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ROS OS-based 3D mapping of Cyber-Physical System Lab by the depth sensor

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***Abstract*— The 21st century is a century of Robotics and thus the appearance of robots in the industries made the "Industrial Revolution 4.0" in which we can control and analyze the system using HMI's or wirelessly over the network and it's a great example of industry 4.0 component. Nowadays robots are a very important part of the industry's processing unit as they tend to work 24/7 thus increases the efficiency of processing and production units.**

In our project, a depth sensor (Microsoft's Xbox Kinect) is mounted on a mobile robot whose main task is to map our Cyber-Physical System Lab in 3-Dimensional which uses a ROS OS software installed on a Linux machine.

The robot will use a Simultaneous localization and mapping (SLAM) process to map an environment while currently generating an estimate for the location of the Robot.

Keywords*— Robot; Depth Sensor (Kinect Xbox 360); Industry 4.0; ROS OS; Visual Odometry; Remote control; Linux Operating System

I. Introduction

A Robot is a machine which lies in the field of embedded system and composed of mechanical parts, software, programmed to perform some specific task continuously and efficiently. Sometimes these Robots are also programmed using artificial intelligence which is capable of learning things around them by themselves. On this basis, robots are divided into two sub-field: mechanical robots and bots.

Mechanical robots are the robots who perform actions physically and solve complex tasks whereas bots are the software robots that perform software tasks at the software level only. Some examples of bots are chatbot, social bot, and video game bot.

Our Robotic project is of the first type i.e. mechanical mobile robot which is embedded with the Depth sensor to DaNI robot and will make movement in the cyber-physical system lab to map the lab in a 3-Dimensional view using ROS OS installed on a Linux machine. The main component of this project is the Depth sensor.

This mobile robot can map the 3D environment and can analyze the different objects in the industry and then it will be used to carry products from one place to another place autonomously.

II. Industry 4.0

This project is a great example of an industry 4.0 component. As we can see a lot of Robots working in modern industries autonomously. They are programmed and embedded with so many sensors that they can map their destination by themselves and move the materials from one place to another.

Fig 1: industry 4.0, Internet of Things [2]

The 21st century is the century of automation where we can see that there are cars that run without driver and can take you to your destination by themselves safely and there are some drones that deliver your goods which you bought online. Automation changed everything, how we live and also how Industries work where we don't need to go to every machine to see their efficiency at that time, we can check that by standing at one place through the single screen, and this technological advancement in Industry is known as Industrial Revolution 4.0.

Industry 4.0 can be translated in other words as the fourth industrial revolution. Sometimes it can be interpreted as an industrial Internet or digital factory. Previous Industry 4.0 can be translated in other words as the fourth industrial revolution. Sometimes it can be interpreted as an industrial Internet or digital factory. The previous revolution that is industry 3.0 was

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based on simple automation of single machines and processes however the fourth revolution is based on the implementation of digital systems onto physical components that connects them to different platforms in the digital ecosystems [4]. Mainly these technologies can be summarized into four major components, defining the term "Industry 4.0" or "smart factory".[13]

- Cyber-physical systems
- IoT
- Cloud computing
- Cognitive computing

Cyber-physical systems that monitor the physical world help creating a virtual copy of it.

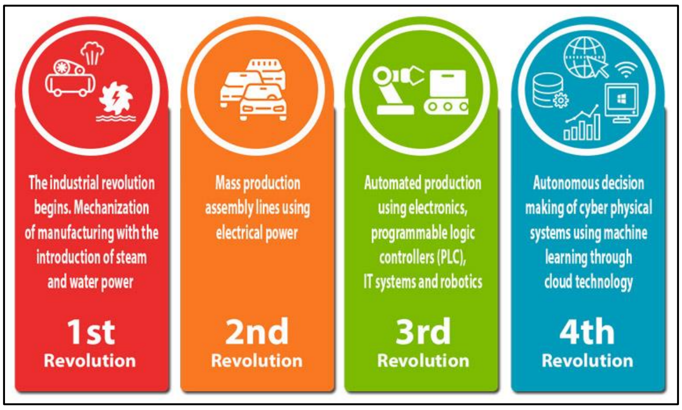

Fig 2: Description of 4 Industrial Revolutions [3]

III. SCHEMATIC DIAGRAM OF PROJECT

Below is the schematic diagram of the project which shows how different components of the project are connected.

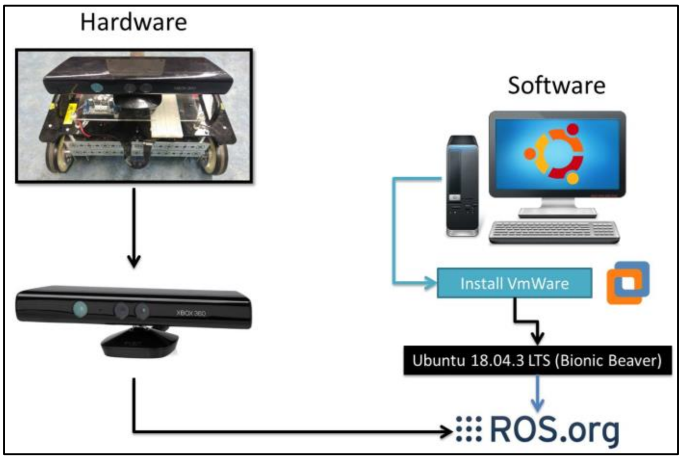

Fig 3: Schematic diagram of the project

The Kinect adaptor is used to power the Kinect and take the output from the Kinect and give it to the controller (in our case, it is a computer machine) through a USB cable. It includes the adaptor, power supply, and USB cable.

The adaptor is compatible with Microsoft Xbox ONE S (Slim), one x, elite, and also works with Windows 8, 8.1, 10, and Linux (as like in our project). The power supply is used to power the adaptor which is further supplied to Kinect to power it. The USB cable is used to make a connection between Xbox/pc and adaptor, where the adaptor is already connected to the Kinect and power supply

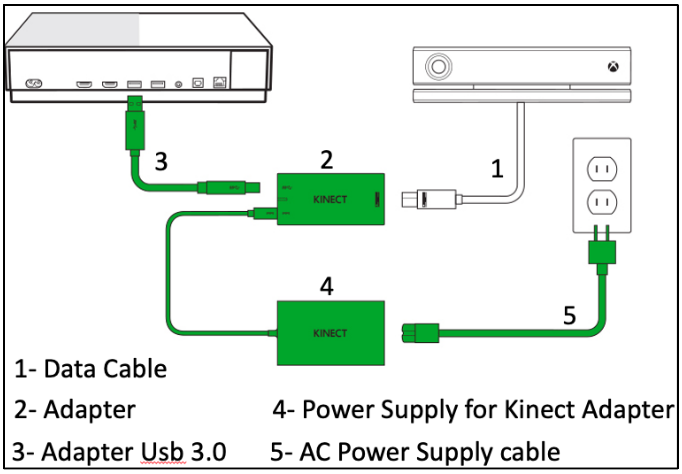

Fig 4: Diagram showing the connection between the host computer and Kinect

IV. REQUIRED COMPONENTS DESCRIPTION

Host computer with Linux operating system or windows with VMware installed on it. ROS OS is open source and available for free on their official website.

A. Depth sensor

A Kinect sensor as a Depth sensor: the Kinect is a device that is designed by Microsoft and generally used in gaming platforms for playing motion games in which a player stands in front of the device and takes his/her moving position as input control for the game.

Working of a Depth sensor: this little device contains an RGB color video camera, a depth sensor, and a microphone array.

The camera of the device detects the three color components (red, green, and blue), and also detects the type of the body to differentiate it with other things. It has a pixel resolution of 640 x 480 and a frame rate of 30 fps. It also helps in face and body recognition.

The depth sensor in the Kinect has a monochrome CMOS and an infrared projector which helps in creating a 3D image of the room. It measures the distance of each point of an object by transmitting an invisible infrared light at an object and then by measuring the 'time of flight' it calculates the distance of the object from itself.

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The array of the microphone on Kinect is used to isolate the different voices of players who are playing the game using Kinect. This feature allows the special feature to the players to use their voice as an extra control in the game.

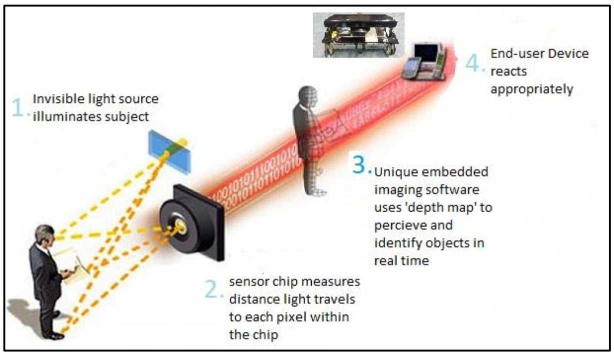

Fig 5: Depth perception using the infrared camera [5]

Advantage of using Kinect as a Depth sensor: the Kinect is a great imaging tool for robots as it contains an infrared projector infrared camera and a color camera. To enhance the autonomous nature of robots and see the environment, this device is perfect for this project. The process to see the things around, the SLAM process is used which means simultaneous localization and mapping. The sensors which are used in the Kinect are costly individually but using the Kinect in the project decreases the cost of the project to some extent as we got all the sensors in the single unit.

B. DaNI Robot Chassis

This is an IoT mobile robot that was created by National Instruments (NI) for educational purposes. this robot comes with different parts that can be reassembled and taken apart. The robotics lab of the university was lucky enough to have one, some of the hardware components that it came with a two-channel motor control unit, two dc motors to run the wheels, it also comes with a battery to provide DC power to run the software components as well as the hardware components. It comes with an aluminum frame system to support and mount all the necessary parts for the project. It comes with a manual that makes it less complicated to handle and explains all the embedded systems and building operations like lab view.

The **Arduino ESP32** is used to provide a link between the automated guide vehicle(avg), the motor control unit (MCU), and the Depth sensor. Specifications of the Arduino esp-32 [15].

- ESP32-WROOM32 module
- MicroUSB connector
- CH340 USB serial converter
- Built-in programmer for Arduino and ESP-IDF
- WIFI, BLE connectivity
- Ethernet 100Mb interface
- MicroSD card
- GPIO 20 pin connector with all ESP32 ports [15].

Fig 6: Arduino esp32 Gateway [14]

Sabertooth2X10RC Motor Driver IC: it can supply two DC brushed motors with up to 10A each. Peak currents of 15A are achievable for a few seconds. Overcurrent and thermal protection mean that one never has to worry about killing the driver with accidental stalls or by hooking up too big of a motor [6].

Features of the motors control unit:

- Up to 18V in 10A continuous,15A peak per channel
- 24V in 8V continuous, 15A peak channel
- 1 heatsinking/airflow, 15A peak per channel
- Synchronous regenerative drive
- Ultra-sonic frequency
- Thermal and overcurrent protection
- Lithium protection mode
- Input modes: Analog, R/C, simplified serial, packetiz ed serial
- Size: 59 x 75 x 17mm [36].

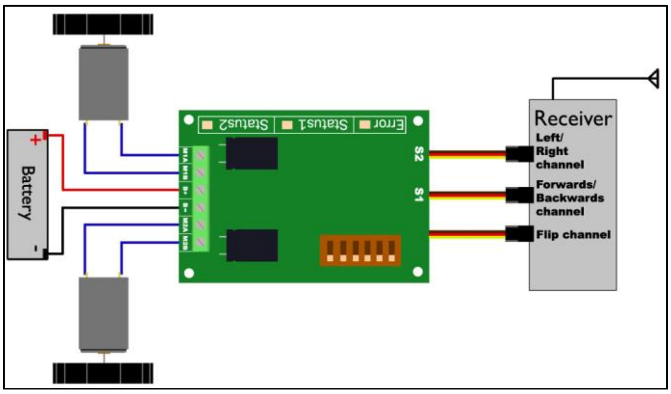

Fig 7: Sabertooth2X10RC Motor Driver [6]

To charge the battery of a robot, one should switch off the master switch first and then disconnect it from the robot and connect it to the charger. Battery connections of the Robot are shown in the picture below:

Below is the complete picture of the chassis we are using in the project.

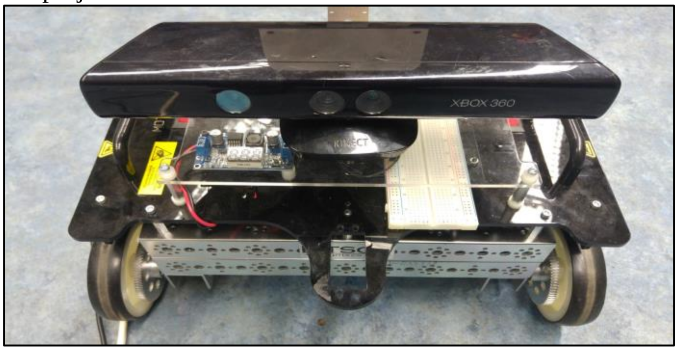

Fig 8: DaNI robot embedded with Depth Sensor

C. Ubuntu 18.04 LTS

Ubuntu is a favorable operating system for this project as it is an open-source GNU/Linux distribution and operating system. Open source meaning software freedom as opposed to pricing. The ubuntu framework allowed the users to download and install different programs which allowed configuration of many programs and modify it according to the need of the project.

Ubuntu's motto on software freedom entails:

- every computer user should have the freedom to download, run, copy, distribute, study, share, change, and improve their software for any purpose, without paying licensing fees.
- every computer user should be able to use their software in the language of their choice.
- every computer user should be given every opportunity to use the software even if they work under a disability [7].

Reason for using Linux: Linus Torvalds developed the first version of Linux in 1991 as an operating system for computers powered by the Intel 80386 microprocessor which of the time was a new and advanced processor. A student by the name Linus studying at the University of Helsinki was enraged by the Unix system (which is free), how it wasn't powerful enough to run his programs. He then decided to write his operating system and give it the necessary components to run complex programs at the time. This allowed him to link to a substantially sized UNIX system at the end of his course year it had improved and he later posted an early release in 1991 [8].

Linux is an operating system with a combination of programs and is an environment that lets us interact with the different parts of the computer and let us run our programs on it. It is an open-source operating system which means it is free to use and necessary modifications can be done in it by the user which he needs. Linux is considered to be the most secure operating system in the industry as it doesn't run .exe files that are used in windows operating systems. Most of the viruses are .exe files and designed for windows operating system users as the number of windows OS is far more than the Linux OS users.

Some of the advantages that make Linux better [8]:

- it allows programmers to use Linux to be able to design their custom operating systems.
- since it is an open-source operating system, programmers can modify it.
- due to the number of users and programmers, it has gained a huge number of programs or applications to choose from which are mostly free
- due to its stability and reliability many environments choose the Linux operating system, its reliability and stability allow them to be able to run nonstop without a reboot for years continuously.
- Linux is constantly upgraded by the development community that looks at ways to improve its security, this eliminates the need for installing antivirus programs and ensures the comfort of enjoying a secure platform.
- The constant upgrades of the system are aimed at making it less complicated to work with, making it more and more user-friendly as time goes on.

D. Robot Operating System (ROS)

Robot Operating System is a collection of software libraries for robot software development. As we know that ROS is not an operating system but it provides the environment to program robots using many inbuilt robotic libraries and features and minimizes our calculation using these libraries.

Ros allows the system to interact with the external devices and sensors like an ultrasonic sensor, lidar sensor, depth sensor, radar sensor, cameras, etc. Ros platform allows users and researchers to perform their tasks and researches on these devices and sensors.

Fig 9: ROS logo

It is an open-source operating system that allows uses for researchers to use the platform or their software packages without the need of paying for licenses: this can reduce the overall cost of the project carried out by the users. This operating system allows scripts to be written in different programming languages such as C++, LISP Java, and a few others. ROS is supported by a non-profit organization that is the open-source robotics foundation, which provides the platform for distribution and periodic updates of the software packages which can be found on the website [10].

ROS allows the code for one hardware to be used on other hardware devices, thereby giving a substantial number of libraries at the full disposal of the interested parties [11].

The robot operating system makes it easy for users by providing libraries with small executables such as nodes, which subscribe to messages of a given topic in the bus which makes it easy to identify content in the message.

V. Connect Kinect depth sensor to ROS OS

For creating the 3D image of the object, we generally use the RGBD SLAM process: simultaneous localization and mapping using an RGB image and depth to make an accurate point cloud. The main advantage of using a SLAM algorithm is that when the mapping takes place, the algorithm calculates the position of the camera from the object and generates a map.

Visual odometry: VO is a process of estimating the position of a robot's motion (translational and rotational motion of robot concerning a reference image or frame) by observing the sequence of images of its environment. VO is a technique also known as Structure From Motion (SFM) that solves the problem of 3D representation of the structure of the environment and unordered image sets [18]. In recent years, many VO methods have been proposed which can be divided into two types named monocular [1] and stereo camera methods [3].

Some approaches to visual odometry are based on the following stages:

- Acquire input images.
- Image correction using different image processing techniques.
- Feature detection: define interest operators and match features across images or frames and then construct an optical data flow.
- Motion Estimation: Estimating the camera position from the optical data flow.
- Periodic collection of track points to maintain coverage across the frames.

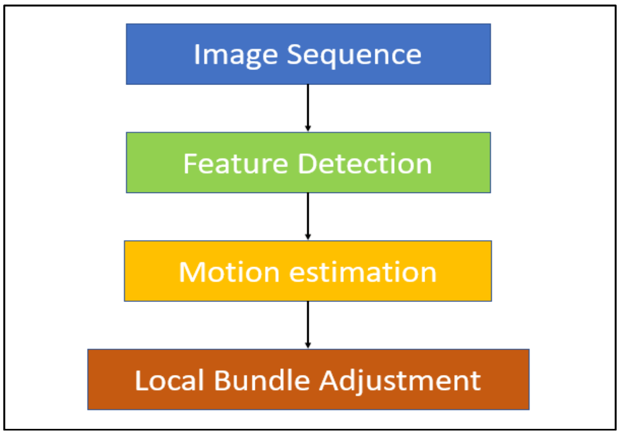

Fig 10: Block Diagram showing the main components of VO

Steps to install ROS and connection to Kinect:

First, we need to install the ROS OS. Currently, the latest edition on the official site is ROS Melody. For this program group, the most suitable Linux distribution is Ubuntu Bionic. After it, make sure your Debian package index is up to date using the following command in the terminal window.

1. In ubuntu's Software&updates program, we must allow to install from "restricted," "universe," and "multiverse" repositories.
2. We need to add the link of the ROS OS repository:
   sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu $(lsb_release -sc) main" > /etc/apt/sources.list.d/ros-latest.list'
3. Installing keys.
4. Installing the ROS OS
6. Required programs for miscellaneous modules.

You can also install a specific ROS package (replace underscores with dashes of the package name).

Before you can use many ROS tools, you will need to initialize rodeo. Rodeo enables you to easily install system dependencies for the source you want to compile and is required to run some core components in ROS.

VI. Final results of the mapping

Finally, the mobile robot is used to map the environment of the Cyber-physical System Lab at the University of Debrecen. The Robot is moving around the lab and collecting all the data from the depth sensor and showing the point cloud on the screen.

During the mapping, we can see that software was lagging as the algorithm was taking time to process the data. The data coming from the sensor was in a large amount which includes RGB images, odometry image, and the formation of a 3D point cloud was taking place at the same time.

There was some lag due to the virtual machine also. As the software and hardware were not connected directly but through the virtual machine where the hardware needs to ask for access from the real machine which increases the lag in the process of mapping.

Below are the pictures of the video that was seen on the screen while the robot was mapping the environment.

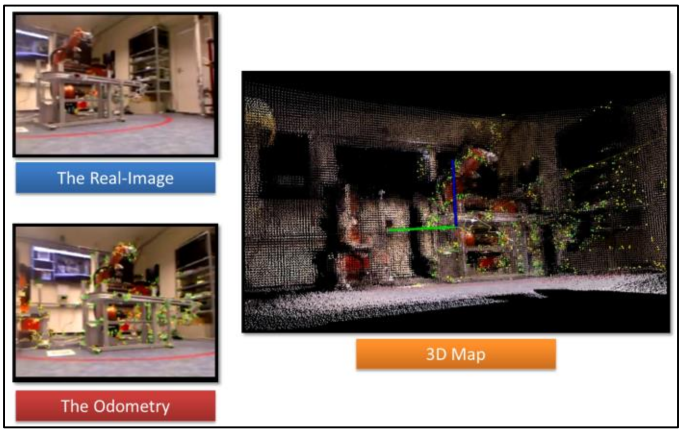

Fig 11: 3D mapped image on the screen

VII. Conclusion

The main purpose of this project was to carry out environmental mapping using an IOT mobile robot-assisted with the Depth sensor. The Depth sensor has shown that it can create maps that can be able to be used by autonomous vehicles to navigate the surroundings. One of the advantages found when using the Depth sensor is that it is relatively expensive and can easily be mounted onto the autonomous vehicles due to its possible size.

During set up of the sensor, we realized that the operation of the sensor is not so complex and easy to follow manual, apart from a few incompatibilities in software that led to a few trial and errors, the rest of the installation and running of the necessary drives was not so difficult and was completed easily without much difficulty in the end.

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VIII. Acknowledgment

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IX. References

[1] Campbell, J., Sukthankar, R., Nourbakhsh, I., Pahwa, A.: A robust visual odometry and precipice detection system using consumer-grade monocular vision. In: Proceedings of the 2005 IEEE International Conference on Robotics and Automation (ICRA 2005), pp. 3421–3427 (2005)

[2] Good Practices for Security of Internet of Things in the context of Smart Manufacturing, ENISA.

[3] Study Malaysia (2020.02.17). [Online]. Available: https://www.studymalaysia.com/education/top-stories/the-fourth-industrial-revolution-ir-4.0-and-what-it-means-for-students-like-you

[4] J. V. S. S. Reinhard Geissbauer, A Strategist's Guide to Industry 4.0, In strategy+business, 2008.

[5] Jameco (2020.02.17). [Online]. Available: https://www.jameco.com/Jameco/workshop/Howitworks/xboxkinect.html

[6] Dimension Engineering (2020.02.16). [Online]. Available:https://www.dimensionengineering.com/products/sabertooth2x12rc

[7] B. M. Hill, M. Helmke, A. Graner, and C. Burger, The Official UBUNTU Book, prentice hall, 2011, p. 15.

[8] R. Love, Linux Kernel Development, Addison Wisely, 2010

[9] d. i. team, "UBUNTU Installation guide," 2018. [Online]. Available: https://help.ubuntu.com/lts/installation-guide/s390x/install.en.pdf.

[10] C. Fairchild and D. T. Harman, ROS robotics by example; Learning to control wheeled, limbed, and flying robots using ROS Kinetic Kame, Birmingham-Mumbai: Pakt, 2016.

[11] A. Kouba, Robot Operating System (ROS) volume 3, Springer International Publishing, 2016.

[12] S. Kohlbrecher, "Hector mapping," 2012. [Online]. Available: http://wiki.ros.org/hector_mapping.

[13] "How To Define Industry 4.0: Main Pillars Of Industry 4.0". *ResearchGate*. Retrieved 9 June 2019.

[14] "Amazon," [Online]. Available: https://www.amazon.com/dp/B075C7WVJF?tag=videosofproducts-20.

[15] A. Kurniawan, Arduino sketch for ESP32 development workshop, 2018.

[16] RGB-D SLAM http://felixendres.github.io/rgbdslam_v2/

[17] Maimone, M.; Cheng, Y.; Matthies, L. (2007). "Two years of Visual Odometry on the Mars Exploration Rovers" (PDF). *Journal of Field Robotics*. **24** (3): 169–186. CiteSeerX 10.1.1.104.3110. DOI:10.1002/rob.20184. Retrieved 2008-07-10.

[18] Scaramuzza, D., Fraundorfer, F.: Visual odometry: part I—the first 30 years and fundamentals. IEEE Robot. Autom. Mag. **18**(4), 80–92 (2011)

[19] Matthies, L.: Error modeling in stereo navigation. IEEE J. Robot. Autom. **3**, 239–250 (1987)