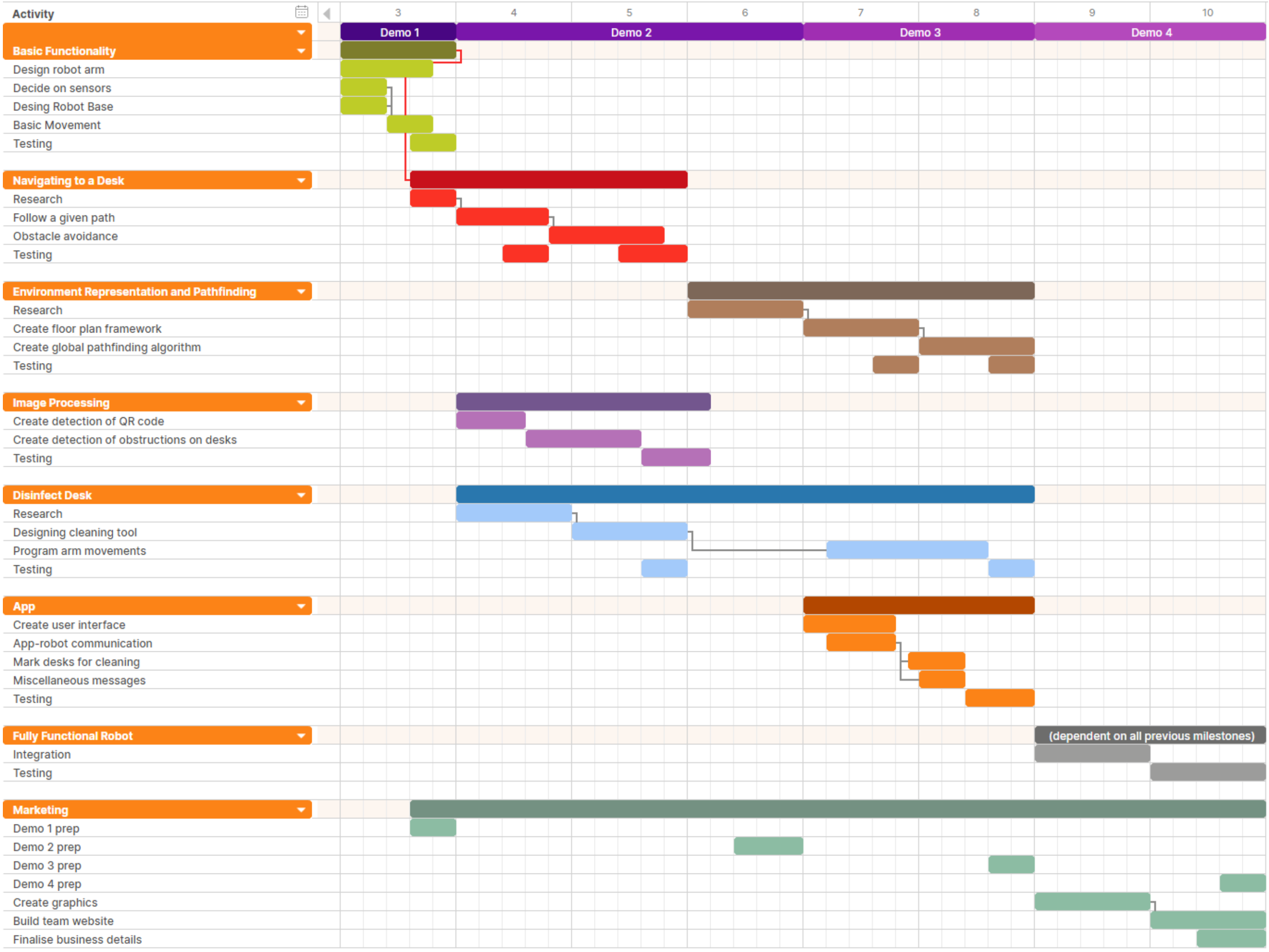

Figure 1. Gantt chart visualising how and when each milestone will be completed

together all the previous milestones. The robot should be able to navigate and orient itself in a space with several desks, and clean the ones it has been assigned. Additionally the robot should have a floor plan, a pathfinding algorithm and be able to communicate information to the phone app. This will ideally be tested in the Main Library with a physical test, as reproducing the conditions there in a simulation will be difficult. We expect to have this completed by demo 4 on the 31st of March.

2.2. Task decomposition

We decided upon 7 milestones for this project. These milestones have been decomposed into sub-tasks, as seen in table 1, which provides a brief description of each sub-task and an estimated time to complete them. These include preparation for writing and delivering our demos. See figure 1 for a Gantt chart showing these sub-tasks' allotted time.

2.3. Resource distribution

2.3.1 Team:

In order to complete the project efficiently, we have divided into several sub-teams; according to each person's strengths, different roles are assigned. In the first week of the project we shared everyone's strengths and weaknesses, main skills, and relevant experience. The team realises that the success of the project requires the joint efforts of each sub-team: Hardware, Software, Marketing and Web page design. As indicated in the reference document, each team member should spend 200 hours on this course. The pie chart (figure 2) indicates the distribution of these 200 hours.

2.3.2 Skills:

At our group meeting we identified that most of us had varying levels of robotics experience, and all of the group members were capable of working on the programming tasks. In addition, we all have experience with software engineering.

Ryan has identified that he has experience in graphic design and public speaking, which is very useful for our project. He designed and presented our first project pitch successfully. Lars and Ryan both have experience with

Table 1. Task decomposition for the system

Milestone	Task	Estimated Time (days)	Dependency	Description
Basic Functionality	Design robot base	2		Basic design of robot base, made in simulation, keeping in mind available hardware.
	Design robot arm	4		Basic design of the robot arm that performs sanitising, making sure it keeps the robot balanced.
	Basic Movement	2	Design robot base, sensors	Ensuring movement control and range of motion is adequate.
	Decide on sensors	2		Decide sensors needed for future tasks, like obstacle avoidance and image processing.
	Testing	2	All in milestone	Ensure the results of each individual task integrate together, like that the arm is balanced when the robot moves.
Navigating to a Desk	Research	2		We need to do research to find the best suited way to control the robot.
	Follow a given path	4	Research	The ability for the robot to move along a given path found by the global algorithm without failure.
	Obstacle avoidance	5	Follow a given path	The functionality where the robot can attempt to drive around a small obstacle which is blocking the given path.
	Testing	5	All in milestone	Ensure previous tasks integrate, like that robot can navigate between two points while avoiding obstacles.
Environment representation and pathfinding	Research	5		We need to research and decide what the best method is to create the floor plan and how to store it.
	Create floor plan framework	5	Research	The framework for storing the floor plan needs to be created.
	Create global pathfinding algorithm	5	Create floor plan framework.	The pathfinding algorithm will use the floor plan to deliver the robot to its objective.
	Testing	5	All in milestone	Ensure the robot successfully navigates the floor plan.
Image processing	Create detection of QR code	3		The camera must be able to detect the QR code on the target desk from above in order to properly orient the robot.
	Create detection of obstructions on desks	5		The camera must scan the desk and find any obstructions to see if the desk should be cleaned.
	Testing	3	All in the milestone	Ensure the robot avoids any tables with obstructions on it.
Disinfecting Desk	Research	5		Research must be done to find information that may help in designing the method that we will use to disinfect the desks.
	Designing cleaning tool	5	Research	We need to design a tool to be placed on the robots end effector that can dispense appropriate amounts of alcohol-based disinfectant and also wipe it off.
	Program arm movements	7	Designing cleaning tool	Successfully move the robot's end effector to clean the desk.
	Testing	2		Ensure the robot arm is capable of carrying out the motions to properly disinfect the desk.
App	Create User interface	4		An efficient and good looking UI must be created for users to utilise to mark what desks should be cleaned.
	App-robot communication	2		Make sure the robot and the app can communicate effectively. Decide on means of communication (Wi-Fi, Bluetooth etc.)
	Mark desks for cleaning	3	App-robot communication	The app can inform the robot which desks are queued to be cleaned
	Miscellaneous messages	2	App-robot communication	Implement other messages such as the robot indicating it's low battery or telling the robot to go back home.
	Testing	3	All in milestone	Ensure the app can perform all functionality above. e.x.successfully sending a message to user.
Fully functional robot	Integration	5		Integration of all the milestones to create the fully-featured robot.
	Testing	5	All in milestone	Rigorous testing to ensure the robot works as intended.
Marketing	Demo Prep	9		We need to prepare for each demo so we can demonstrate the state of the project at each demo.
	Create Graphics	5		Attractive graph as an aid to describe the robot and ensure aesthetics.
	Build Team Website	5	Create graphics	A website with graphics videos and explanations of our project.
	Finalise business details	3		Consolidate the entire marketing section.

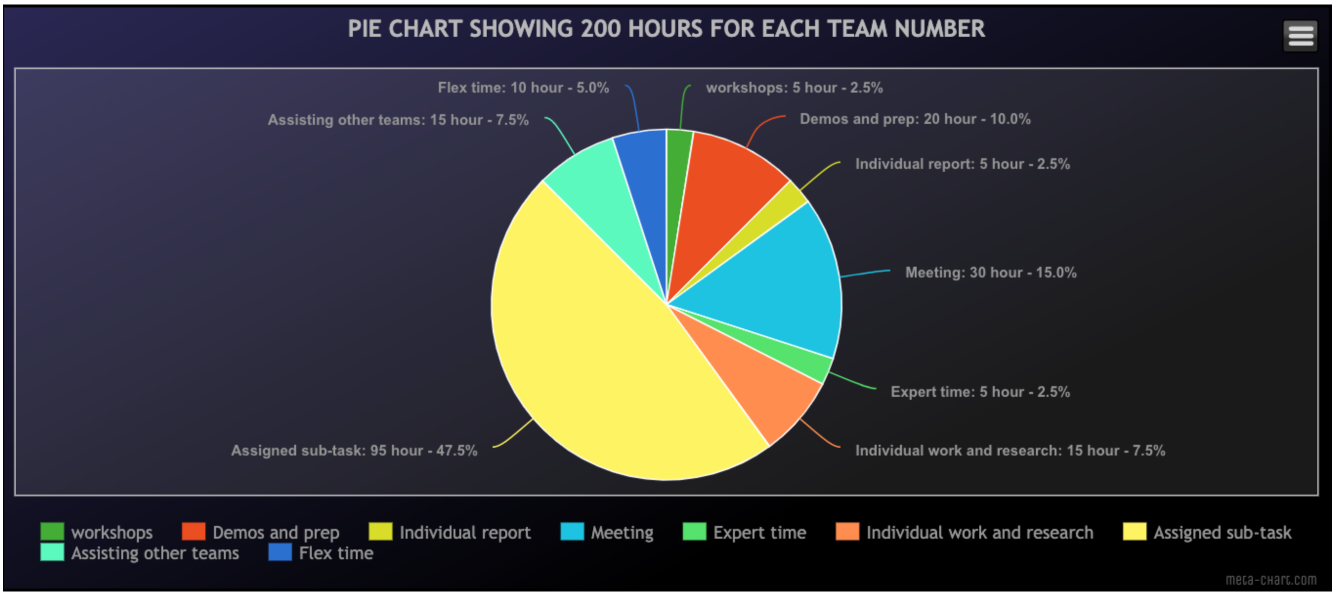

Figure 2. Pie chart indicating time usage per team member

group-based programming through internships, and so they could assign project tasks reasonably. Lars also has experience with administration from running student societies, and has worked in a hardware-oriented tech company. Sean told us that he could take responsibility for the financial aspects, as he has experience in accountancy. Janek is an eager musician, and has identified he could make music for our project videos and presentation.

A number of members are taking the software testing course parallel to SDP, which will provide helpful knowledge for when testing the functionality of the robot. All group members are familiar with the use of version control systems, such as Git, which will greatly improve efficiency when integrating our individual tasks. The majority of group member also have experience with basic machine learning and image processing algorithms, the combination of which would be particularly helpful for this project.

2.3.3 Equipment and Budget:

We have a budget of £200 for this project. This budget will be split between the robot development, at an estimated £170, and marketing, at an estimated £30, if needed. The £170 in development will be allocated mainly to hardware. The purchase of a laser sensor, movement motors and probably some 3D printing for the final robot frame will take up a large part of the budget. Some items we may need and their costs are:

— 3D printed material @ £0.05/g
— 3D printing @ £2 / use
— EV3 Larger Servo Motor @ £32.39 / motor
— EV3 Medium Servo Motor @ £25.79 / motor
— Lego Sensors @ £15 - 30 / sensor
— YDLIDAR X2 360° Laser Scanner @ £63.70 / sensor
— Bluetooth USB Stick @ £5 / stick
— Lego module @ £15 / kg

2.4. Risk assessment

There are a variety of risks that, if realised, threaten the success of the project. By identifying the potential risks ahead of time and ways to mitigate these risks, as well as contingency planning in case the risks are realised, we can limit the effect these risks may have on our project. The following section outlines the risks that we have identified, their estimated likelihoods, severity if realised, and ways to both help prevent and deal with them should they occur.

2.4.1 Cleaning could be impossible or ineffective:

Likelihood: Medium. **Severity:** High.

Description: The primary focus of our robot is to sanitise desks of infectious diseases. If our robot failed to eliminate these diseases it would present both a failure of the robot to complete its task and a major risk to the health of the people who use the desks. Additionally, there may be occasions upon which the robot is unable to clean a desk at all. For example, the periphery of the desk could be blocked by obstacles the robot cannot navigate around, or the desk's surface itself could be blocked by objects that have not been cleared.

Contingencies and Mitigation:

- Should the robot not be able to reach a desk or a desk is blocked, it should alert the staff of the building so that they may solve the issue, and it should mark the desk as unsafe on the app to prevent others from using it until it has been cleaned. The app could have trusted individuals who are alerted by notification that a desk is obstructed and/or unsafe.
- The robot should be thoroughly tested to ensure the robot always, or acceptably frequently, leaves a desk satisfactorily clean. There should be a target metric of cleanliness the robot needs to achieve per desk.

2.4.2 External interference:

Likelihood: Medium. **Severity:** High.
Description: The robot will not always work in a predictable environment; the robot will be working around the people inside the building. This presents the risk of the robot harming the people around it, such as bumping into them, blocking their path, or spraying them with sanitizer. Furthermore, malicious actors may try to prevent the robot from communicating with the app or even take control of the robot.
Contingencies and Mitigation:

- The robot should have sensors that allow it to be aware of its changing environment, assisting it in obstacle avoidance. This could be done with cameras or LIDAR. The robot should be sufficiently fast at identifying an obstacle.
- The robot should make sure to only make use of its sanitiser when it is sure there is nothing on the desk, nor people nearby. It could do this by making use of object detection algorithms. The hardware and software should be reasonably robust to malicious attacks. Should the robot lose contact with the app it should return to a known, safe location. General software security principles would help guard against attacks.

2.4.3 Robot damages items on/around the desk:
Likelihood: Low. **Severity:** Medium.
Description: As the robot is using liquids in a working environment, there is a risk of damage to property - especially electrical goods such as laptops, phones, or tablets - that have been left on or around the desk.
Contingencies and Mitigation:

- The robot should be able to determine whether or not the desk is sufficiently clear of objects, taking care not to begin cleaning the desk if objects remain on it. It should use background removal, colour masking or other methods of object identification to identify areas of the desk that are not clear.
- The robot should take care to keep liquids on the desk, without spilling or spraying liquid over the sides. It should be able to consistently identify the limits of the desk surface and work only within that area.This could be done with edge detection algorithms such as convolution with kernels.
- The robot should be able to detect and avoid obstacles around desks, and should be able to tell when it is impossible for the robot to reach the desk.

2.4.4 Desk geometry, shape and location problems:
Likelihood: High. **Severity:** Medium.
Description: Not all desks are equal, they vary in height and shape. Furthermore, desks may be in locations inaccessible to the robot. This presents the risk of the robot being unable to determine the edges of the desk or to reach the desk surface.
Contingencies and Mitigation:

- The robot should be able to work on a variety of desk sizes and shapes. This could be achieved by one or many actuators of variable length to allow the robot to cover a larger work-space.
- The robot should be able to operate in many environments, such as thin corridors or areas with multiple obstacles.

2.4.5 Robot becomes lost/stuck:
Likelihood: Medium. **Severity:** High.
Description: Given the robot's dynamic environment, there is the risk that the robot navigates into a position that becomes blocked. Additionally, the robot may not always be able to reach its objective due to obstacles. Both scenarios would result in the robot being unable to carry out its task.
Contingencies and Mitigation:

- The robot should be able to successfully identify when it is unable to reach its objective. The robot could identify a reasonable time within which it must navigate to an objective, or determine whether there are no routes to the objective. When this happens, the robot could alert building staff that it requires assistance.

2.4.6 Timeframes underestimated
Likelihood: Medium. **Severity:** Medium.
Description: It is not always clear how long tasks may take. Sometimes, insufficient time may be allotted to tasks. This would result in incomplete tasks - harming progress - and cause undue stress to team members.
Contingencies and Mitigation:

- An amount of 'flexible' time should be set aside for tasks that take longer than expected.
- Reviews will be held frequently on time allocations to evaluate whether enough time has been given to tasks and if time can be taken from other tasks with too much time allotted.

2.4.7 Team members unavailable:
Likelihood: High. **Severity:** Low.
Description: One or more team members may become unavailable at different stages of the project, due to outside commitments, other courseworks, personal reasons, etc. This could lead to organisational issues resulting from managing the excess workload.
Contingencies and Mitigation:

- No subteam will be assigned less than 2 members, ensuring the teammate(s) can temporarily cover for unavailable members.
- Subteams will provide regular progress updates to the entire group, allowing for these team members to flexibly move between subteams if needed without having to 'play catch-up'.

2.4.8 Inadequate communication between subteams:
Likelihood: Low. **Severity:** Medium.
Description: Lack of communication between subteams may also cause organisational issues for the project, potentially resulting in misunderstandings, conflict, and missed deadlines.
Contingencies and Mitigation:

- Team Discord channel will remain active with regular updates on subteam progress.
- Planned weekly team meetings to update team members on overall progress.
- Trello boards will be updated regularly to ensure the current tasks and timeframes (for both the entire group and subteams) are visible at any time to team members.

2.4.9 Interpersonal conflicts:
Likelihood: Low. **Severity:** Low.
Description: Given any group of people, conflicts and disagreements may arise. Interpersonal conflicts between team members may result in delays to the project as a whole, and should therefore be resolved as quickly as possible.
Contingencies and Mitigation:

- If a conflict does arise, a group/subteam meeting will be urgently held to resolve any differences.

2.4.10 COVID-19 constraints:
Likelihood: High. **Severity:** Medium.
Description: The current pandemic situation means the hardware elements of our project will likely be displayed entirely in a simulated environment. This could cause difficulties in our ability to fully demonstrate how the solution will work in a real-world environment.
Contingencies and Mitigation:

- The simulated environment in which the robot operates will be designed, using Webots, with a high-degree of realism, in order to accurately model a typical real-world environment.
- Each element of the system will be fully integrated to allow the start-to-finish operation of the robot to be shown.

2.4.11 Underestimate scope:
Likelihood: High. **Severity:** High.
Description: Our combined lack of experience in projects of this sort could likely lead us to underestimate the actual scope of developing such a complex system.
Contingencies and Mitigation:

- Trello boards will be updated regularly to ensure timeframes remain viable.
- If current timeframes are no longer viable, the project scope will be updated to provide less functionality. The current scope aims to include a full desk booking system integrated with the mobile app - since this is not entirely essential in displaying the functionality of the system, this can be dropped to allow the timeframes for more essential tasks to be extended.

2.4.12 Inadequate testing:
Likelihood: Low. **Severity:** High.
Description: Inadequate testing of the system could result in unseen errors at demo or final testing stages. Attempting to fix these may lead to serious delays and even loss of functionality.
Contingencies and Mitigation:

- A strict testing strategy will be followed throughout development as described by the Agile approach. Individual functions will be fully tested before being deployed to ensure a working version of the project is maintained at all times.
- Regression testing will be carried out after each change to the system to ensure the addition of new functionality does not break any of the old functionality.

2.4.13 Time zone differences:
Likelihood: Low. **Severity:** Low.
Description: Our group contains a number of members currently located in China at GMT+8. Ensuring these team members remain included in meetings and discussions throughout development is essential to the success of this project.
Contingencies and Mitigation:

- We have decided on a window between 10:00 to 15:00 GMT during which all meetings must be held to allow these team members to participate.

3. Group organisation

3.1 Team Structure:

As a group, we have divided our members into different sub teams based on expertise. Generally, we have three major teams: Hardware team, Software team and Marketing Team. Each team has been assigned a leader and divided into smaller fractions according to a specific tasks for individuals. The group as a whole has also been assigned a general leader to keep the project on track. Different members will have regular group meetings both within their subteam, and with other teams, to exchange ideas and ensure teams their tasks can be integrated together . Members are encouraged to ask for help when facing difficulties, and also help other teams when capable.

3.2. Sub-Team Tasks And Member Allocation:

General team leader: Ryan
Ryan is very experienced in leading a team, decisive when making choices and has a high passion, skills of organizing the team. In this role, he will be assigning tasks to sub teams and keep tracking the progress of each to make sure the group members are all working together properly.

3.2.1 Hardware Team:

This team handles the physical design of the robot. This includes which sensors are going to be used to solve various physical challenges (based on the needs of the Software team). This team will build the robot design by looking for possible accessories in Webots and simulating any of the robot's behaviour.

Team leader: Lars

- Lars has experience in building robots with high creativity and is capable of breaking down a task into different small sub-tasks, assigning them to members with comprehensive consideration on individuals' working load and interest.

Sub-team:

- Base: Jeffrey, Adel
- Cleaning and Sanitizing: Lars, Adel, Ryan, Jeffrey
- Arm: Lars

3.2.2 Software Team:
This team handles the implementation of the robot's functionality, and the corresponding app as a user interface. This is an essential part of the project, including dealing with the movement and navigation of the robot, as well as distinguishing the desks that need cleaning. Each function will be simulated in Webots first. Different members in the group will focus on assigned tasks with regular communication. Each member will strive to write high quality code, expanding on relevant knowledge and making use of existing libraries where possible.

Team leader: Josh

- Josh has extensive experience and high passion for building robotics controlling systems, also in the area of image processing. In this role, Josh will be responsible for keeping all sub tasks' progress on schedule and communicate with the hardware team to indicate requirements for hardware components.

Sub-team:

- Movement and path finding: Sean, Janek
- Image processing: Ivan, Josh, Shining
- App development: Shining

3.2.3 Marketing Team: This team works on the preparation for each demo as well as advertising the product. The team will also be responsible for designing an attractive website, including any images, graphs, or videos involved. Team members will analyze the feedback from clients and advise the development team on how to improve the product. This is a relatively smaller fraction of work, thus it's not a permanent team, and each group member can be assigned to this team when able to help.

Team leader: Ryan

- Graphic Design: Ryan
- Website: Ivan

3.2.3 Testing Policy:

Testing will be carried out after each milestone. Each member/team is responsible for testing their own assigned task or section. For example, the hardware team will ensure the robot can capably perform the physical aspects of the cleaning tasks, as well as ensuring the design itself is structurally viable. The software team will follow an Agile process throughout development of the robot, performing unit, functional and regression tests before and after each deliverable is integrated. Before submitting any demos, full system tests will be carried out, integrating both the software and hardware aspects of the robot.

3.3. Organisation and Collaboration

3.3.1 Meetings: The group will meet as a whole with our mentor on each Monday - this meeting will go through what has been achieved during the previous week and discuss the new milestones for current week. Subteams will also conduct their own weekly meeting guided by the team leader. All scheduled meetings will be pinned in Discord as a reminder. Each member should attend all the scheduled meetings unless informed in advance. When there is a workshop, attending participants should also discuss the workshop contents with the rest of the group in the next meeting.

3.3.1 Communication: The majority of team communication will take place in Discord - the group has a general channel as well as individual channels for each subteam.

3.3.2 Code-sharing: All code work should be written in python with a specified version and code work should be uploaded to Trello and Github repos for sharing and version control purposes. Each team's leader has a responsibility to check this is done by their team members and ensure good coding practice, consistent, readable code. If using an external package, reference must be attached with codes.

3.3.3 Process tracking: All members have a responsibility to keep a record of their time spent on the project each week. The weekly tasks will appear on the Trello board after Monday's weekly meeting, including the specific member assigned to each task and the planned time to finish. Each subteam leader has responsibility to check the progress of each team member's sub task. If there is an unsolvable issue within the sub team, the problem should be reported to the general team leader and a meeting will be scheduled to discuss solutions.
When preparing for demos, all members should contribute giving an explanation of work done. The final draft of each version will be reviewed by all members before being submitted by the general team leader.

References

Cleaning robot market size to reach $6.2 billion by 2025 owing to increasing penetration of automation and artificial intelligence in household applications. *Million Insights*, 2020. URL https://www.prnewswire.com/news-releases/cleaning-robot-market-size-to-reach-6-2-billion-by-2025-owing-to-inc html.

Ackerman, Evan. Review: irobot roomba 980. 2015. URL https://spectrum.ieee.org/automaton/robotics/home-robots/review-irobot-roomba-980.

Gill, Victoria. Coronavirus: This is not the last pandemic. 2020. URL https://www.bbc.com/news/science-environment-52775386.

indeed. How much does a cleaner make in united kingdom? 2021. URL https://www.indeed.co.uk/career/cleaner/salaries.

Treasury, HM. Policy paper spending review 2020, 2020. URL https://www.gov.uk/government/

publications/spending-review-2020-documents/
spending-review-2020#responding-to-covid-19-1.