!spam

User Guide

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1. Introduction

Congratulations on your purchase of the *!spam* robot, an automated mail delivery robot for office environments. After being loaded with letters, it takes care of all the rest - recognizing the recipients and delivering mail right to their desks. The robot acts in coordination with a web page hosted on a server so that you may control it from any web browser.

This User Guide provides both the general and technical details you need to operate your robot. It should be read carefully before use by the receptionist using the system and by the IT administrator that will support the system.
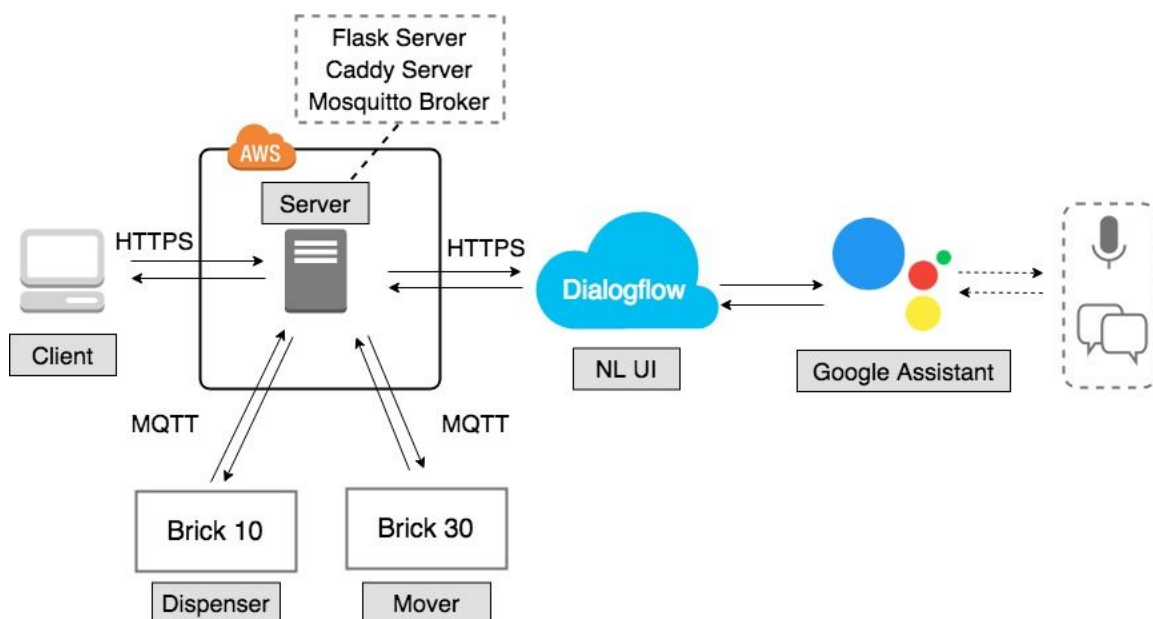
2. *!spam* overview

Figure 1: Diagram of system interactions.

!spam **Hardware** (powered by 2 EV3 bricks - Mover and Dispenser) works in conjunction with a **Website User Interface** (Client) and a **Conversational Interface** (Google Assistant), the latter is an optional feature. This prototype also requires specially formatted letters and a line-mapped office (details in the Appendix, section 6.1).

2.1 Hardware

The following numbers refer to sections of the robot. These correspond to the labels on the next pages' picture:

1) The **two colour sensors** are the primary way in which *!spam* finds its way around the line-mapped office. The right sensor is used to PID-track the line, while the left is used to detect junctions and desks.
2) The 'eyes' of *!spam* are an **ultrasonic distance sensor**. It detects obstacles that are in *!spam*'s way so that it stops instead of crashing into them.
3) *!spam*'s 4 (independently-powered, perpendicularly positioned, holonomic) **wheels** allow it to rotate in-place and easily align itself with desks. As this drive allows for movement in 3

degrees of freedom, it enables *!spam* to approach a desk in a straight line while rotating through 90°.

4) The 2 **EV3 bricks** behind are the brain of *!spam* (see Appendix 6.4 for cabling schema). They work together and with the external server to make sure that everything keeps running correctly.

5) The **classifying module** is where letters are inserted into the robot by the receptionist. Behind the grey plate of lego is a transparent plastic tunnel which guides the letters to wherever the top slider points.

6) The **top slider** directs letters to drop into appropriate slots or holds them in place while they are captured by the camera (by pointing to a wall between slots).

7) The **camera** captures pictures of the letters to determine who their recipients are.

8) The **dispensing module** is where the classifying module drops the letters into once the camera has figured out who they belong to. This part of *!spam* features 4 letter slots, a separate parcel slot, and motors which push the floor of each slot up, emptying the contents. One of these motors powers a prismatic joint going upwards and the other enables sideways switching between the slots. The sideways drive also moves the top slider.
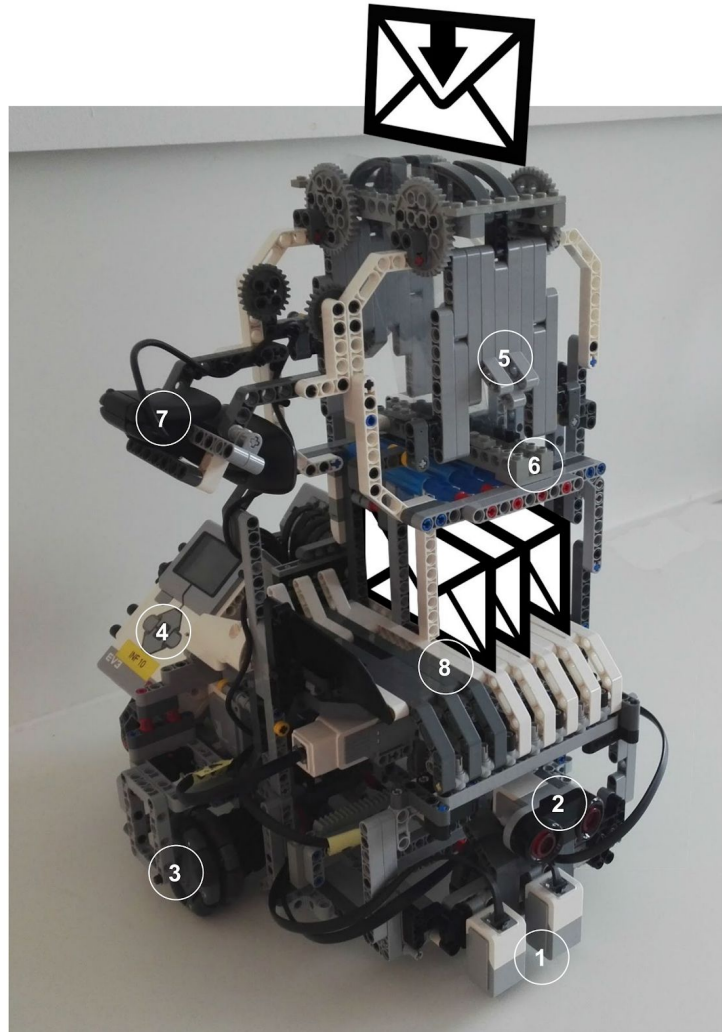

Figure 2: Hardware Overview.

3. Quick Start (Hosted)

!spam offers hosting services for your robot's server. This means you don't need a lengthy configuration process and may immediately go to www.spamrobot.ml to control your robot. The *!spam* team already mapped your office floor plan and desk locations and your robot is ready for plug and play. There is just one last step you need to complete before you may go to section 4: "Using *!spam*", which is connecting your robot to the internet. If you would like to self-host and/or reprogram the map see Appendix 6.2 for Advanced Installation.

3.1 Connecting the robot to the internet

The EV3 bricks use Bluetooth to connect to the internet, so we recommend using your phone's Bluetooth tethering functionality to provide it.

On your device, make sure you are connected to a Wi-Fi or 4G Network. Open the Settings menu and navigate to Hotspot & Tethering to turn Bluetooth tethering on. For more in-depth instructions refer to http://support.google.com/nexus/answer/2812516?hl=en-GB for Android support.

Now for the robot. Turn both bricks on by pressing the centre button on each brick. For each of them, one at a time, do the following:

- Navigate to Wireless and Networks ➔ Bluetooth.
- Check the Powered and Visible checkboxes.
- On the Android device, select "ev3dev" to pair and confirm the passkeys on both devices.
- On the EV3 brick, select the phone you just paired with.
- Navigate to Network Connection ➔ Connect.
- Turn on Connect Automatically to do it on boot and make this a one-time setup.
- You should now see on the screen "State: Online" and the bricks IP address above whenever it's connected.

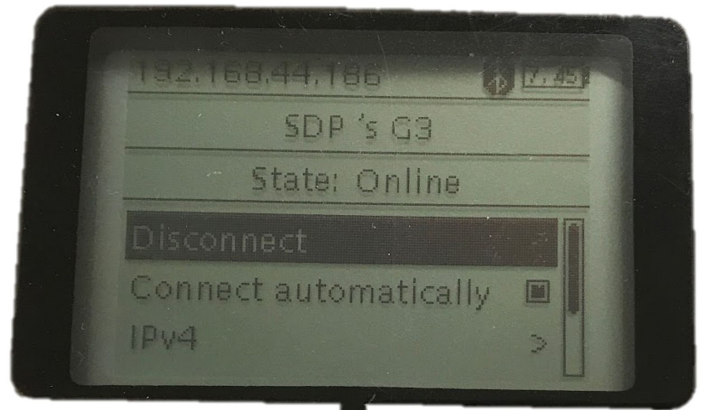In case there is a problem with connection, refer to the OS instructions at https://goo.gl/g3Fk4N.

Figure 3: Example of when the robot is connected.

4. Using *!spam*

4.1 As the receptionist

4.1.1 Accessing the website

!spam's user interface is a website hosted remotely, accessible from anywhere - phones (left image) and computers (right image) alike. Navigate to your website (default of www.spamrobot.ml) to check if it is accessible. You should see the login page. If not, go to troubleshooting entry #12.
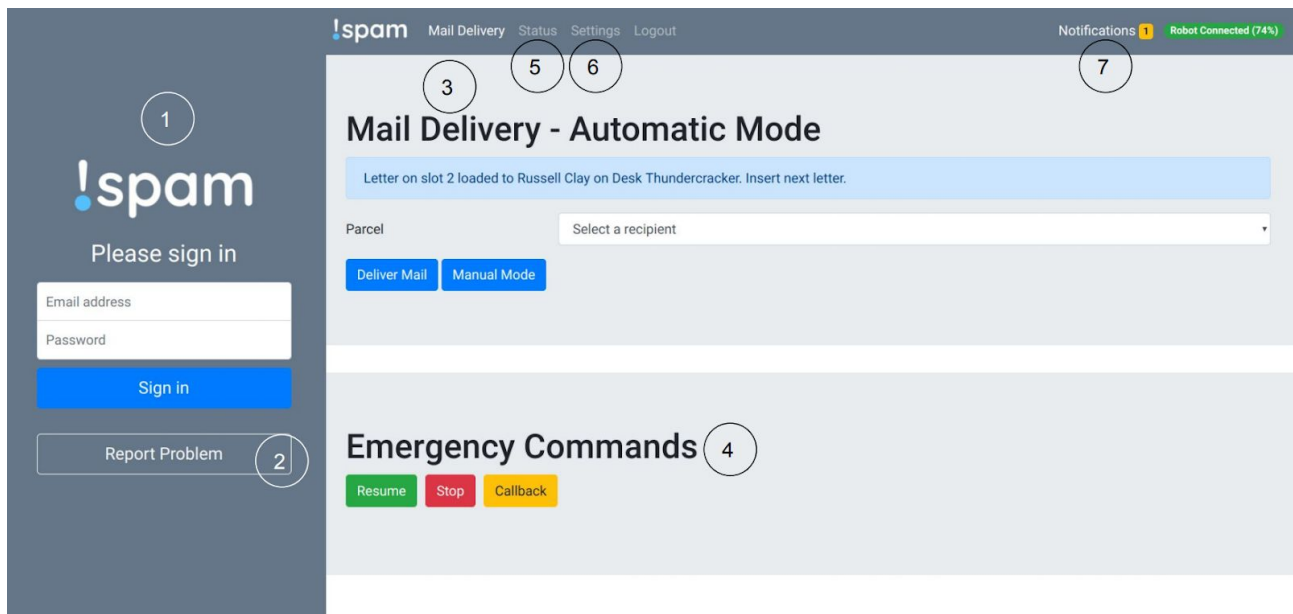
Figure 4: Website Overview.

Outline of the website's functionality (the numbers correspond to the picture's labels):

1) The first screen is the **Login page**. It allows the receptionist to log into the robot control section of the site.
2) The **Report Problem** button is for employees in the office to report problems about their mail or with the robot. It directs them to a simple form without having to log in.

3) The **Mail Delivery** section is the primary way that the receptionist interacts with the robot. The snapshot above shows the default **Automatic Mode** of interacting with *!spam*. There is also a **Manual Mode** explained further on.

4) The **Emergency Commands** section allows the receptionist to issue commands after sending the robot out for delivery. **Callback** causes the robot to return to the reception at any point whilst delivering. **Stop** immediately stops the robot, no matter what it is doing. **Resume** makes the robot continue its previous route, the one it was on when it received the Stop command.

5) The **Status** page displays connection status, battery life and the last known location of the robot, along with the number of mail pieces delivered. Information about connectivity and battery levels is also visible at a glance in the upper right corner.

6) The **Settings** page allows users to edit who is working at which desks. It is useful if more staff are hired, or if someone changes their desks.

7) The **Notifications** tab is how *!spam* tells the receptionist if something has gone wrong at any point during delivery. This is also where problems reported by office workers appear.

4.1.2 Conversational interface

It is also possible to use *!spam* with a voice or text bot. This requires equipment compatible with Google Assistant (e.g. Google Home Mini). To start, ask Google Assistant "Ok Google, Ask Spam Robot...". These are the questions you can ask:

- Check the battery levels: "How are the battery levels?"
- Check the connection status: "Are the bricks connected?"
- Initiate callback: "Come back to reception"
- Initiate mail delivery: "Start delivery [with a parcel for John]"
- Ask where someone works: "Where does John work?"
- Check the location of the robot: "Where are you?"
- Ask who works on a desk: "Who works on desk Megatron?"
- Read notifications: "Do I have notifications?"
- Amount of objects delivered: "How many parcels were delivered?"
- Stop the robot: "Stop moving."
- Resume operations: "Start again."
- Check the robot's status: "What are you doing?"

4.1.3 Starting the robot

Figure 5: Turning !spam on.

Turn the robot on by pressing the centre buttons (see label 1) on both bricks. This may take a few minutes. Next, check the bricks are connected to the internet, as described in 3.1. If that is not the case, look at troubleshooting entry #2. Navigate to the File Browser and use the centre buttons (see label 1) to run 00runme.sh on both bricks. Again, wait a few minutes for the robot to start. Once everything is working, the bricks will display "*!spam*" on their screens and the connection status on the website will display "Robot Connected". If this is not the case navigate to troubleshooting entry #4. The top slider will go to its initial position on startup.

4.1.4 Battery Management

With both bricks fully charged, *!spam* can operate for 3 hours. You may check the battery levels of both bricks on the Status page along with other information pertaining to the robot. The upper right battery indicator takes the minimum of the two levels. It is also possible to ask the Google Assistant "How are the battery levels?".
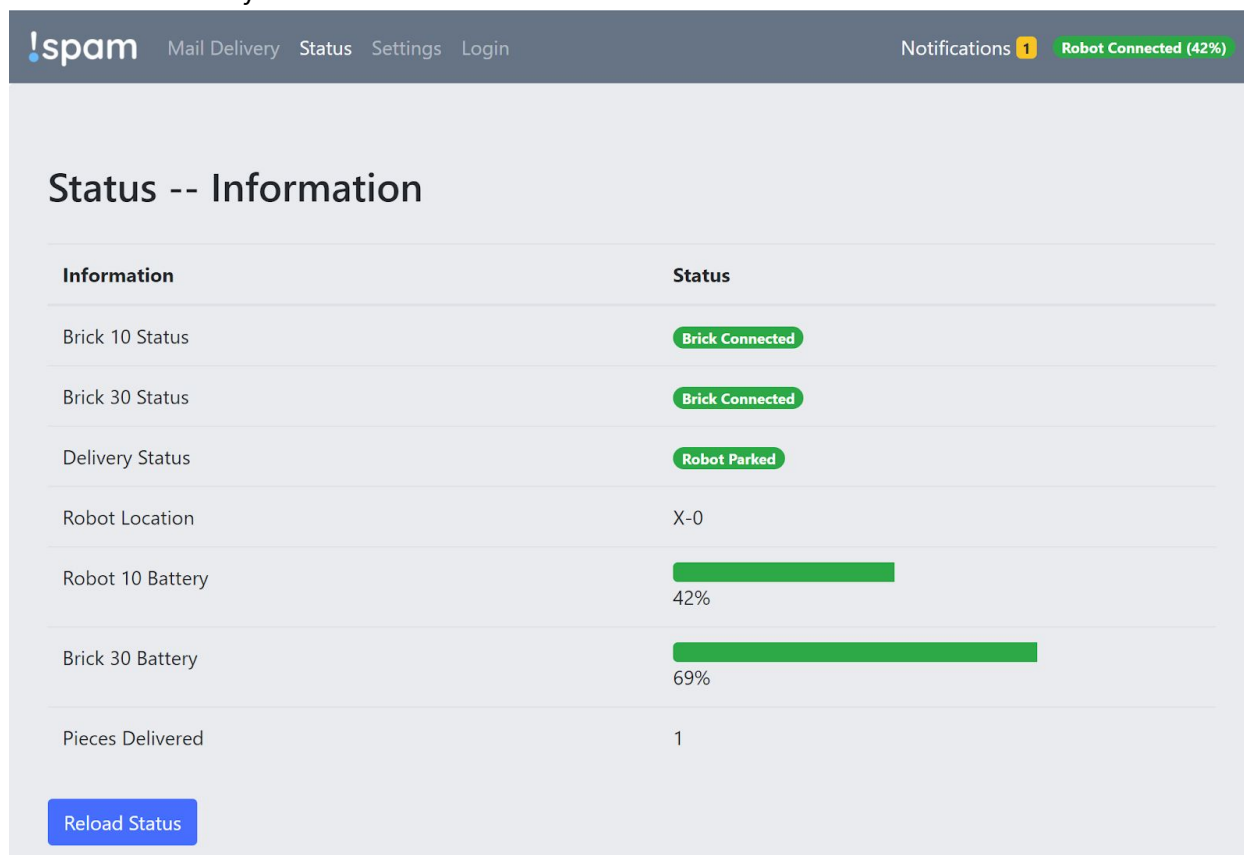

Figure 6: Status page of the website.

If the batteries are running low, you may find them in the back of each brick. It is not necessary to remove the batteries to charge the robot. Simply connect the 2 provided chargers to the ports at the bottom of the bricks. Do not use the robot while charging. To remove and/or replace batteries, detach the LEGO connections on both sides of the brick and remove the cables on the bottom of the brick. Carefully rotate the brick upwards and detach the batteries by pressing the side tabs.
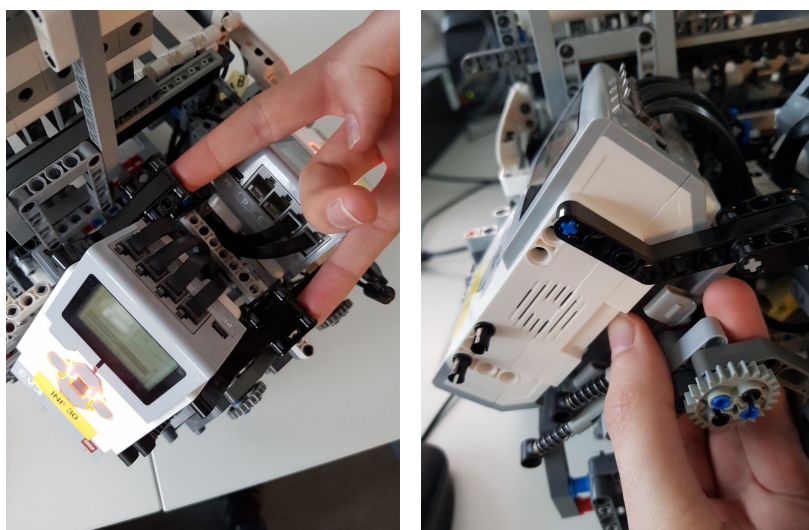

Figure 7: Replacing the brick's batteries.

4.1.5 Loading

After the robot is running and connected, always start its delivery cycle in the reception area (see diagram in Appendix 6.1.2). Make sure to line up the red shining sensor with the white line. You have two choices as to how you can load the robot. By default, the **Automatic Mode**, which uses the classifying module, is selected and a prompt to load the first letter is displayed on the website (4.1.5.A). However, you can also select to do it manually in **Manual Mode** (4.1.5.M).
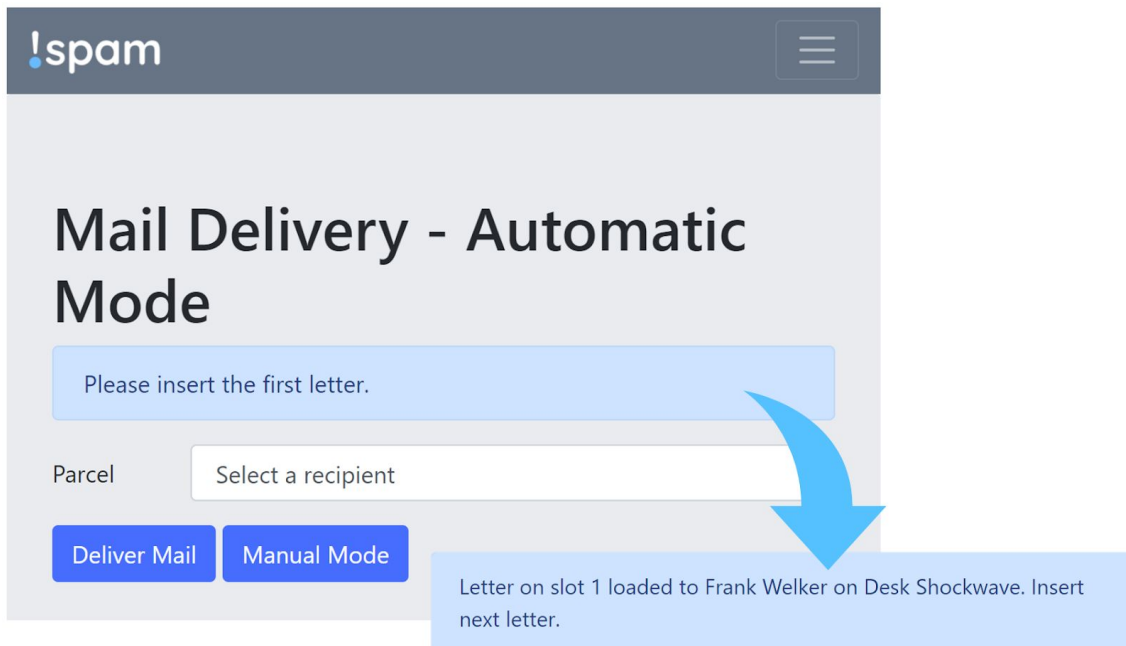
4.1.5.A Automatic Mode

Figure 8: Automatic mode operation.

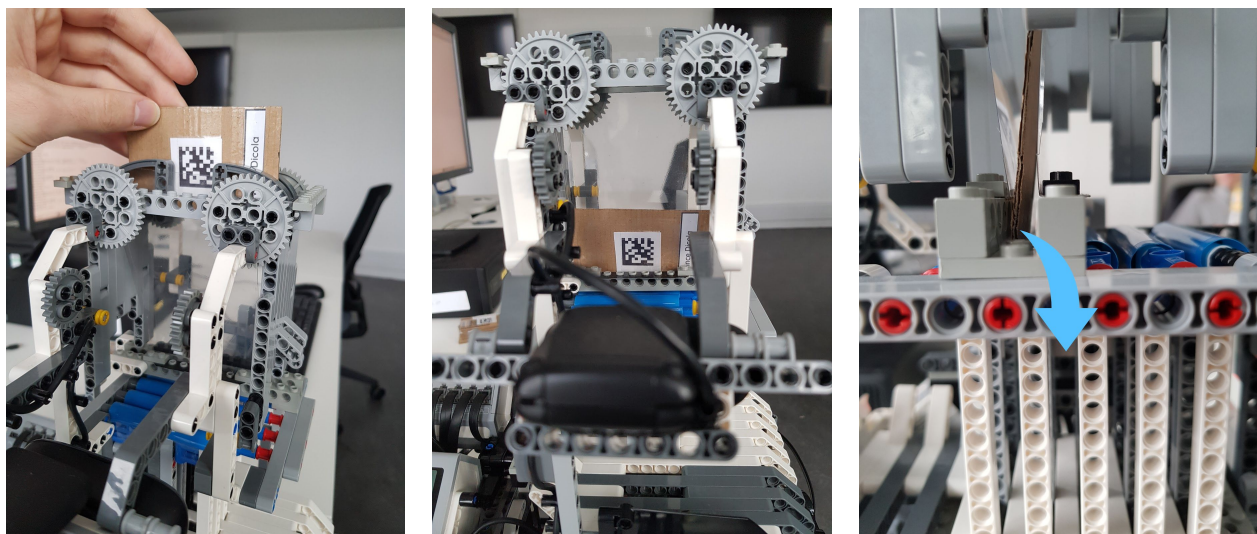| Load the letters in landscape one by one following the audio prompts from the robot and the messages displayed on the website. | The top slider will move sideways to point to walls between the slots to be filled - stopping the letters and allowing the camera to capture them. | Upon successful letter classification, the top slider will drop that letter into a slot, re-calibrate itself on an inner wall, and go to the next wall. |

Figure 9: Inserting, reading and classifying letters

If all 4 letter slots are filled, the top slider will stay above the first slot instead of proceeding to the next wall. The receptionist will be notified *!spam* is full.

If the robot fails to classify a letter, it will also be dropped and the cause will be displayed on the website. You will be instructed to remove it and insert another letter.

> Last letter was loaded to Tobias Hawk on Desk Galvatron. Press Deliver Mail when ready.

> Couldn't know in which desk Joshua Joyce works. Remove letter from slot 1 and insert a new letter

> Couldn't find the recipient of this letter in the office. Please remove the letter from slot 1 and insert a new letter.

Figure 10: Example messages in automatic mode.

The parcel recipient can be added via the menu on the website or with a voice command. Once the mail is loaded, press deliver mail or issue the appropriate voice command (section 4.1.2) to start the delivery.

4.1.5.M Manual Mode

To operate manually, first press the Manual Mode button on the website. If there is an unclassified letter in the classifying module it will be dropped for removal. Remove all the other letters too. The website will navigate to the following screen with drop-down menus to select whom the letters should be delivered to.

Fill up the slots on the robot from the front. Make sure the slots correspond to the slots picked on the website, these are numbered from right to left. After this is done, press the deliver mail button to begin delivery.
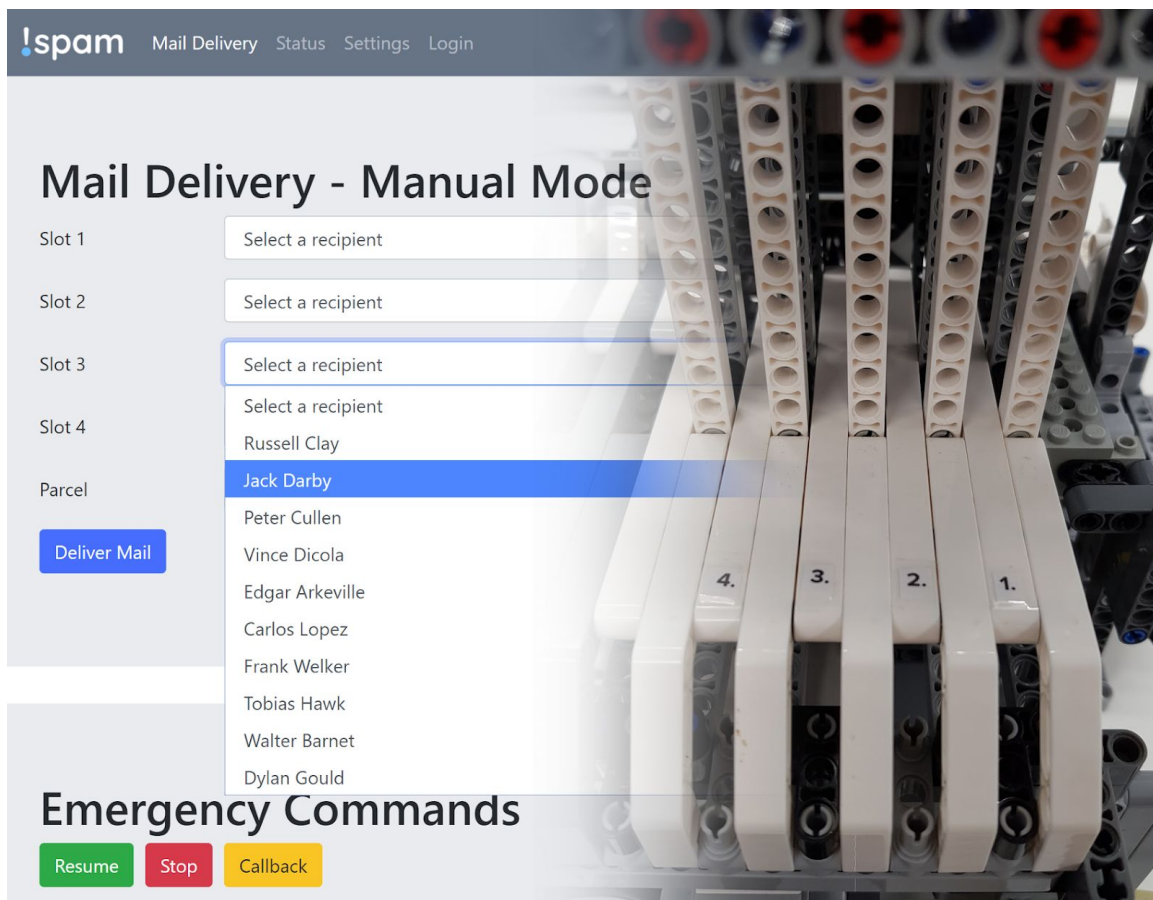

Figure 11: Manual mode and slot numbering.

4.1.6 During Delivery

!spam will advance through the map, following an optimal path to each desk, dispensing mail when appropriate. It will follow straight or curved white lines using a PID strategy from junction to junction (denoted by green markings) at which it will rotate in-place. At desks, it will use a special straight line approach while rotating through 90° in order to dispense in the correct orientation (refer to map in Appendix 6.1.2).

With the exception of approaching a desk, it is never expected to lose sight of the white line. If it does, consequently missing an expected green marking, it will panic. This means it will stop in place, send the receptionist a notification with its last position and wait for assistance (to be transported back to the reception and loaded with letters again). If it encounters an obstacle on its path, it will stop and wait for it to clear, or panic if it waits for too long.
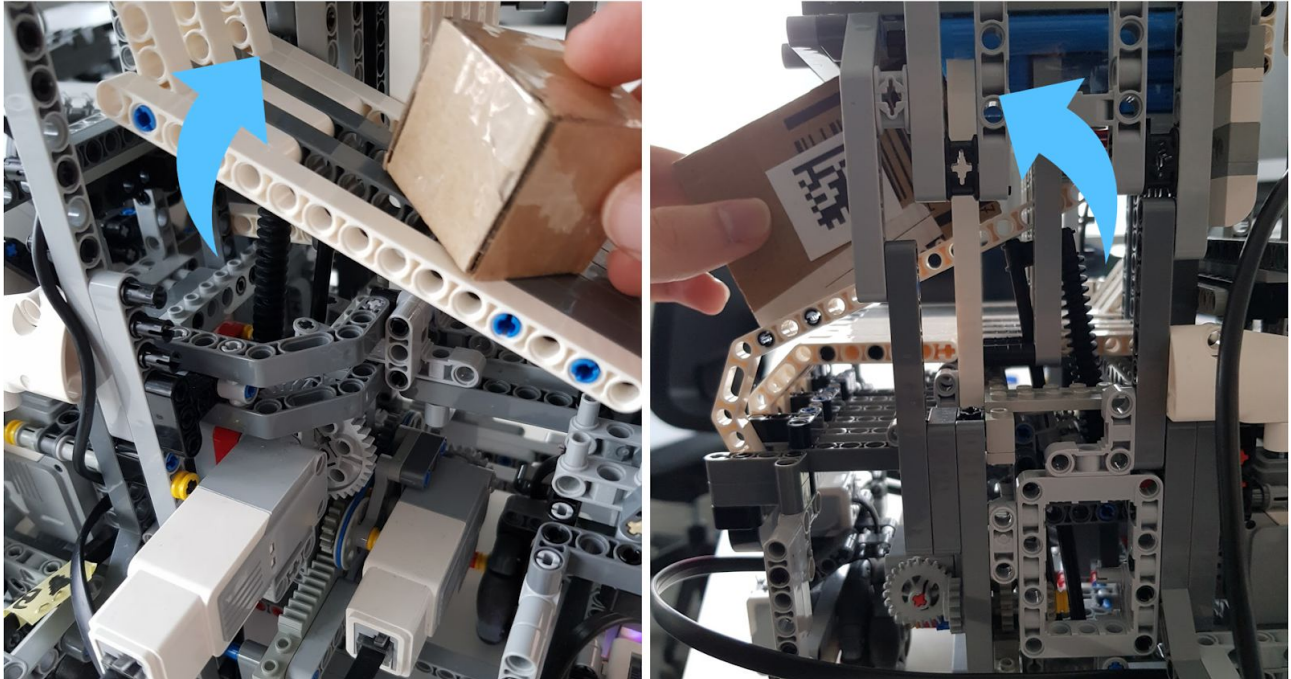

Figure 12: Dispensing mechanism.

Dispensing a letter consists of the dispensing assembly being positioned beneath the appropriate slot and pushing it up and forwards. It shakes the mail out for redundancy.

Additionally, between dispensing each letter, the robot requires the dispenser assembly position to be re-calibrated on an inner wall. Just like in classification.

The receptionist may interact with the robot during delivery through the emergency commands explained in 2.1.2. After the robot is done delivering its batch of mail, it will head back to the reception ready for another batch to be loaded.
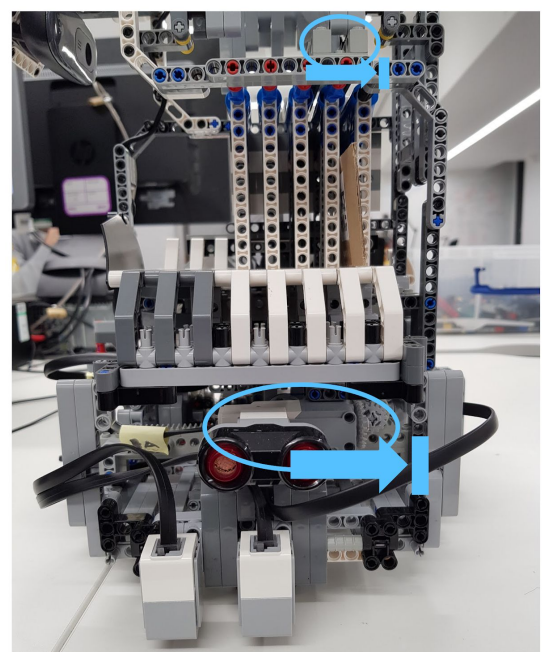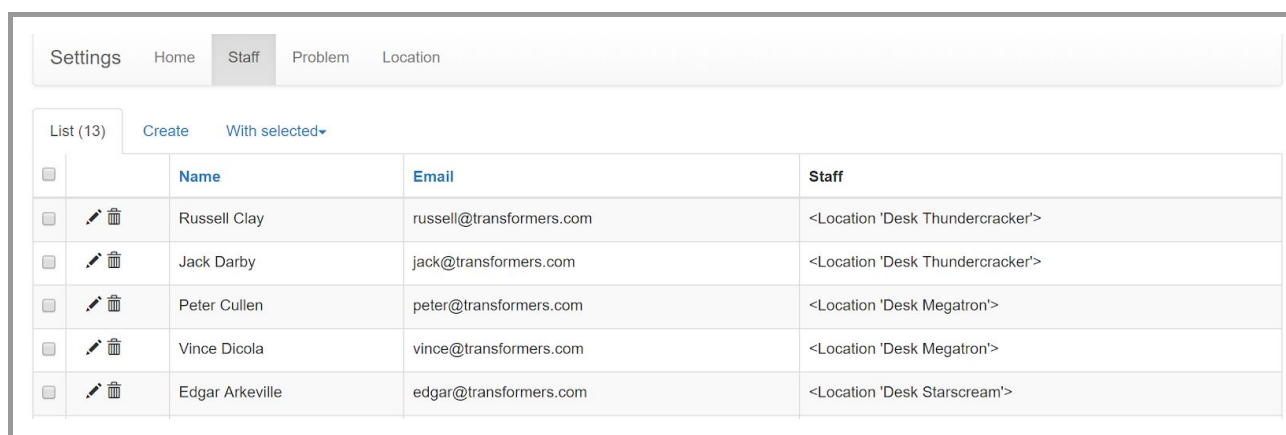

Figure 13: Recalibration of the dispensing assembly.

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4.1.7 Managing people and desks
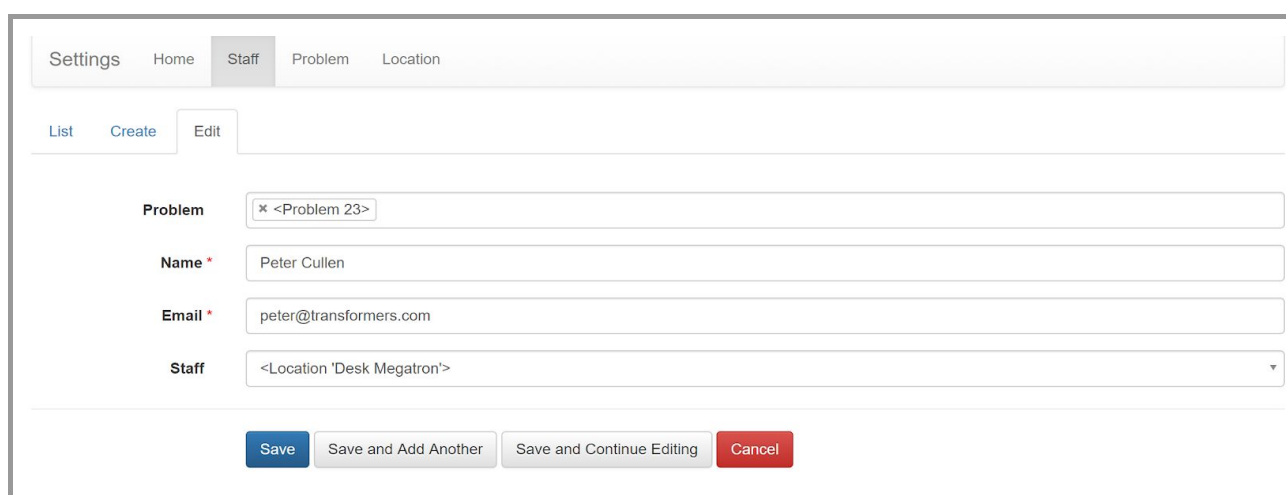To add staff or change their desk assignment go to the Settings page of the website:

Figure 14: Managing staff allocation.

Click "Create" to add Staff. The pen icon allows you to change existing ones:

Figure 15: Editing the user entry.

4.1.8 Shut Down
The robot is intended to be on at all times. However, if needed, it is very straightforward to shut it down. First, you need to stop the programs running on both the bricks by pressing the top left button for a few seconds. Next, hold the same button to bring up the shutdown menu. Finally, press the centre button to initiate shutdown. The connection state will then propagate to the server accordingly.

4.2 As an employee

Employees will receive email notifications if they have incoming mail. If an employee has a problem with the mail delivery (e.g. missing mail or incorrectly classified mail), they can

Figure 16: Notifications page (receptionist view).

head to the website login page and report a problem (as mentioned in section 4.1.1). This will notify the receptionist to fix the problem in the Notifications section of the website.
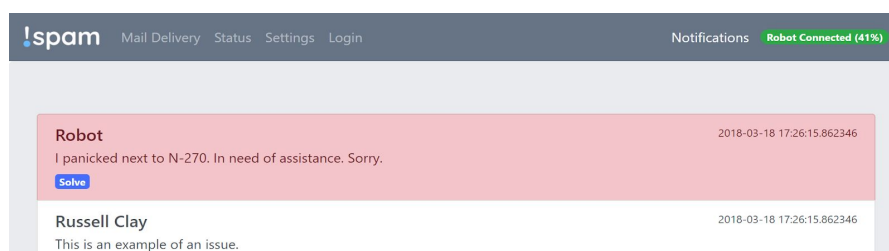
5. Troubleshooting

No.	Issue	Cause	Possible Solutions
#1	Robot doesn't turn on	Batteries are not charged	Charge or change the batteries before using.
#2	No IP in the top left/The EV3 brick programs crash on initialization	The phone is not connected to wifi or 4G/Bluetooth is not correctly paired	Make sure you are connected to the internet/Try removing the existing Bluetooth pair and re-pair.
#3	EV3 bricks won't pair with the phone on start	Configuration parameter missing	Ensure that you have checked Connect Automatically on the brick. See Section 3.1.
#4	Website status is "Disconnected"	One brick is waiting for another to connect	Make sure you started running the programs on both bricks. Be patient, it takes a long time.
#5	A brick is not responsive	The OS crashed	Reinsert the battery. Turn the brick on again.
#6	Upon classification, a person doesn't have a desk assigned	Recipient unrecognized	The person you are trying to deliver mail to must exist and be assigned a desk. See section 4.1.7.
#7	Robot moves very slowly or shows that a sensor has been disconnected	Battery deterioration	Low battery levels make the robot move slower or even not recognize sensors. Charge the batteries.
#8	Robot is rotating in place instead of delivering.	Wrong initial position: sensor misaligned	Ensure that the red-shining colour sensor is above the white line at the start of delivery.
#9	Robot hits an obstacle.	Too small of an obstacle for the robot to see	The ultrasonic distance sensor has trouble detecting small objects. Pick a bigger obstacle.
#10	Robot jams during dumping or classification	Lego-caused imprecisions	Manually remove the letter from the slot.
#11	A letter falls in portrait instead of landscape.	Incorrect insertion	The letter will fall through, but it won't be able to be dispensed properly. Please reorient it correctly.
Advanced Install related issues (Appendix 6.2)			
#12	Website not accessible	Firewall not configured properly	Open ports 80, 443, 1883 and 5000 to incoming and outgoing traffic.
#13	Google Assistant doesn't respond	Fulfillment link is incorrect	Go to dialogflow.com ➜ Fulfillment and confirm the URL is https://<yourdomain>/fulfillment
#14	Website shows as insecure on the browser	HTTP being used instead of HTTPS	Confirm the first line in sdp2018/spam/Caddyfile is just your domain (e.g. spamrobot.ml).
#15	Robot panics unexpectedly	Map configuration	Distance measures on the map are incorrect. Remeasure the affected route.
#16	The robot turns the wrong way	Map configuration	Angles stored in the map are incorrect. Remeasure the angles of all lines from that node.

6. Appendix

6.1 Additional Components

6.1.1 Letter mock-ups

Our *!spam* prototype is not full-scale and hence we use reduced-sized letters of dimensions 5.5 by 8.5 cm. The recipient information is encoded in the industry used data matrix standard. Each letter is double-sided. This is an emulation of handwritten addressed letters.
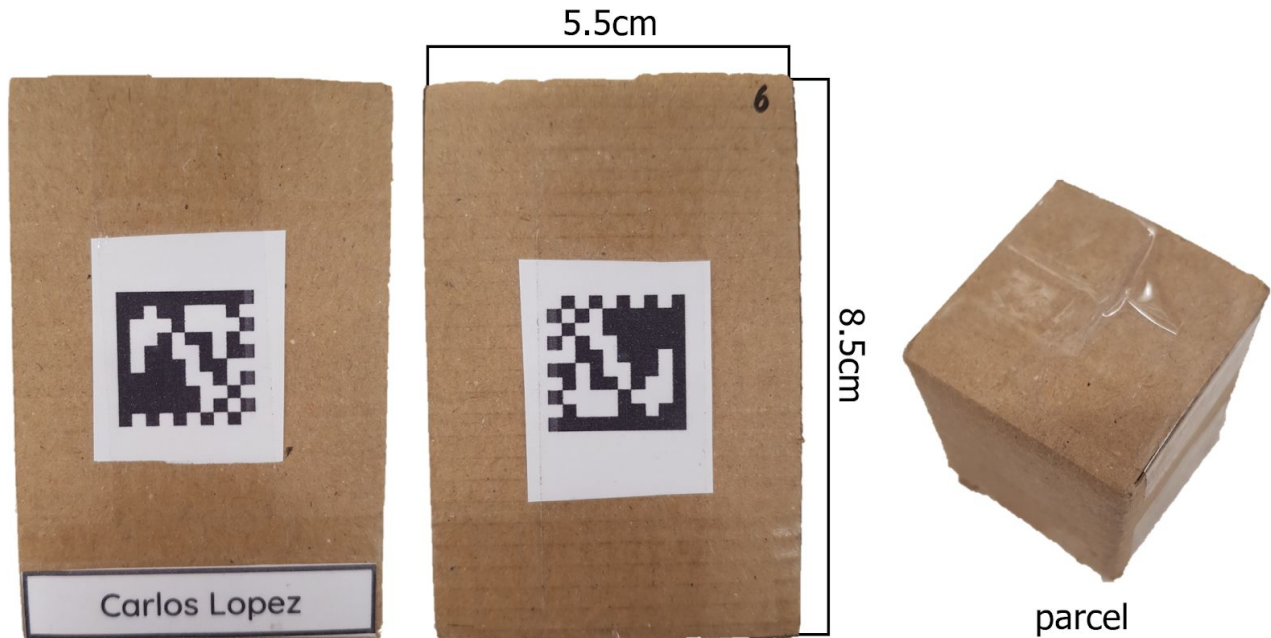

Figure 17: Letter and parcel prototypes.

6.1.2 Office map

It consists of 50mm white lines for the robot to follow, and asymmetrical green markings denoting junctions and desks. This is for the robot to centre itself on the junctions by overrunning them - this is possible as it only has a colour sensor on one side. The overrun required for junctions is 15cm from the centre of the junction. Correspondingly the distance between the similar desk junction markings is 30cm. The robot is placed at the reception by aligning its back with the first green marking and its red-shining sensor with the white line.
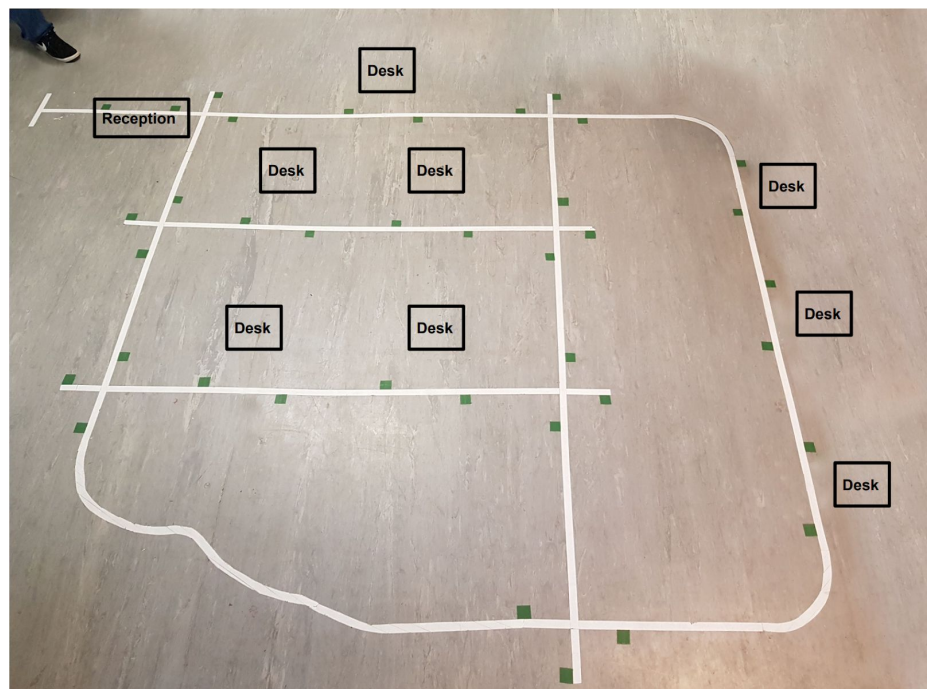

Figure 18: Map prototype.

6.2 Advanced installation (Self-hosted)

The sections below provide the capability to self-host our software, that is, install *!spam* on a custom domain and Ubuntu server. This also allows a custom conversational interface. Note the advanced installation is not recommended for offices without an IT administrator.

Please also note a domain is necessary for issuing an SSL certificate for Google Assistant compatibility. *!spam* uses Caddy which in turn uses Let's Encrypt as Certificate Authority (CA). Certificates are automatically managed, issued and renewed.

6.2.1 Codebase
To prepare the codebase for the deployment:
1. run `$ git fork https://github.com/jcatarino/sdp2018.git`
2. From the GitHub website, set the two variables in ip.conf located in the top directory to the desired domain name and IP address respectively.
3. You will see the following directories in the repository:

/spam:	**/robot:**
Contains the code for the server. Running install.sh in this directory will install all the components required for the server. It will also start the web server. This should be run after modifying ip.conf (in step 2).	Contains the code for the robot. Running install.sh in this directory will guide you through the installation of the code onto the robot in the case code modification is desired. This should be run after modifying ip.conf (in step 2). The script requires a DICE machine to run.
/cpp:	**/dialogflow.zip:**
Path planning code. This should not need to be edited. But if it is , /spam/install.sh should be run (refer to 3.c. in section 6.2.2), to re-compile.	Optional data for Google Assistant integration. See section 6.2.3 for installation instructions.

6.2.2 Setup the server
Follow these steps to prepare the server:
1. On the DNS domain manager, add an A record with the target to the server's IP.
2. SSH into the server where you intend to deploy. For detailed instructions, visit https://goo.gl/47rw6n.
3. On the SSH session:
   a. run `$ git clone <your repository url>`
   b. run `$ cd sdp2018/spam`
   c. run `$ ./install.sh` (this may take a few minutes)
4. Check the website is accessible using a web browser.

6.2.3 Setup the Google Assistant App
4. Create a Dialogflow agent at https://dialogflow.com/
5. Click on the settings button ➜ Export and Import ➜ Restore from zip ➜ select sdp2018/dialogflow.zip
6. Head to Fulfillment ➜ Enable Webhook ➜ Insert "https://<your domain>/fulfillment"

6.2.4 Setup the Office Environment

To change the map layout of the robot, open the configuration file in sdp2018/spam/spam/map.conf in which paths are defined as follows (note the trailing commas):

<Initial Node> : {<End Node> : (<Distance in cm>, <initial orientation>, <final orientation>),

<End Node> :(<Distance in cm>, <initial orientation>, <final orientation>),

…},

Specifying each edge in one direction is enough. The distance is measured from the centre of one junction to the centre of another. Orientation is the way in which the robot will be facing relative to the 0° starting point orientation - assuming it is north, 270° would be west. Desks are encoded as 0 distance from a junction and only include the orientations for distinguishing which side of the line they are, eg. 90° for a desk on the east of a line going north. The desk's final orientation is always the opposite of initial orientation, eg. 270° in this case. Only edit the indicated regions. After updating the map on the robot, the desks on the server side need to be updated too. Update the list of desks by heading to the website ➜ Settings ➜ Location and their owners by heading to the website ➜ Settings ➜ Staff as shown in 4.1.7.
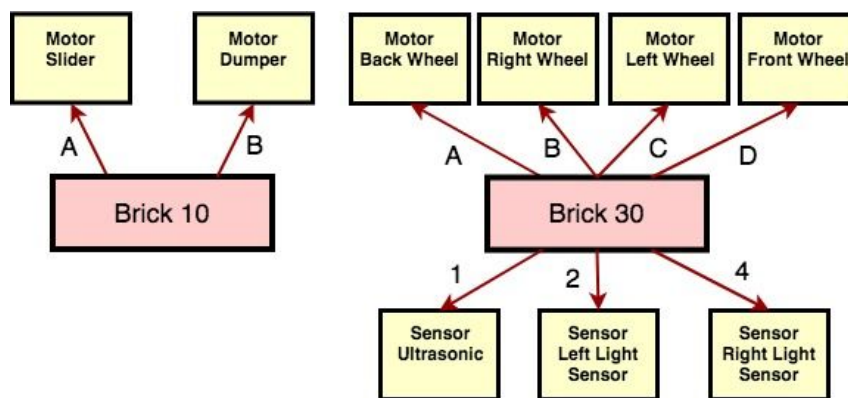
6.4 Cabling scheme

Figure 19: Cable connections in !spam.

Contacts:

If you have any problems, need support, or need help to install/troubleshoot, contact *!spam* at support@spamrobot.ml.

This report was improved with the feedback of a first year Computer Science student.