A Seminar Report on

"FAULT VISUALIZATION IN INDUSTRIAL ROBOTIC TASKS USING AUGMENTED REALITY"

Submitted to

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR, ANANTAPURAMU.

In Partial Fulfillment of the Requirements for the Award of the Degree

of

BACHELOR OF TECHNOLOGY
IN
COMPUTER SCIENCE AND SYSTEMS ENGINEERING

Submitted by

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Under the Guidance of

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SREE VIDYANIKETHAN ENGINEERING COLLEGE (AUTONOMOUS)

(Affiliated to JNTUA, Anantapuramu, Approved by AICTE, New Delhi, Accredited by

NBA& NAAC 'A' Grade)

Sree Sainath Nagar, A. Rangampet – 517 102

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CERTIFICATE

This is to certify that the Seminar Report entitled

"FAULT VISUALIZATION IN INDUSTRIAL ROBOTIC TASKS USING AUGMENTED REALITY"

is the Bonafide work done

by

RAMISETTY CHANDANA **17121A1591**

In the Department of **Computer Science and Systems Engineering**, **Sree Vidyanikethan Engineering College,** A.Rangampet and is submitted to Jawaharlal Nehru Technological University Anantapur, Anantapuramu in partial fulfillment of the requirement of the award of B.Tech Degree in Computer Science and Systems Engineering during the academic year 2019-2020.

Head of the Department ***Senior Faculty Member*** ***Supervisor***

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ABSTRACT

In industries robots plays a key role. Due to digitalization automated systems are transforming into intelligent ones. Sometimes factories are required to face an increasingly competitive market, which requires being able to dynamically adapt to different situations and conditions. Hence, facilities are moving towards systems that telly on the collaboration between humans and machines. Human workers should understand the behaviour of the robots, placing trust in them to properly collaborate. If a fault occurs on a manipulator, its movements are suddenly stopped for security reasons, thus workers are not able to understand what happened to the robot. Therefore, the operators stress and anxiety may increase It proposes an Augmented Reality system to display industrial robot faults by means of the Microsoft HoloLens device. Developing a methodology employed to identify which virtual metaphors best evoke robot faults, an adaptive modality is presented to dynamically display the metaphors in positions close to the fault position, always visible from the user and not occluded by the manipulator. Adaptive modality allows users to recognize faults faster and with fewer movements than the non-adaptive one, thus overcoming the limitation of the narrow field-of-view of the HoloLens device.

CONTENTS

1. INTRODUCTION

From the three past industrial revolutions, Industry 4.0 consists into a transformation process of the factory itself, from an automated facility to an intelligent one. By analysing the 2009 - 2014 period, it can be inferred a constant increase in the number of robots. it is necessary to develop new technologies that enhance the collaboration between humans and machines. One of the main goals of the Human-Robot Collaboration (HRC) is to develop innovative interfaces that allow machines and human operators to collaborate in the same environment. There are several technologies that can foster collaboration between humans and machines. Augmented Reality (AR) seems to be a promising technology that can enhance the collaboration between industrial robots and human operators. Technological improvements allowed the development of more sophisticated devices, capable of displaying 2D/3D high-definition virtual assets in the real environment. Three different visualization paradigms exist: handheld, projected and wearable see-through. AR shows its effectiveness in several industrial scenarios, such as maintenance and repair operations, inspection processes and to improve the collaboration with industrial machines. Although AR is used in several ways with industrial robots (e.g., visualizing trajectories, intentions or the workspace of the manipulator ,very few works have tried to explore the idea of visualizing industrial robot faults by means of virtual metaphors. When a fault occurs on a manipulator, the robot is suddenly stopped to avoid any possible accident. Since in a human-robot collaborative scenario, human operators work side-by-side with industrial robots, an unexpected block of the robot's movements may increase stress and anxiety in the human operators because they are not aware of what is happening in the manipulator's controller. This work proposes an AR system to display industrial robot faults.

2. LITERATURE SURVEY

The analysis reviews the field of human-robot interaction with a focus on communication and collaboration. It also identifies promising areas for future research focusing on how Augmented Reality technology can support natural spatial dialogue and thus enhance human-robot collaboration. First an overview of models of human-human collaboration and how they could be used to develop a model for human-robot collaboration is presented. Next, the current state of human-robot interaction is reviewed and how it fits into a model of human-robot collaboration is explored. [1]

The use of industrial robots and new technologies leads to a rapid increase in production in the automotive industry, both in terms of number of produced vehicles and the number of different models. When it comes to the automotive industry, the application of industrial robots at the very beginning was related to the performance of activities that affected the health of workers, such as welding and painting. The development of information technology and sensor technology led to the development of industrial robotics, so we have a concurrent connection of several industrial robots in performing identical operations. [2]

The development of new technologies and innovations is leading to the development of robotic technology which has been increasingly used in the automation of production processes. This will, in return, lead to the development and application of "smart automation" or "smart factories" in the future that will, besides vehicles, also produce other high quality products in short time period and with large varieties. [3]

As robots are gradually leaving highly structured factory environments and moving into human populated environments, they need to possess more complex cognitive abilities. They do not only have to operate efficiently and safely in natural, populated environments, but also be able to achieve higher levels of cooperation and communication with humans. This work gives a survey of the state of the art of human robot collaboration. [4]

This work reviews the field of human-robot interaction and augmented reality, investigates the potential avenues for creating natural human-robot collaboration through spatial dialogue utilizing AR and proposes a holistic architectural design for human-robot collaboration. [5]

The fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves. The retinal image of the real objects which we see is, after all, only two-dimensional. Thus if we can place suitable two-dimensional images on the observer's retinas, we can create the illusion that he is seeing a three-dimensional object. [6]

This work focuses on Mixed Reality (MR) visual displays, a particular subset of Virtual Reality (VR) related technologies that involve the merging of real and virtual worlds somewhere along the “virtual continuum” which connects completely real environments to completely virtual ones. Probably the best known of these is Augmented Reality (AR), which refers to all cases in which the display of an otherwise real environment is augmented by means of virtual (computer graphic) objects. [7]

This work provides an overview on the most important applications of AR regarding the industry domain. Key among the issues raised in this work are the various applications of AR that enhance the user's ability to understand the movement of mobile robot, the movements of a robot arm and the forces applied by a robot. It is recommended that, in view of the rising need for both users and data privacy, technologies which compose basis for Industry 4.0 will need to change their own way of working to embrace data privacy. [8]

3. FAULT VISUALIZATION IN INDUSTRIAL ROBOTIC TASKS USING AUGMENTED REALITY

The overall working flowchart is composed by four different steps

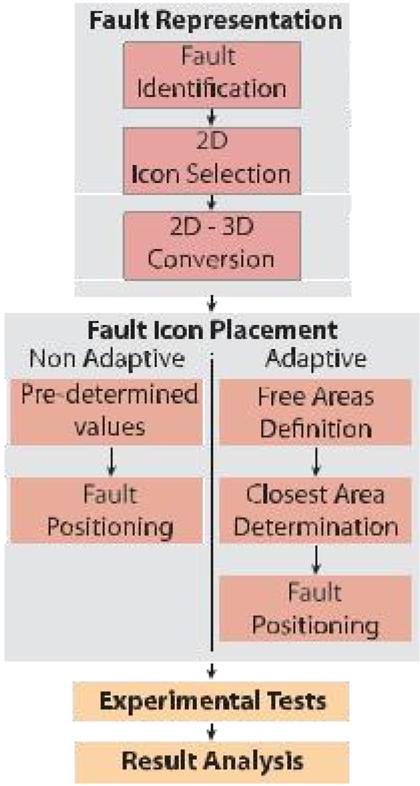

Figure 3.1 The working flow chart

1) Fault Representation (FR)
2) Fault Icon Placement (FIP)
3) Experimental Tests (ET)
4) Result Analysis (RA)

FAULT REPRESENTATION

In order to figure out which 2D icons best represent industrial manipulator faults, a rigorous design approach has been adopted:
1) Semantic analysis: extraction of the most relevant terms regarding industrial robot faults and generation of a 2D icon dataset;
2) 2D icon design: re-design process of the 2D icon dataset
3) 2D icon selection: selection of the most representative 2D icons

SEMANTIC ANALYSIS

Table 3.1 The *synonym_list_sentences* set. The word *fault* has two synonyms (in yellow). The word *speed* has three synonyms (in green). No synonyms have been found for *reducer*.

fault	speed	reducer
fault	velocity	reducer
fault	speeding	reducer
fault	hurrying	reducer
defect	speed	reducer
defect	velocity	reducer
defect	speeding	reducer
defect	hurrying	reducer
flaw	speed	reducer
flaw	velocity	reducer
flaw	speeding	reducer
flaw	hurrying	reducer

2D ICON DESIGN

1. Due to the huge number of collected icons, images not strictly related to the ten fault categories.
2. Based on category the icons are subdivided.
3. Images not related to fault categories have been discarded.
4. The final dataset was composed of 121 icons, not uniformly subdivided into ten faults categories.
5. There is a need of redesign the process by composition, bordering etc.

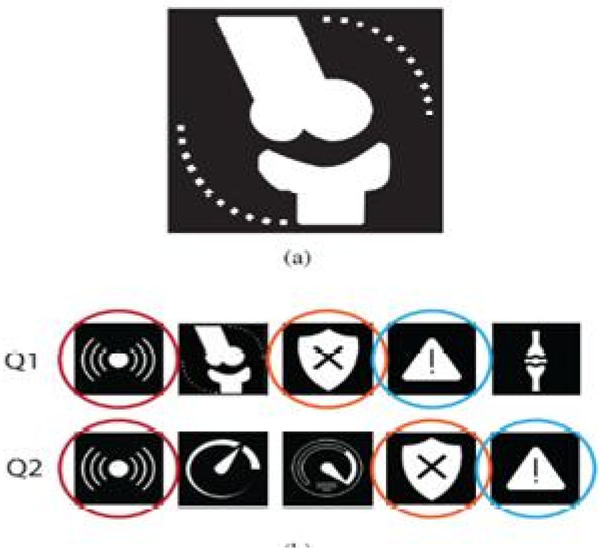

Figure 3.2 An example of re-designed 2D icon. B: an example of icons that appear in different categories.

Table 3.2 The number of collected icons, divided by category

	Category	# 2D Icons
Q1	Fault on joint position sensor	19
Q2	Fault on velocity sensor	14
Q3	Fault on a current sensor	13
Q4	Overload	7
Q5	Fault in a speed reducer	15
Q6	Collision	8
Q7	Fault in the brake	8
Q8	Fault in the controller input/output board	14
Q9	Fault in a motor drive	10
Q10	Software error	13
	Tot	**121**

THE ARCHITECTURE

The hardware architecture is composed by three main actors: the industrial manipulator, the AR client and a remote server.

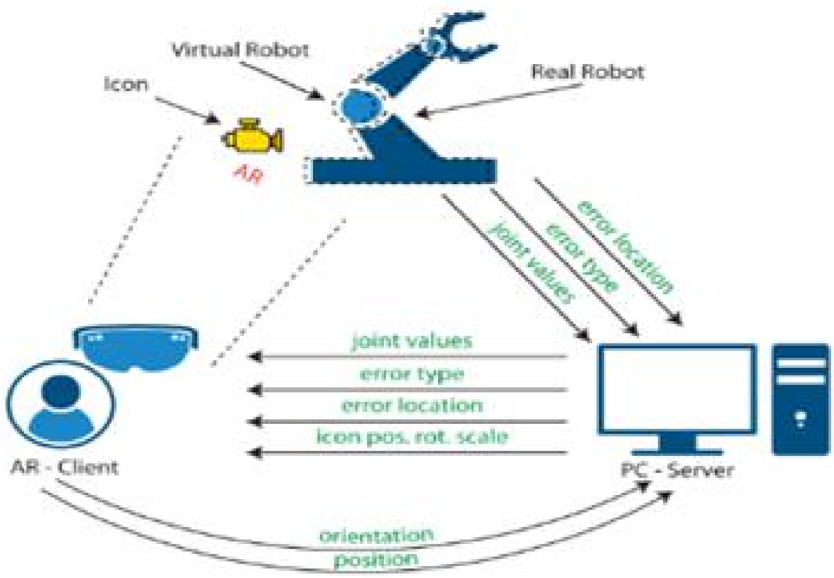

Figure 3.3 The hardware architecture

The AR client is represented by the Microsoft HoloLens, a HeadMounted Display (HMD) device. A wearable device has been preferred respect to a handheld or projected solution. Therefore, technicians can keep their hands free to perform any possible tasks. The server is represented by a desktop Personal Computer (PC) that runs an algorithm capable of acting in two different modalities: adaptive and non-adaptive.

SOFTWARE ARCHITECTURE

The software architecture is composed by three main actors: the industrial manipulator, the AR client and a remote server.

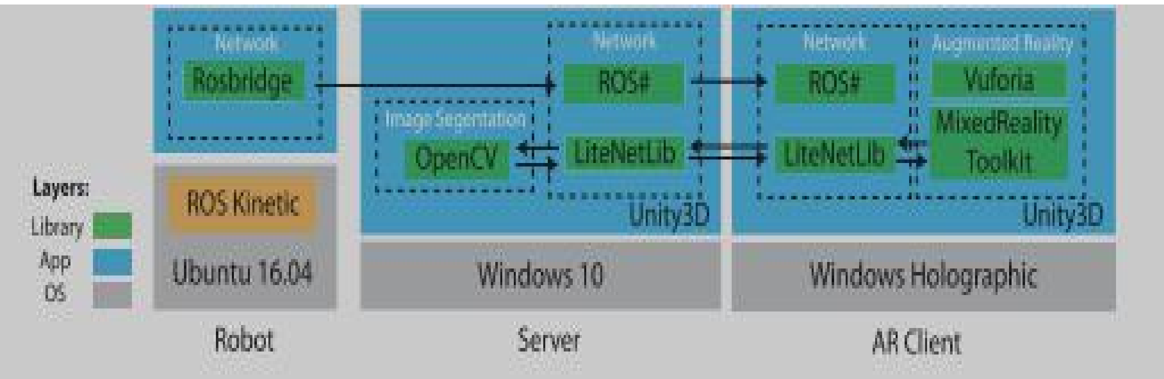

Figure 3.4 The software architecture

4. CURRENT RESEARCH

The algorithm running at the server side is capable of acting in two different modalities: adaptive and non-adaptive. Independently of the employed modality, the server receives from the real robot:

Error location: an integer number corresponding to the joint affected by the fault (values range from 0 to 5);
Joint configuration: the values of the robot joints.

Server is capable of generating a faithful representation of the actual state of the manipulator**.** The server sends to the AR client:
Joint configuration;
Error location and type;
Position, orientation and scale factor of the 3D icon to be aligned with respect to the real robot.

THE SERVER

The server is in charge of deciding the position, orientation and scale of the 3D fault icons.

NON ADAPTIVE MODALITY

In the NA modality, some predefined values are sent to the AR client. Concerning the position value, the icon has been placed at a predefined distance *k* along the Z direction of the

local reference system of the joint affected by the fault. The *k* constant has been defined as:

$$k = 2 * Lma$$

ADAPTIVE MODALITY

In the A modality, the server tries to place the 3D icon in a position close to the joint, always visible to the user and not occluded by the real manipulator.

$$Sicon = (Sc /Drobot) * DJV$$

The AR interface has been designed to assist technicians that work close to industrial manipulators. When a fault occurs on the robot, the robot's movements are suddenly stopped and technicians may not be aware of what is happening in the manipulator. Moreover, at the fault time, users may not have their attention paid to the manipulator. Hence, a combination of virtual assets and sound is employed to draw their attention toward the robot. The virtual assets are the following:

1. A virtual representation of the Niryo robot;
2. A virtual arrow;
3. The virtual fault icons

5. MERITS

1. Increased efficiency

Recognizing faults faster makes Robots to complete certain tasks faster and perform these tasks with a higher accuracy level.

2. Improved working environment

Using industrial robots can improve the working conditions and safety in factory or production process. Visualizing faults helps to improve the working condition of the robots.

3. Increased profitability

By increasing the efficiency of your production process, reducing the resource and time needed to complete it, and also achieving higher quality products.

6. DEMERITS

1. High initial investment:

Robots typically require a large upfront investment and relating it with good technology requires high investment

2. Expertise can be scarce:

Industrial robots need sophisticated operation, maintenance and programming.

7. APPLICATIONS

1. **Task Support and Collaboration**

Industrial robots would work alongside the human workers who jointly perform the assigned tasks. Recent researches revealed that recognised human motions could be used as input for industrial robots control.

2. **Robot training**

Augmented reality can be utilized to train robots for different tasks. For this purpose, organizations can use dual neural networks. With the help of dual neural networks, robots can learn new tasks by observing and breaking down several actions. The first network, known as the visual network, captures an image using the robot's camera to understand the current state of an object. The other network, imitation network, tries to understand a demonstration and analyse how an action is being performed.

8. CONCLUSION

This work proposes an adaptive AR system to display industrial robot faults using a wearable AR device. Starting from the identification of the most common industrial errors, a methodological approach has been employed to figure out which 3D virtual metaphors best evoke faults on industrial robots. Results suggest that with the adaptive modality users have been able to recognize faults faster with less movements than with the non-adaptive solution. The capability of placing the icons in positions always visible from the users has allowed to reduce the troublesome limitations of the narrow FoV of the HoloLens device. Future developments will be focused on testing the adaptive modality on the HoloLens itself evaluating the impact of the computational effort. Finally, to better understand the effectiveness of the adaptive modality, some tests will be carried out with high-payload industrial robots.

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