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Autonomous Medicine Delivering Robot for Elderly Care

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Abstract
The field of autonomous robotics is expanding quickly. Robots are used in almost every aspect of modern life, from homes and hospitals to businesses and military operations. Autonomous robots have evolved to be powerful enough to operate alongside humans and do tasks effectively. Humans naturally sense information about the physical forces at work in their environment, such as gravity, the sensation of motion, etc. The autonomous delivery robot is meant to give medicine to the elder person. The delivery robot is capable of moving a defined path to give medicine to elder people with voice output. And also give intimation about whether the person takes medicine or not.

1. INTRODUCTION

The robotic, which is sometimes referred to as the next technology generation, has undoubtedly improved many aspects of our life, such as the military, education, and other fields.Since robots have advantages such as low labour cost and consistent working performance, their dominance in several fields has sparked a new revolution in real life. In other words, robots have been deeply ingrained in society, yet much work still has to be done to develop their capabilities. For instance, within the coffee save of the future, the robotic not only makes the coffee, but also precisely provides by way of itself. An autonomous robot that can deliver food will reduce labour costs significantly, but the route to the destination may not always be clean and safe. As a result, a solution is needed to allow robots to recognise their surroundings and respond appropriately, but their inability to avoid obstacles raises safety concerns. Detection, analysis, and control systems with high performance can reduce failure rates. The price would be too high for industrial uses, though. Because of this, the transport robot continues to be a long way from daily life.

Objective

The primary goal is to create an autonomous non-humanoid robot that can provide medication to patients.

2. LITERATURE SURVEY

In this work, robotic medicine distribution in hospital wards utilising artificial intelligence techniques is examined due to the safety and medical concerns of patients and the people handing over medications in a timely manner. Using an intelligence-based algorithm based on sensors and indicators marked in the wards, the robot moves through the areas where the medication needs to be provided in the quickest possible route. The robot then leaves the area. The robot would be protected from human and robot collisions by the programme, which would also look for the location of the indicator where the medication needed to be supplied quickly. By doing this, we may make sure that infectious diseases are not spread throughout the hard process of delivering medications as well as when compared to manual completion of the same task. Using a firebird V robot in the lab for the algorithm, this proposed method's functionality and algorithm were successfully tested on a prototype arena. The suggested method is simple to implement, saves time and human resources, and can be tracked externally by the health centre reception.

Since China reported the first incident in December 2019, officials have recorded roughly 174.4 million coronavirus illnesses and 3.8 million fatalities as of June 2021. This knowledge was obtained from CNN-Health.The "MedBuddy" project seeks to lower the incidence of coronavirus outbreaks among clinical staff members and medical specialists who provide care and medication to isolated patients in general wards. To achieve this, an Arduino Uno microcontroller is used to build a Bluetooth-controlled robot car that is outfitted with a spare phone whose digital camera can stream live video to MIT App Inventor software. The robot has a tray that makes it simple and safe to add medication to patients while standing a distance away. As a result, patients will receive their medications on time, and unnecessary contact with the patients will be reduced, lowering the risk to medical staff. People who are compelled to live at home because of the coronavirus situation in the area have serious worries about secure and contactless home delivery services. We have presented a prototype robot that could be very useful in lowering the risk of infectious disease transmission inside the product delivery equipment due to the current focused focus on healthcare and sanitation. An autonomous mobile robotic prototype that successfully carries programmes to a target location using the GPS has been designed and developed.The delivery package is held by the robot in a password-protected container, ensuring a smooth delivery without any human interaction. By receiving GPS coordinates from satellites and adjusting its trajectory with the aid of a virtual compass, the four-wheeled driven robot can successfully navigate to a specific area. The robot waits for the user to release the field when it reaches its destination. The customer must provide a password after delivery in order to unlock the container and obtain the goods they ordered. The customer can receive this password along with the message confirming their order. The robot has the ability to return to its starting location on its own once the shipping has been completed. The heading attitude accuracy check and the trajectory of completion accuracy test has been used to gauge the robot's accuracy. In addition to significantly reducing last-mile transportation costs and delivering a product free of infection hazards, our robot can be a powerful technical solution to the last-mile problem.

The effective and efficient transportation of numerous commodities in hospitals depends on logistic management For the treatment of patients who require specialised care because to the quarantine protocol, a specific in-patient cohort unit is established during pandemic scenarios, such as COVID-19. In order to maintain the physical separation between patients and medical staff, autonomous mobile robots (AMR) are utilised to bring meals and medical supplies to specific patients. This study simulates the delivery of care utilising multiple AMRs operating in the in-patient ward. AMR operations in various settings are studied using simulation software created on the Unity platform.

Proposed system

We suggest a novel method for a robot system that administers medication. An IR sensor and a microcontroller make up the suggested system. To administer medicine to the elderly person at the appropriate time, the robot follows a predetermined path. to announce the taking of medicine through voice output. The IR sensor tracks whether or not the drug is taken. A warning message is delivered to the family members if the patient refuses to take the medication.

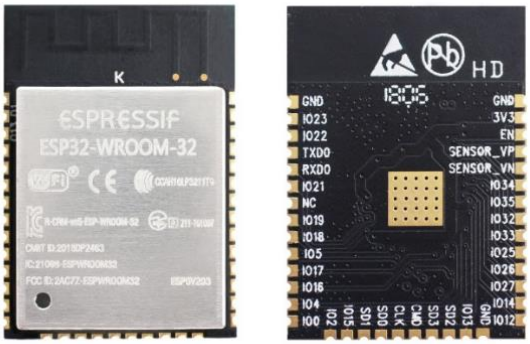
Description of Modules:

MICROCONTROLLER

ESP32

For those new to the world of microcontrollers and embedded systems, Arduino is a fantastic platform. With several accessible sensors and modules, you may launch a number of projects, either for fun or possibly for profit. The Internet of Things, sometimes known as IoT, is one specific idea that came into play as generational advancement occurred. It is a platform that allows information to be shared with a variety of "things" or devices over the internet. In the DIY community, home automation and smart home applications are the most popular Internet of Things projects, however the implementations of commercial and business IoT programmes are far more complicated.This brief introduction's key

argument is that any IoT project, whether it's a straightforward hobby project or a complex industrial enterprise, needs Internet access. This is where gadgets like the ESP32 and ESP8266 are useful. If you need to incorporate Wi-Fi connectivity into your projects, the ESP8266 is a fantastic choice. But ESP32 is your only choice if you want to create a fully functional device with Wi-Fi, Bluetooth, high-precision ADCs, DAC, serial connection, and many other capabilities. What exactly is ESP32? The same business that developed the well-known ESP8266 SoC also produces a low-cost System on Chip (SoC) Microcontroller called the ESP32.The ESP8266 SoC is replaced by Tensilica's 32-bit Xtensa LX6 Microprocessor, which comes in single-middle and dual-center versions and has integrated Wi-Fi and Bluetooth. The presence of RF components such a power amplifier, low-noise receiver amplifier, antenna switch, filters, and RF balun is the primary distinction between ESP32 and ESP8266. As only a few external components are required, this makes creating hardware for the ESP32 quite straightforward. It's also very important to know that the ESP32 is produced utilising TSMC's ultra-low-energy 40 nm technology. As a result, employing ESP32 must be quite straightforward when developing battery-powered programmes for items like wearable technology, music equipment, baby monitors, smart watches,etc.



16×2 LCD

Crystal display for liquid Sizes range from 8x1 to 8x2, 10x2, 16x1, 16x2, 16x4, 24x2, 30x2, 32x2, 40x2, etc. Numerous multinational companies, like Philips, Hitachi, and Panasonic, produce their own special sort of LCD for use in their products. All LCD panels perform the same functions, including displaying characters, numerals, special characters, ASCII characters, etc. They all share the same programming and have the same 14 or 16 pins (0–13). Alphanumeric presentations are used by many devices, including mobile phones, word processors, photocopiers, point-of-sale terminals, handheld computers, and more.

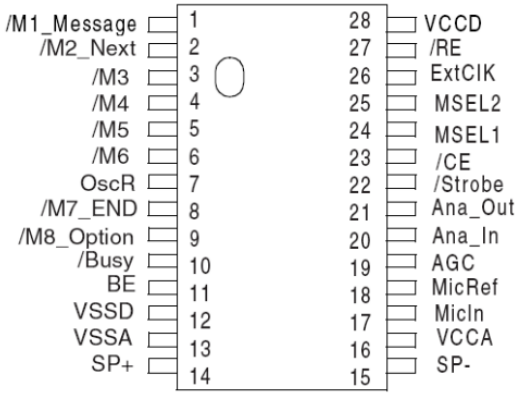
Product Description

It is a customised LCD screen for E-blocks. A single, 9-way D-type connector and a 2-line, 16-character alphanumeric LCD display are included. This allows the tool to be connected to as many E-Block I/O ports as possible. Records for the LCD display must be in a serial format, as outlined in the user manual below. Additionally, a 5V power source is required for the presentation. To avoid damaging the gadget, please be careful not to exceed 5V. The E-blocks Multi programmer or a 5V fixed regulated power supply work best for producing 5V. The sixteen by two intelligent alphanumeric dot matrix display can display 224 unique characters and symbols.

VOICE IC-APR9600

The APR9600 tool provides playback, non-unstable storage, and 40–60 seconds of genuine single-chip speech recording. The programme makes it simpler to read both randomly generated and sequential texts. Users' choice of sample rates enables designers to adapt their concepts for certain quality and storage concerns. The device can be used in a variety of consumer and commercial applications, including toys and portable speech recorders. Using a sophisticated Flash non-risky memory approach that allows each memory module to hold 256 voltage levels, PLUS integrated is able to reach high levels of storage performance. Now, voice indicators can be produced using the APR9600 tool in their original format. There is no longer a need for encoding and compression, which frequently result in distortion.

Pin diagram of APR9600



Message Management

Message Management General Description

On-chip circuitry is used to help regulate playback and report activities. Various messaging modes are available based on the required operation. The message control style, message length, and outside element count are determined by these message modes. As a result, the designer should choose the optimal running mode before beginning the design. Operating modes are no longer a determining factor in voice quality; for details on the variables that do, see the Sampling Rate & Voice Quality section. The gadget is compatible with the subsequent three message control modes: which are illustrated in Figures 1 and 2 by the MSEL1, MSEL2, and /M8_Option pins: • Random get right of entry mode with two, four, or eight messages of a fixed length• Tape mode offers the following possibilities with a few messages of varying lengths:

- Auto rewind

- Normal

Modes cannot be mixed. It is not recommended to swap modes once the first message has been recorded on the device. After making a preliminary recording, moving between modes may also leave a few inconsistent message fragments behind that are audible when played back in the new mode.After a document operation inside the newly chosen mode, these pieces will vanish. The significance of choosing the preferred mode for interpreting is defined. One important aspect of the APR9600 message control is its capacity to audibly notify the user of changes in the device's state via "beeps".
It is superimposed on the output of the gadget. Maintaining an excessive degree of common sense at the BE pin enables this trait.

Recording in Random Access Mode: Functional Description
As soon as it is turned on, Any enabled communication segment can be recorded or replayed by the device. If the BE pin is high, enabling the beep tone to be played, the tool reacts with a single beep at the speaker outputs to indicate that real recording has begun. If the message cause pin is left low for longer than is authorised, regardless of its position, the recording terminates instantly. Once the message cause pin is high again, the chip switches to low-electricity mode. The chip enters standby mode following a second time the message cause pin is set to high. Recording will begin at the beginning of the equal message segment at the subsequent high-to-low transition at the equal message cause pin. The new message then fully replaces the previous one, regardless of how long it is.

Functional Analysis of Random Access Playback
As soon as strength is enhanced, the tool is prepared to report or playback in any of the enabled message segments. If a high to low area occurs while the current message is still playing back, it is immediately stopped.. If a good message reason pin pulses in the playback direction, the current message is stopped immediately, and the next message phase is started. Before the tool starts loading the new message, the pattern clock may take up to 8,400 cycles to complete one cycle. A message cause pin will repeat the chosen message if it is held low for an extended period of time. To let the listener know when the message is about to cease and begin, looping can add an 8-second silence followed by 400 ticks of the Sampling clock.

Tape Mode:
Tape mode manages messages in a manner akin to vintage cassette tape recorders. Tape mode has two settings: auto-rewind and standard. When the system is set to auto rewind, after recording or replaying a message, it will immediately resume at the beginning. Similar to a conventional cassette tape recorder, messages must be recorded or performed consecutively in tape mode.

Recording in Tape Mode with the Normal Option according to the Function Description
The system has been turned on and is prepared to begin recording or playing back from the beginning of the memory array.When the recording is complete, the system will immediately resume playing the most recent message that was previously recorded and wait for further user input. Since there is no need to rewind, the auto-rewind option enables instant replay and message interpretation. Care must be exercised because unless the user remembers to pulse the Next pin to advance the device past the current message, the last message recorded will be overwritten by the subsequent report action. An existing message and a new file action are both overwritten by successive falling faces on the Message pin. The previous recorded message can be preserved by using the Next input to begin recording in the next available message segment. A user can completely file over the prior message in the vehicle mobile rewind mode by beginning a file series without first activating the Next pin. However, there is a particular order that must be taken in order to record over another connection. To start over at the beginning of the voice memory, pulse the pin low once. In order to advance to the beginning of the message you want to overwrite, the Next pin should be pulsed low for the required number of times.

You can begin a report collection when you reach the desired message to replace the previously recorded content. The only message that is still accessible after replacing this one is the one that was originally recorded. If the tool runs out of memory while processing a document, it will double beep and stop recording right away while holding the END pin low for 1600 sample clock cycles. Playback will start in this final message if the Next pin is pulsed after that point, at which point the tool will enter a "overflow state." Following the tool's entry into an overrun kingdom, any further pulses on Next or Message will only result in a double beep and a momentary low setting of the END pin equal to 400 cycles of the pattern clock. The tool needs to be turned back to the start of the memory array in order for the user to continue.

Playback in Tape Mode with the Normal Option Function Description:
During a document operation, if all available memory is used up, the tool will immediately stop recording (double beep) and keep the END pin low for 1600 cycles of the sample clock. If the Next pin is pulsed after playback has begun in this final message, the tool will enter a "overflow state." Any additional pulses on Next or Message after the tool enters an overrun kingdom will only cause a double beep and a temporary low setting of the END pin equal to 400 cycles of the pattern clock. The tool needs to be turned back to the start of the memory array in order for the user to continue. The playback of the current message restarts at the beginning when the Message pin pulses low three times. The same message will play and loop if the Message pin is held low all the time. The user is informed of the change in the message's beginning and ending positions via a 1,530 millisecond pause added when looping.. When in auto-rewind mode, keep in mind that the device always goes back to the beginning of the current message. The gadget must be fast-forwarded past the current message to the following message in order to listen to a subsequent broadcast. The Next pin is adjusted from high to low to achieve this. For at least 400 cycles of the sample clock, the pulse must be low. The user can start message playback using the previously specified playback technique once the device has advanced to the selected message. When playback starts and the Next pin goes low, an odd thing happens. The gadget will beep, go to the next message, and start playing that message after the current message has finished playing. The system will beep, reset to the first message, and wait for another playback instruction if the /CE pin drops low while playback is in progress.After reaching the end of the memory array, if you pulse the Message or Next pin again, you will only hear a double beep. The user must spin the device backward to the start of the memory array in order to continue past this point. To do this, you can either cycle the power or set the /CE pin to low.

Functional Description for the Auto Rewind Option when Recording in Tape Mode
As soon as the device is powered on, it is ready to record or playback, starting at the first handle inside the memory array. To allow the device and recording, respectively, you must first turn the /RE and /CE entrances to low. The instrument will beep and start recording as soon as the Message pin starts to fall. The recording will stop and be replaced with a single beep on the Message pin. Whatever the message pin's position, if it is maintained low past the available memory limit, recording instantly stops and sounds are added. When the Message pin is raised, the device goes into standby mode. A subsequent dropping aspect starts a new document action on the Message pin. The memory array is now preserving the final recorded message because it is doing so in line with the final recorded message.

After the device has been reset to the initial message, the /CE pin must be pulsed low in order to record all prior messages. After that, you can begin a document sequence as indicated earlier to record a new message. The most recent recording becomes the final one, and any subsequent recordings are rendered unreachable. Use the Auto Rewind option rather than the Normal option if you want to save any current messages. The following collection can be utilised if choosing the Normal option is not an option. You can't record a new message until you've fast-forwarded past the ones you wish to save in order to preserve the present ones. Select play mode and listen to each message until you reach the first one you want to replace in order to proceed while using the Normal option. You must now alter the desired

message before switching back to report mode. The most recent message that can be recorded becomes the last message that can be recorded after this one, and all previously recorded messages are no longer available. All inputs, excluding /CE, are not acknowledged at some point in the recording.

Functional Description of Tape Mode Playback with Auto Rewind Option

After turning on or after a low to high transition on /RE, the device is immediately ready to record or playback, beginning at the first address inside the memory array. Before you can begin replaying messages, you must first activate the device by setting the /CE input to low and enable playback by setting it to high. The first excessive to-low going pulse of the Message pin signals the beginning of the cutting-edge message, and playback then starts from that point. When the Message pin pulses twice from high to low, the current message's playback is immediately terminated. When the Message pin pulses three times too quickly, the succeeding message begins to playback. The message pin is released, the memory array is finished, and the last message is shown by this. If the most recent recorded message has been played and there are any further transitions on the Message pin, a double beep will sound as a warning and the END pin will shift low. To end this circumstance when the device is in standby, pulse the /CE pin low once to move the pointer back to the beginning of the first message. The A P R 9 6 0 tool contains a variety of features made to make managing messages controlled by microprocessors easier. The microprocessor effectively toggles the pins as specified in the aforementioned message control sections when controlling messages. To make handshaking between the CPU and the APR9600 easier, the /Busy, /Strobe, and END pins are covered. The /Busy pinwhile low signal informs the host processor that the tool is occupied and no longer accepting instructions. When this pin is set too high, the tool is ready to accept commands from the host and carry them out. Every time a memory region is used, the /Strobe pin pulses low. The host processor can determine how much recording time is still available by counting the pulses on this pin. There are 80 memory segments in the APR9600 altogether. The END pin indicates that the tool has terminated the playback or current document action. A low-going pulse while recording indicates that a memory has been consumed. When the playback is interrupted by a low pulse, the ending message has finished. The total amount of recording time available can be increased by using microprocessor control to link several APR9600 devices together. This programme enables the speaker and microphone warnings to be associated simultaneously. The CPU may then switch each device on or off using its corresponding /CE pins to determine which one is currently powering the speaker. On some devices, a continuous message cannot be recorded, although this is significant because switching between devices would impede playback. Tool and message barriers should always line up, it is highly recommended.

Signal Storage:

Incoming voice alarms are sampled by the APR 9 0 0 and the instant voltage samples are saved in secure FLASH memory cells. The range of voltage levels that each memory mobile can support is zero to 256. The equivalent of these 256 discrete voltage levels in binary form is 8 bits (28=256). The recorded signals are read out of memory during replay, It is then amplified and delivered to an external speaker after being smoothed to create a continuous stream.

Rate of Sampling and Voice Quality:

The best feasible frequency input delivered to a sampling device must be equal to or less than half the sample rate, according to Shannon's sampling theorem. Aliasing mistakes must be less common. To meet this demand, the APR9600 automatically filters input based only on the selected sample frequency. Higher sampling rates need more memory cells per unit of recording time, but they also result in better speech quality and bandwidth. Lower sampling rates reduce incoming signal bandwidth while requiring fewer memory cells and essentially extending the device's period possibilities. Up to 8 kHz and as low as 4 kHz sampling rates are supported by the A P R 9 6 0.Altering the sampling frequency can alter the quality/period trade-off. For the APR 9600, a built-in oscillator produces the

sampling clock. You can modify values, the corresponding sample frequencies, as well as the resulting input bandwidth and length, by modifying the resistance.

IR SENSOR

General Description

Infrared radiation will be emitted by the IR LED. The ground is illuminated inside the front of the LED by this radiation. Depending on how reflective a surface is, different amounts of light are reflected. This perplexed light is inadvertently produced on an IR sensor with a bias in the opposite direction. The intensity of incident IR light affects how many electron-hole pairs are created. Therefore, the voltage across the resistor will change in line with changes in the incident ray's intensity.

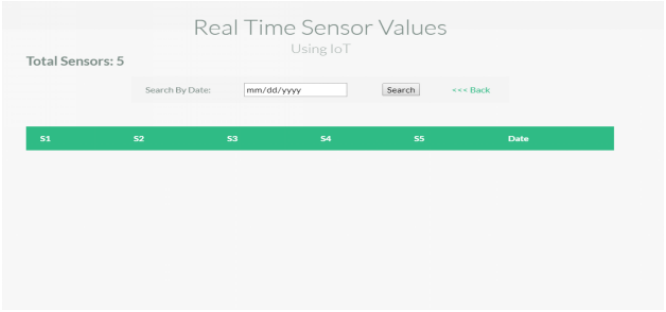
Product Description

In order to sense certain features of its environment, a digital device known as an infrared sensor produces infrared light. An IR sensor can monitor both object heat and motion. Every gadget typically emits some form of heat radiation that belongs to the infrared spectrum.An infrared radiation sensor may be able to pick up radiation that is not visible to the naked eye. The emitter is an IR LED, and the detector is an IR Photodiode, which is sensitive to infrared light with a wavelength matching the IR LED's emission. When IR light strikes a photodiode, the output voltages and resistances of the component change in direct proportion to the IR light's intensity.

IOT

A digital gadget called an IR sensor emits light as a means of taking in some aspects of the environment. Both motion and object heat can be measured using an IR sensor. Typically, every device emits some type of thermal radiation that falls inside the infrared spectrum. Despite being invisible to the human eye, certain radiation types are detectable by infrared sensors.

WEB SERVER

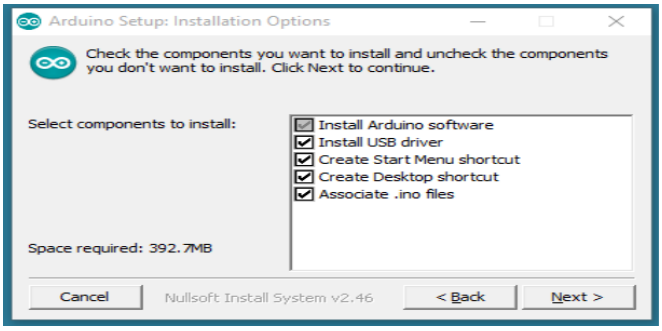


Espresso's ESP32EX offers fully integrated Wi-Fi SoC solutions to meet users' ongoing demands for effective power management, a small design, and consistent performance in the Internet of Things area. The ESP32EX can function as a master MCU or a slave programme and has robust, independent Wi-Fi networking capabilities. The ESP32EX immediately begins operating when hosting the programme after the flash. By improving device memory, the built-in high-speed cache contributes to performance growth. The ESP8266EX can be integrated into any microcontroller configuration as a Wi-Fi adaptor by using the SPI/SDIO or I2C/UART interfaces. The ESP32EX comes with a variety of components, including filters, an RF balun, power amplifiers, low noise receive amplifiers, and low noise receive amplifiers.Less external circuitry is needed and the length of the PCB is decreased with compact design. A better 32-bit L106 Diamond collection processor and on-chip SRAM are also features of the ESP8266EX in addition to Wi-Fi functionality.It may interact with other devices and external sensors via the GPIOs.Software Development Kit (SDK) pattern codes are offered for a number of applications.

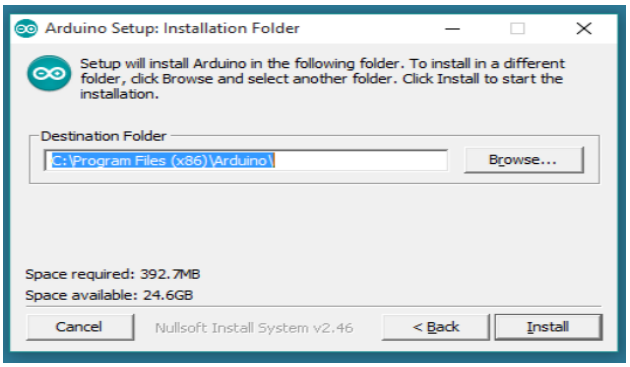
SOFTWARE REQUIREMENTS

ARDUINO SOFTWARE (IDE)

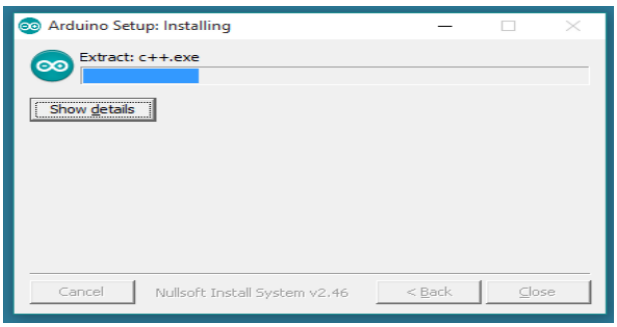
We advise you to choose the default one because it automatically installs all the drivers and the Arduino Software (IDE) that you need. You should manually insert the drivers inside the Zip bundle. If you need to make a portable installation, the Zip report is very helpful. Continue with the installation after the download is complete, and if the running system warns you, please let the driver installation process run.



Choose the components to install



Choose the installation directory (we suggest to keep the default one)



Arduino Boot loader Issue

The Arduino UNO's current bootloader is not compatible with ROBOTC. The ROBOTC Firmware can currently only be downloaded to the Arduino UNO; user programmes cannot be downloaded at this time.
This is caused by a flaw in the firmware for the Arduino UNO that prevents flash write commands from starting anywhere other than at 0x000000 at the start of flash memory.

You will need to use the Arduino Open Source programming language and a modified bootloader file to re-burn your bootloader on your Arduino UNO boards because ROBOTC is currently unable to burn a new bootloader. The original bootloader and the improved bootloader are backwards compatible. This implies that in addition to ROBOTC for Arduino, you can still programme it using the Arduino programming environment..

3. CONCLUSION

Our objective was to create an autonomous delivery robot that could give elderly patients medicine. It is less expensive and very compatible. When compared to a man providing medicine, it is incredibly effective.

4. REFERENCES:

1. Coronavirus Confirmed As Pandemic by World Health Organization. [Online]. Available: https://www.bbc.com/news/world-51839944
2. US Ecommerce Sales Rise 25% Since the Beginning of March. [Online]. Available: https://www.digitalcommerce360.com/2020/04/01/usecommerce-sales-rise-25-since-beginning-of-march/
3. V. Chamola, V. Hassija, V. Gupta and M. Guizani, “A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact,” in IEEE Access, vol. 8, pp. 90225-90265, 2020, doi: 10.1109/ACCESS.2020.2992341.
4. L. Ranieri, S. Digiesi, B. Silvestri and M. Roccotelli, “A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision,” Sustainability, MDPI, Open Access Journal, vol. 10(3), pp. 1-18, 2018.
5. G. Prause, I. Boevsky, “Delivery Robots for Smart Rural Development,” Bulgarian Journal of Agricultural Economics and Management, vol. 63, No. 4, pp. 57-65, 2018.
6. “Unity,” Unity Technologies, 2020. [Online]. Available: https://unity.com/.
7. G. Bocewicz, I. Nielsen, and Z. Banaszak, “Automated guided vehicles fleet match-up scheduling with production flow constraints,” Eng. Appl. Artif. Intell., vol. 30, pp. 49–62, 2014.
8. V. Digani, M. A. Hsieh, L. Sabattini, and C. Secchi, “A Quadratic Programming approach for coordinating multi-AGV systems,” IEEE Int. Conf. Autom. Sci. Eng., vol. 2015-October, pp. 600–605, 2015.
9. A. Mannucci, L. Pallottino, and F. Pecora, “Provably safe multi-robot coordination with unreliable communication,” IEEE Robot. Autom. Lett., vol. 4, no. 4, pp. 3232–3239, 2019.

10. L. Sabattini, V. Digani, C. Secchi, and C. Fantuzzi, “Hierarchical coordination strategy for multi-AGV systems based on dynamic geodesic environment partitioning,” IEEE Int. Conf. Intell. Robot. Syst., vol. 2016-November, pp. 4418–4423, 2016.