CYBERWORKS ROBOTICS

OPERATOR GUIDE FOR NILFISK SC1500

OCTOBER 2023

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INTRODUCTION

Cyberworks Robotics has taken the popular Nilfisk Advance SC1500™ commercial stand-up floor scrubber to the next level of robotics. Through its proprietary custom software, the platform is empowered to operate autonomously, while delivering the same cleaning performance as the original product. It follows predefined routes and replicates the cleaning techniques employed by seasoned professionals. At the same time, the cleaning crew can redirect their attention to other tasks, optimizing time and cleaning quality.

THE SCRUBBER ENHANCED WITH A CYBERCUBE KIT CONTAINING THE ELECTRONICS AND COMPUTER ALLOWING AUTONOMOUS NAVIGATION.

The machine has undergone a significant enhancement, incorporating a CyberCube kit that houses the autonomous system. This compact metal box encompasses all the essential electronic components for self-driving navigation, including the onboard computer, five depth cameras, an IMU, and a LiDAR laser. In addition, encoder sensors have been integrated into each wheel, ensuring precise wheel odometry.

To initiate the training process, the Operator begins by mapping the environment during the **Mapping phase**. Subsequently, in the **Teaching phase**, the Operator teaches the scrubber a specific cleaning route. With the **Mapping** and **Teaching** phases successfully completed, the scrubber transitions to the **Repeating** phase, autonomously replaying the taught route while avoiding obstacles. The Advance SC1500 is capable of scrubbing for up to 6 hours on a single charge.

The machine is equipped with an intuitive touchscreen interface that provides real-time monitoring of the robot's progress within the mapped environment. For in-depth guidance on the autonomy system, please refer to the accompanying document.

Additionally, it can be manually operated at any time, allowing it to perform cleaning tasks just like the traditional product. For comprehensive instructions on proper device usage, please consult the manufacturer's complete Operator's Manual.

INTRODUCTION

There are several advantages to adopting Cyberworks's Teach & Repeat approach for indoor cleaning tasks. This method offers the flexibility to record multiple routes in the same area, catering to the Operator's preferences, whether it involves alternating between full coverage paths, high-traffic routes or any other variations.
One key benefit is its strict adherence to the designated route, ensuring the scrubber never veers into unsafe areas. From a cleaning standpoint, this approach accommodates a wide array of cleaning routes, including well-known patterns like Zamboni and ox-plow cleaning techniques. Once the map is created and the route is taught, immediate replay capability becomes available.

Throughout the **Repeating** phase, the machine detects any potential failures and notifies the Operator by email of its progress. At the end of a cleaning session, the Operator receives a comprehensive cleaning report that contains key navigation metrics.

SAFETY

> Please consult the manufacturer's complete Operators Manual for detailed instructions on proper device use.

GENERAL SAFETY INSTRUCTIONS

- This machine is intended for use exclusively by individuals who have received proper training and authorization.
- When operating on ramps or inclined surfaces, exercise caution and refrain from making sudden stops or abrupt sharp turns.
- Maintain a safe environment by keeping sparks, flames, and smoking materials away from the batteries. Charge batteries only in well-ventilated areas, far from any open flames.
- For any electrical component servicing, ensure the machine's power is turned OFF, and disconnect the batteries before commencing work.

SAFETY

GENERAL SAFETY WARNINGS [CONTINUED]

- This machine is strictly not approved for use on public paths or roads.
- Please be aware that this machine is not suitable for picking up hazardous dust.
- When operating the machine, take all necessary precautions to ensure the safety of third parties, especially children.
- Before performing any service function, thoroughly review all instructions related to that specific service task.
- Prior to scrapping the machine, be sure to remove the batteries from the unit.
- This machine should be used and stored indoors exclusively. Never store or operate it in freezing conditions, as freezing water in the solution, recovery, or detergent tanks, as well as in the hose lines, can lead to damage to valves, pumps, and fittings.
- Do not operate the machine in environments exceeding 104°F (40°C).
- Avoid spraying pressurized water onto the machine, and refrain from cleaning it with a pressure washer.
- Exercise caution and avoid driving the machine onto stairways, escalators, or areas with significant drops in elevation. Serious damage may occur if it falls down stairs. The machine is not designed to climb stairs and is intended for use on flat surfaces (with inclines less than 2 degrees).
- While manually driving the machine, it is the Operator's responsibility to avoid collisions with obstacles and individuals, as the machine does not possess autonomous safety functions during manual operation.

SAFETY

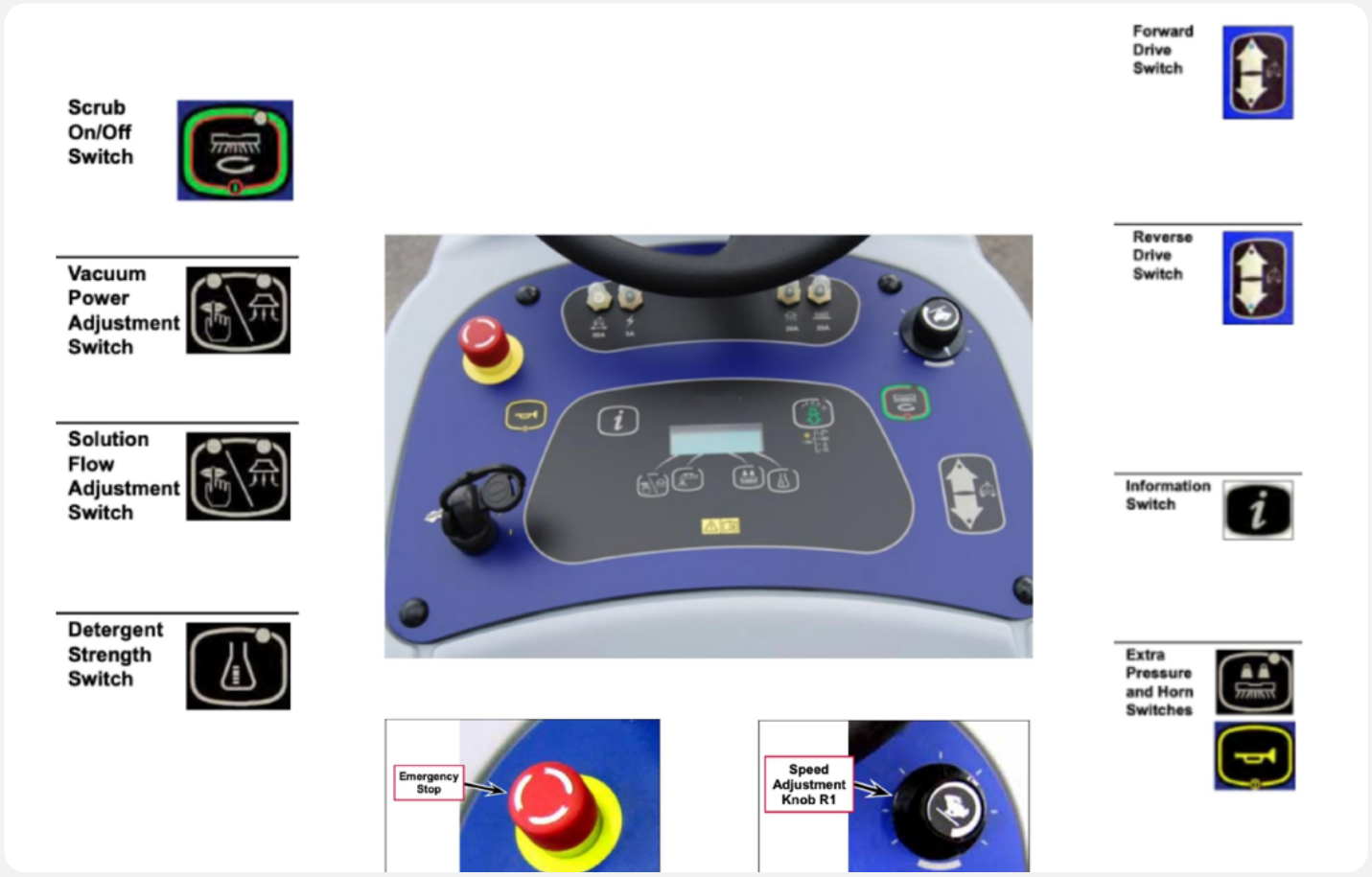
GENERAL SAFETY WARNINGS [CONTINUED]

- Following use, always power off the machine.
- Avoid dispensing flammable cleaning agents or operating this machine in close proximity to such agents. Do not use the machine in areas where flammable liquids are present.
- Unless trained, refrain from attempting to dissemble the machine.

SENSOR CAUTION

- Please refrain from any attempts to adjust the position and orientation of the sensors or open the camera housing.This could have significant impacts on obstacle detection and avoidance.
- While the machine is operating in **Mapping, Teaching** or **Repeating** Phase, do not open the lid. This action moves the LiDAR position and immediately causes an abrupt loss of localization in the map.
- Never look directly into the laser without wearing protective laser safety glasses.
- Keep in mind that the cameras are sensitive to dust. Regularly clean their lenses, particularly if the machine is stored in a dusty environment. Do not spray water directly onto the camera lenses. Also, regularly clean the laser component.
- Regularly inspect the sensors to ensure they haven't been displaced, and ensure that the laser remains parallel to the floor at all times.

KNOWING YOUR MACHINE



CONTROL PANEL

Main commands - Refer to the Operator Manual for further details.

CYBERCUBE KIT

The CyberCube kit comprises a substantial gray metal box positioned atop the machine platform. It houses the essential electronic components and devices responsible for converting the standard scrubber into a self-driving robot. Additionally, the onboard computer is located within this kit. The presence of fans on both sides of the CyberCube ensures effective heat dissipation, preventing overheating.

Left side : Laser on top of the light, left and center depth cameras

Front side : Laser on top of the light, center depth camera and bottom laser camera.

Right side : Laser on top of the light, right and center depth cameras.

KNOW YOUR MACHINE

TURNING ON/OFF THE MACHINE

The machine is equipped with two sets of keys: one for the CyberCube kit and another for the machine's power (control panel key). Both keys must be turned on to activate the robot's autonomous system. If desired, the scrubber can be manually driven without the CyberCube by turning on only the control panel key.

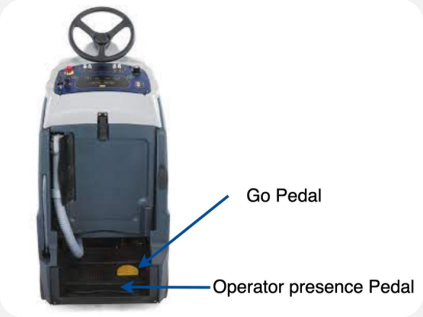
TURNING ON

To initiate the computer, turn the CyberCube key to the right. To activate the drive motors, turn the control panel key to the right. At this point, the Operator can either manually operate the scrubber or use the interface to enable the autonomous mode.

TURNING OFF

From the Interface main menu, select Quit the application to turn off the computer, then turn the CyberCube key to the left to deactivate the CyberCube. Finally, turn the control panel key to the left to deactivate the drive motors of the machine.

DRIVING THE MACHINE



- To initiate operation, stand on the platform and engage the Operator Presence Pedal to activate the driving motors.
- Press the yellow Go Pedal to engage movement. The amount of pressure applied to the Go Pedal directly influences the robot's speed.
- Fine-tune the maximum speed using the Speed knob and steer with precision using the steering wheel.
- If a change in direction is required, activate the forward/reverse switch as needed. The machine can be manually driven in reverse direction. However, note that this isn't possible during autonomous driving.

Note that when the robot is in autonomous mode, manual driving is disabled. To regain manual control, the robot must be paused, allowing the Operator to resume command.

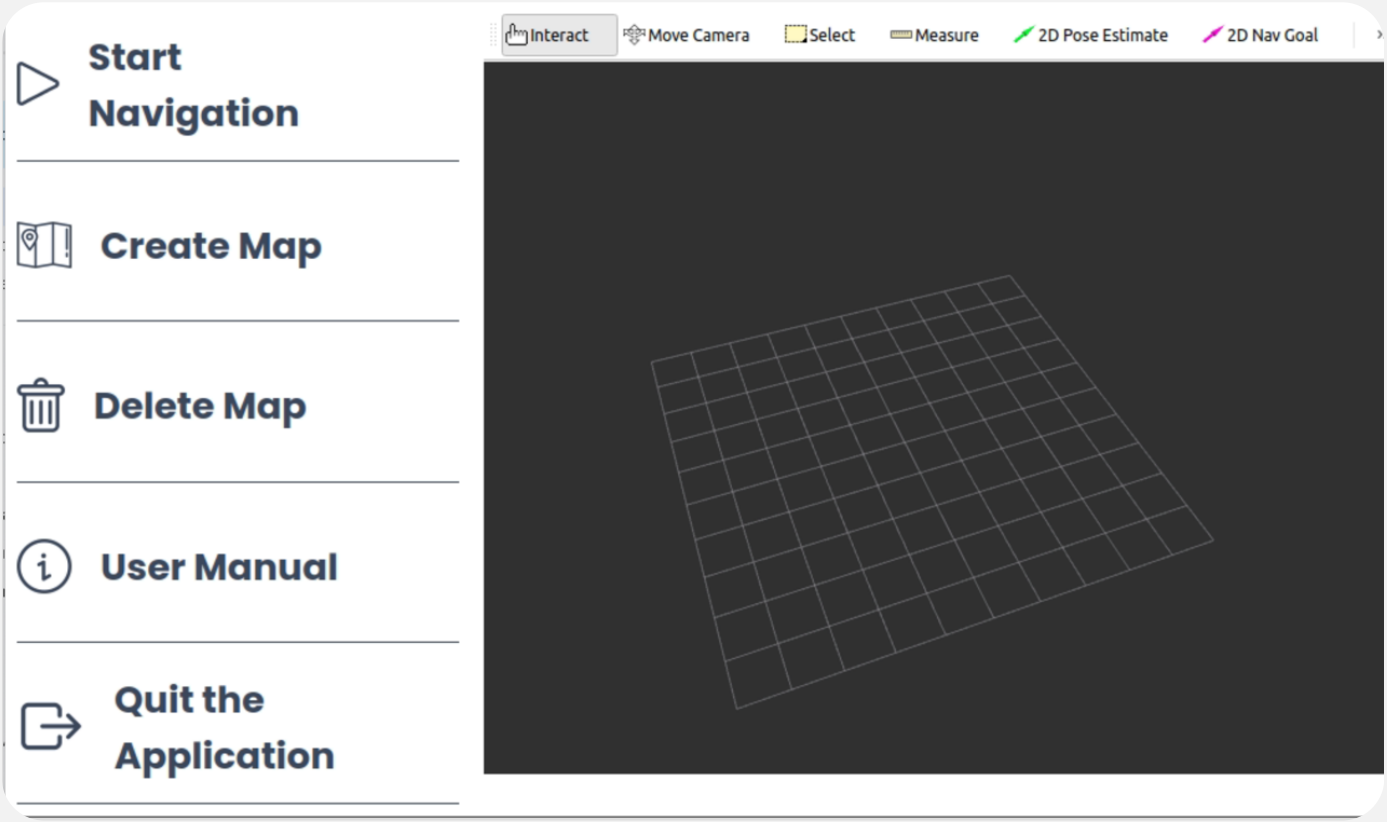
TOUCHSCREEN INTERFACE

A touchscreen interface helps the Operator navigate through the different phases. It starts at the same time as the computer, displaying the menus shown below to the Operator.

The Interface is separated into two panels :

- The left panel containing all menu options and allowing the Operator to select features based on touchscreen buttons
- The right panel displays a grid showing - when the robot is launched either in Mapping or Localization mode - the robot position update live in the current map.

START MENU (ALSO REFFERED AS MAP MENU)



MAP MENU OPTIONS (MAIN MENU)

START NAVIGATION

Select a saved map and access the Route Menu, which leads to the **Teaching** or **Repeating** phase within the selected map. The map of the environment must first be created to allow the creation or the replay of a cleaning route. The Operator can only access the Route menu if at least one map has already been created and stored in the database. Further details on the **Teaching** and **Repeating** phases are discussed later in this document. When selecting the map, the interface prompts a Localization tool, helping the Operator to easily localize within the selected map.

TOUCHSCREEN INTERFACE

MAP MENU OPTIONS (MAIN MENU) [CONTINUED]

CREATE MAP	Access the Mapping phase and save the map in the database, once completed. Further details on the Mapping instructions are discussed later in the document.
DELETE MAP	Access the database and delete any map currently saved from it
USER MANUAL	Provide more information about the current interface menu options.
QUIT THE APPLICATION	Exit the Interface and shut down the computer.

ROUTE MENU

ROUTE MENU OPTIONS

START NAVIGATION	Select a route and access the **Repeating** phase. The **Repeating** phase menu can only be accessed if at least one route in this map has already been taught and stored in the database.

TOUCHSCREEN INTERFACE

ROUTE MENU OPTIONS [CONTINUED]

CREATE ROUTE	Access the **Teaching** phase menu and save the route associated with the current map the robot is localized in, once completed. Further details on the Teaching phase are discussed later in this document.
DELETE ROUTE	Access the route database and delete any route associated with the selected map.
OBSTACLE MAP	Access the Obstacle Map menu. Further details about this are discussed later in this document.
MAIN MENU	Return to the main menu (also known as the map menu). The current map is shut down.

> This menu can only be accessed when the robot has localized within the selected map.

NAVIGATION MENU

TOUCHSCREEN INTERFACE

NAVIGATION MENU OPTIONS

START CLEANING	Engage the **Repeating** phase. The robot starts driving in full autonomy after a quick calibration routine.
BACK TO THE ROUTE MENU	Leave the Navigation menu and access back the Route menu.

Once navigation is started, the Navigation menu and access back the Route menu

PAUSE CLEANING	Pause the robot temporarily at any time during the cleaning session. The Operator can unpause it by clicking on the Resume button that appears once the robot is paused
END CLEANING	Terminate current cleaning session

MAPPING PHASE

WHATS A MAP?

Before teaching the robot specific routes, it is imperative to generate a comprehensive map of the environment. This map serves as a repository for all the environmental data captured by the robot at laser height, including walls and large static obstacles. This map enables the robot to precisely track its position during subsequent phases.

The **Mapping** phase serves as a prerequisite for both the **Teaching** and **Repeating** phases.

From the Operator's perspective, this entails executing an environment exploration routine through manual driving, called **Mapping**. Throughout this process, the LiDAR captures environmental data and saves it into a graph, enabling the robot to later recollect previous locations it has memorized and localize within them. Typically, the **Mapping** process for an environment is only required during the robot's on-site installation. However, in the event of substantial changes in the environment - such as a complete overhaul of its configuration with larger, semi-permanent obstacles that may obstruct the existing taught cleaning routes - it is strongly advisable to create a new map, associated with fresh cleaning routes.

The map undergoes continuous real-time updates as the robot explores the environment during the **Mapping** phase. After saving the map, the Operator can localize the machine back in it, following a **Localization routine**. A map can contain several routes associated with it, depending on the area the Operator wishes to clean.

It is essential to rigorously follow the routine to ensure the robot maintains accurate localization throughout the entire **Repeating** phase, preventing any chances of getting lost.

PREPARING THE SCRUBBER

> Before engaging **Mapping**, consider the current status of the machine sensors and the environment to be mapped :

- Begin by checking the LiDAR's alignment to ensure it is parallel to the floor. Clean it.
- Carefully inspect the camera lenses and remove any potential obstructions to maintain clear vision.
- Check on the environment to be mapped. Consider the most suitable routes for its cleaning purpose and identify any areas where the robot should never navigate. It is crucial to have a clear plan for the cleaning route before starting the **Mapping** process.
- Take into account the size of the environment to be mapped. Are there distinct sections within it, such as rooms, atriums, or corridors? Treat each of these areas as separate mapping sections.
- When choosing a starting point for the map, prioritize locations that are easy to remember whenever feasible. It's advised to steer clear of selecting a starting location in close proximity to obstacles. In the future, whether creating a new route associated with the map or replaying a route, the Operator is asked to guide the robot back to this specific location to ensure accurate localization within the map. This underscores the strategic significance of choosing this position thoughtfully (Check the Localize back in the environment section of this document for more details).

MAPPING PHASE

PREPARING THE SCRUBBER [CONTINUED]

- Carefully drive the machine to the chosen starting location.
- Access the **Mapping** menu by selecting Create a Map on the touchscreen interface.

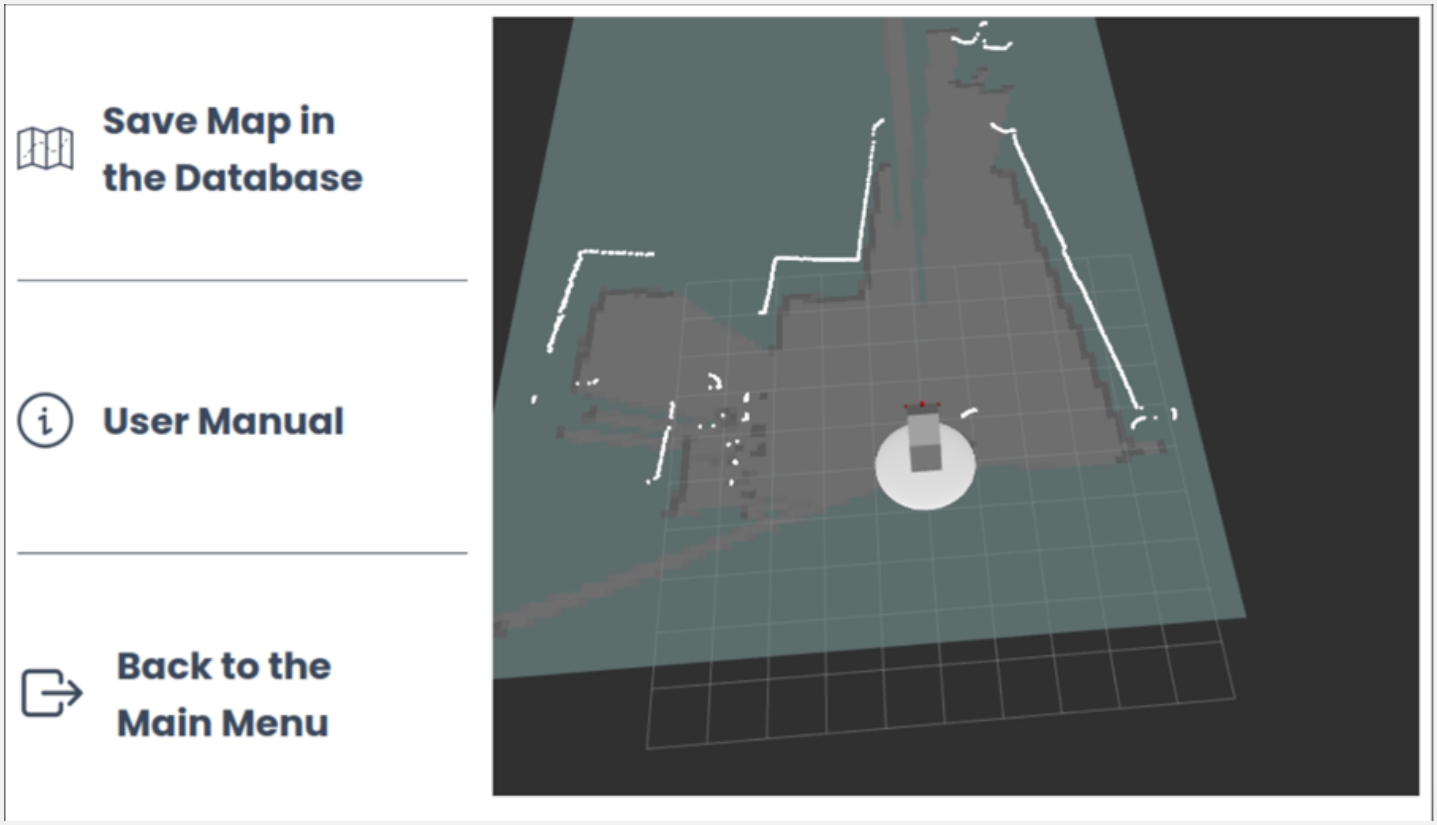
NAMING A MAP

A window appears, prompting the Operator to provide a name for the map. When selecting a name for the map, be specific. This ensures that any future Operator can effortlessly identify the required map during subsequent sessions.

Consider using descriptors such as the current floor number where the robot operates ("Lower_Floor," "First_Floor," "Lobby," etc.) or pinpoint a particular room or office that can be easily recognized ("Company_Name_Office," "Loading_dock"). Once the full name has been entered, press the OK button. Please note that only the following characters are permissible: [A-Z], [a-z], [0-9], "_," and "-." If the name chosen corresponds to an existing map in the Database, the system throws an alert and requests a different name.

To replace an existing map with a new one bearing the same name (ie: remake a saved map), follow these steps: select Delete Map from the Interface Starting menu and select the desired map, then choose Create Map, re-enter the name and start remapping the environment.

BUILDING AND SAVING A MAP IN THE DATABASE



MAPPING PHASE

BUILDING AND SAVING A MAP IN THE DATABASE [CONTINUED]

> The map display window appears on the right side of the Interface, as depicted in the image on the following page. This window provides a real-time view of the environment as perceived by the sensors. The LiDAR scan is visually represented as a white line, and the robot's location is indicated by green circles. The initial map location is also represented as a white circle. The map itself consists of a 2D rendering of the environment, where obstacles are depicted as black lines, and open spaces are represented in white on the computer screen. Please note that the map only includes objects detected at the 2D LiDAR's height.

The system is now ready to begin the **Mapping** process. To create the most accurate map possible, follow these instructions for each identified mapping section:

01 Starting from the initial position of the section, navigate the robot along the perimeter of the section in a clockwise direction, following the room's layout. The map begins to take shape as the robot explores the area. Continue exploring close to the walls until the platform returns to the initial section position or where the loop initially began.

02 As the robot recognizes that it has revisited this location, it updates its position accordingly, a process known as Closing the Loop. This correction can be visually observed on the Interface as it rectifies accumulated errors in the map graph. Regularly check for these corrections and use the Interface touchscreen to monitor the graph's quality.

03 Drive the robot around the same loop once more, returning to the initial position, to ensure proper loop closures for the entire loop.

04 Perform two consecutive loops in the counterclockwise direction, as the robot needs to capture the environment layout in both directions, considering the LiDAR's limited scanning capability. Come back at the initial position of the section.

05 Starting from the initial position of the mapping section, explore all areas that will be covered during the cleaning session. It is advisable for the Operator to simulate the cleaning route at this stage to ensure optimal mapping and localization. The more comprehensive the robot's exploration, the more accurate the map and the safer the robot's performance during the **Repeating** phase.

06 Return to the initial section location and briefly assess the map quality. If validated, proceed to the next mapping section. This new location will serve as the initial position for that section. If not validated, drive more clockwise and anticlockwise loops until the quality of the map improves

07 Repeat the previous steps for each section of the mapped environment.

Only once all sections have been successfully mapped should the Operator save the map in the Database:

08 Drive the machine back to the initial position of the map, which corresponds to the initial location of the first mapping section, once the entire environment has been explored.

MAPPING PHASE

BUILDING AND SAVING A MAP IN THE DATABASE [CONTINUED]

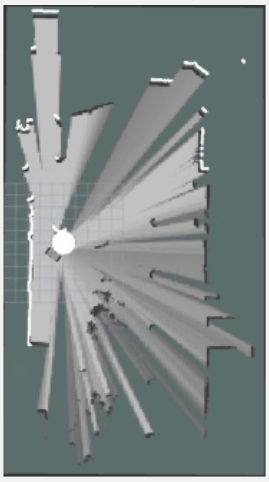
09 Click on Save map in the Database and wait for the system to return to the map menu. The map has been successfully saved. Returning to the initial map position allows the cameras to capture screenshots of that location and assist the Operator in localizing back within the environment.

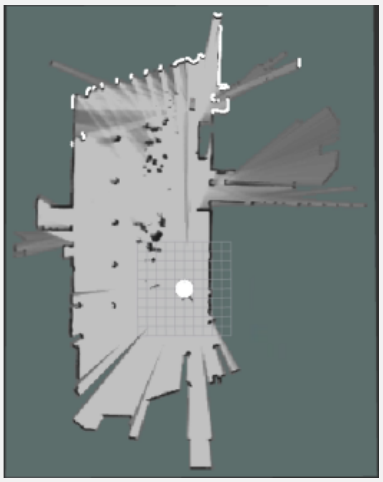
GOOD MAP VS BAD MAP: MAPPING AN ATRIUM

Example of a Good Map:

01 Atrium layout fully visible as black lines.

02 All cells within the atrium are marked as explored with a clear gray color





Example of Bad Maps:

Left Map

01 Atrium layout not fully completed

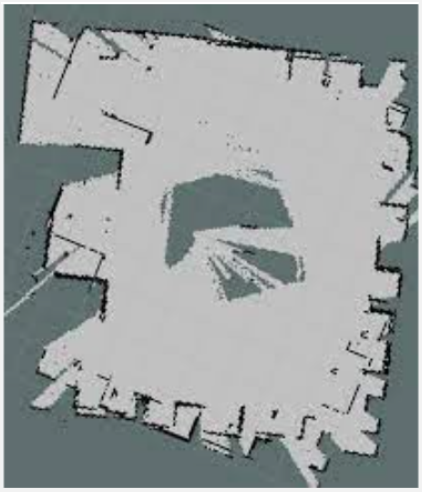
02 Lots of unknown cells within the Atrium marked with a dark gray color

Right Map

01 Atrium layout appears completed

02 Still unknown/unexplored cells within the Atrium. This map requires one extra loop to explore the environment more thoroughly.

These unexplored areas could lead to mislocalization occurrences later during navigation. As a rule of thumb, ensure the entire environment that needs to be cleaned is explored to ensure optimal navigation. Sometimes, loop closures may not work directly (see picture below). In these rare occurrences, it can visually look as if new walls are created and cannot be matched to the existing layout. More loops may be needed to explore the zone to fix these issues until a new loop closure happens. If the loop closure still didn't happen after a few more loops, it may be best to start a new map session.



LOCALIZE BACK IN THE ENVIRONMENT

Once at least one map has been saved in the robot database, the Operator gains the capability to select a map from the main menu for two primary functions: recording a new route associated with the selected map or repeating a cleaning session. However, before accessing these features, an initial quick localization phase is essential to ensure the robot knows where it is when the map is uploaded. To successfully localize the robot, follow these instructions:

01 From the main menu, select Select Map and choose the desired map from the robot database.

02 The localization tool then appears, displaying the camera snapshot captured at the initial map location when the map was saved (on the left) and the current camera stream seen by the camera (on the right). Use this tool to drive the robot until the right image roughly matches the left image position. It's not necessary for a perfect match, but the alignment should be reasonably similar, facing the same direction.

03 Once the robot is in proximity to the initial map location, press Ok. The system then checks for images matches and allows the Operator to correct the position back in case of mismatch detection. If it finds a successful images match, the system then enters localization mode, a process that typically takes between 30 seconds to a minute. After this, the robot should appear directly localized within the environment, as displayed on the right panel of the Interface.

04 The Interface Route Menu is now directly accessible to the Operator and can be used to teach a new Route associated with the map or replay a Route already saved in the database.

Please be aware that at any point during the localization procedure, the Operator has the option to cancel it by selecting Cancel or clicking the x located at the top right corner of the window. In such a case, the software redirects the Operator to the main page of the touchscreen Interface.

TEACHING PHASE

WHATS A ROUTE?

A route is a collection of points saved during the **Teaching** phase, mirroring the exact path manually traversed by the Operator. Each route is associated with an existing map. The **Teaching** phase is only accessible to the Operator once a map exists in the robot’s database. To access the Route Menu, navigate to the touchscreen Interface by clicking on Select Map and select the desired map. Ensure that the selected map aligns with the robot's present location within the environment. For instance, when choosing the "Lobby" map, confirm that the robot is indeed located in the lobby at that moment. Follow the Localization routine to properly start the system in the map.

NAMING A ROUTE

Once within the Route menu, proceed by selecting Create Route. A dialogue box appears, requesting a name for the route. It's advisable to be as specific as possible to facilitate future selections by other Operators. Once the name is entered, click OK. Please note that only the following characters are allowed: [A-Z], [a-z], [0-9], "_," and "-."

In the event that the entered name corresponds to an existing route already present in the Database, the system prompts the Operator to enter a different name. To replace an existing route with a new one bearing the same name, follow these steps: select Delete Route from the Interface route menu, then choose Create Route and re-enter the desired name.

TEACHING AND SAVING A ROUTE IN THE DATABASE

The **Teaching** phase involves the manual operation of the robot to establish the desired cleaning route. Here's a step-by-step guide:

01 Manually maneuver the machine to the initial position of the route as indicated by the Interface pop-up window

02 Click OK to initiate the Teaching process.

03 Drive the robot along the intended cleaning path, and observe as the route materializes on the screen as a real-time pink line. The system can safely learn any cleaning pattern, whether it's a Zamboni-style or u-turns, for instance.

TEACHING PHASE

TEACHING AND SAVING A ROUTE IN THE DATABASE [CONTINUED]

04 Upon completing the Route, press Save Route in the Database. Wait for redirection to the Route menu. The option to **Repeating** the Route becomes immediately available by clicking on Start Navigation.

05 The Route can be cancelled anytime by pressing the Cancel Route button.

TIPS

Here are additional guidelines to consider during the Teaching phase:

- Avoid selecting a starting route location directly in front of or too close to a static obstacle. It's also recommended not to begin the route with a sharp turn.
- Ensure that the entire route falls within the map boundaries, as localization may not work reliably outside the map during the Repeating phase.
- The robot can only autonomously drive forward during teaching; avoid driving backwards when teaching the route.
- While it's possible to stop the robot and execute sharp turns during teaching, this maneuver is not recommended. The navigation software smooths out turns during the Repeating phase.
- Maintain a minimum distance of at least a foot from walls or obstacles during teaching. The navigation software corrects the robot's trajectory if the route is considered too close to an obstacle during the Repeating phase. In rare cases, the robot might get stuck during **Repeating** if the taught path is too close to an obstacle.
- Teach the entire route in a single go, but short interruptions during teaching are allowed.
- While the Operator is teaching the route, the system monitors the robot's localization. In the event of a sudden, significant deviation in localization, the system alerts the Operator. Such high localization jumps typically occur when the map quality is suboptimal, often stemming from incomplete or inadequate mapping procedures. In such cases, it is strongly recommended to rectify the situation by creating a new map and route. Addressing mislocalization is crucial, as it can significantly affect the overall safety and reliability of autonomous navigation.

TEACHING PHASE

OBSTACLE MAP

OBSTACLE MAP MENU

Another valuable feature available through the interface is the manual addition of obstacles within the map using the Obstacle Map tool. This optional functionality can prove essential in certain scenarios, such as when the environment includes potential hazards like glass walls or staircases that may not be detected by the LiDAR or cameras. The Obstacle Map allows for the creation of virtual fake obstacle lines within the map, which can be detected by the sensors and considered as real obstacles. Additionally, it can be employed to prevent the robot from venturing into specific map locations when necessary. To add obstacles to the map, follow these steps:

01 Begin by selecting Obstacle Map from the Route menu.

02 Drive to the part of the map where an Obstacle needs to be added. On the virtual touch keyboard, press the key P and use the arrow to select your first obstacle point. Obstacles are registered as lines so a second point is required to complete the obstacle creation.

03 Any error can be corrected by pressing Remove Obstacle

04 Repeat the process until all obstacles have been collected within the map.

05 Once completed, press Save Obstacle Map. Wait for redirection to the Route Menu.

The Obstacle Map becomes immediately visible within the map and active for navigation. It is displayed in blue on the Interface and is treated by the navigation system as a regular obstacle that the robot will actively avoid.

REPEATING PHASE

This phase is only accessible to the Operator once both a map and route associated to the map exist in the robot's database. It can be accessed directly from the Route Menu. To access the Route Menu, navigate to the touchscreen Interface by clicking on Select Map and select the desired map. Ensure that the selected map aligns with the robot's present location within the environment. For instance, when choosing the "Lobby" map, confirm that the robot is indeed located in the lobby at that moment. Follow the Localization routine to properly start the system in the map. The robot appears localized in the environment and ready to repeat a route.

REPLAY A ROUTE: AUTONOMOUS NAVIGATION

Here are instructions on how to initiate autonomous navigation:

01 Start by clicking on Start Navigation and select the desired route. This action prompts a red arrow on the map, indicating the starting position of the route.

02 Manually drive the machine to the marked position of the red arrow. Ensure that the robot is sufficiently close to the arrow and is facing in the same direction.

03 Click on Start Cleaning. If the robot isn't in close proximity to the starting position, a warning window appears, prompting the Operator to drive the robot closer to the arrow and try again. The **Repeating** phase can only start once this condition is met.

REPEATING PHASE

REPLAY A ROUTE: AUTONOMOUS NAVIGATION [CONTINUED]

04 Ensure that the washer is currently raised, then press OK.

05 Turn the steering wheel all the way to the right to ensure proper calibration during autonomous navigation. The robot's start time can vary, depending on the length of the route. Once the robot is ready, press OK. The steering wheel self-calibrates, the washer goes down, and the robot can now engage fully autonomous navigation along the taught route.

05 At any point during navigation, the system can be paused. To do this, press the Pause button. This halts the robot's movement while keeping the session active. To resume navigation, press the Resume button. When the robot is paused, the Operator can manually drive it if needed.

05 Once the route is completed, press End Cleaning to return to the route menu. The Operator receives a complete report of the latest cleaning session.

POTENTIAL INTERVENTIONS

> In some cases, certain obstacles may cause the machine to come to a complete stop. When this happens, an email notification is sent to the Operator. In such situations, manual intervention is necessary.

- If it's feasible, remove the unexpected obstacle from the robot's path. If this obstacle is likely to remain in the environment permanently, consider creating a new route that avoids this obstacle. As a rule of thumb, it is encouraged to maintain a foot from all obstacles while teaching a route.
- If removing the obstacle isn't an option, manually control the robot to navigate past it. To do this:

01 Press the Pause button on the Interface. This temporarily halts the robot's autonomous navigation

02 Manually drive the robot around the obstacle until it's in a safe position on the cleaning path.

03 Press the Resume button on the Interface.

MONITORING

CLEANING REPORT

> Here is an example of a cleaning report that is sent to the Operator once the route has been successfully repeated.

The document provides a visual representation of the cleaning process, including:

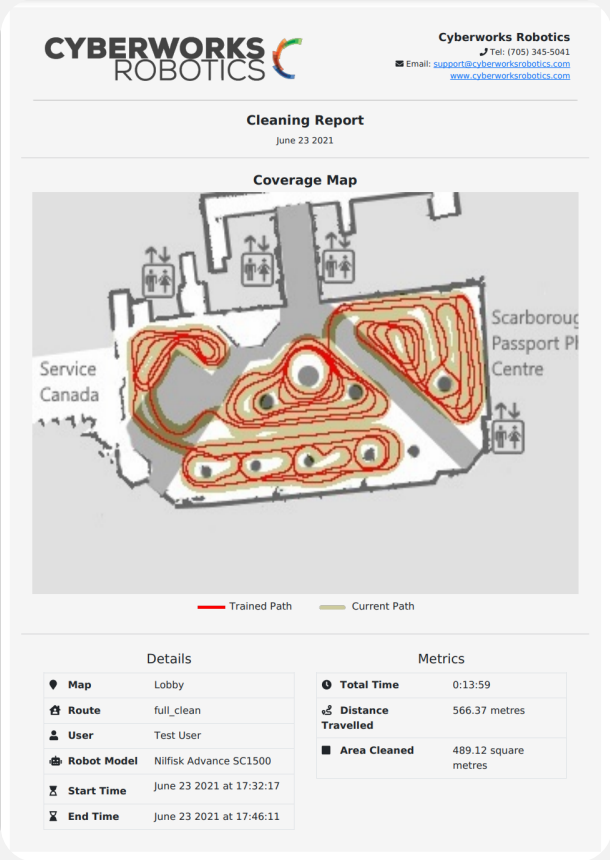
- A map with the trained path highlighted in red.
- The current path taken by the machine during the cleaning session, displayed in yellow.

This visual representation allows the Operator to easily identify when the Robot encountered unexpected obstacles and how closely it followed the trained route.

In addition to the visual data, the report includes essential metrics such as:

- The duration of the cleaning session.
- The total distance traveled by the robot.
- The area covered during the cleaning session.

These metrics offer valuable insights to the Operator to help assess the efficiency and effectiveness of the cleaning operation.



CYBERWORKS ROBOTICS

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www.cyberworksrobotics.com

Cleaning Report
June 23 2021

Coverage Map

Details

Map	Lobby
Route	full_clean
User	Test User
Robot Model	Nilfisk Advance SC1500
Start Time	June 23 2021 at 17:32:17
End Time	June 23 2021 at 17:46:11

Metrics

Total Time	0:13:59
Distance Travelled	566.37 metres
Area Cleaned	489.12 square metres

FAILURE MONITORING

Each robot comes equipped with a failure detection system, akin to the principles employed in an airplane's black box. This system continuously monitors the real-time status of all machine components. Upon detecting any anomalies, the system employs the following procedures:

- The system assesses the severity of the issue.
- If an anomaly is detected, the system alerts the user.

It's important to note that the system categorizes anomalies into different severity levels:

01 **Severity 1:** This level signifies a low risk to the system. While the issue is recorded for future reference, the machine is not paused or halted.

REPEATING PHASE

FAILURE MONITORING [CONTINUED]

02 **Severity 2:** This level indicates a moderate risk to the system. When such an issue is detected, it is recorded for future reference, and the Operator is promptly notified via email. The robot's autonomous navigation is temporarily paused. After acknowledging the alert by pressing Ok, the robot can resume its operation with full autonomy.

03 **Severity 3:** This level signifies a significant risk to the system. The system records the problem for reference, and the Operator receives an immediate email alert. Simultaneously, the robot's operation is halted, and the ongoing cleaning session is aborted for safety reasons.

Please find below the table list of current potential issues:

Internal Failures	Sensors	Software	System Failure
• Temperature Monitoring • Memory Monitoring • CPU usage • RAM Usage	• Sensor Streaming Detection • Sensor Frequency Monitoring	• Software Issues detection • Node status monitoring	• Steering Failure • Collision • RobotStuck • Robot Not Moving • Low Battery

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