GRADUATE CERTIFICATE - INTELLIGENT REASONING SYSTEMS

PROJECT REPORT

Cognitive robots imitate human action using a knowledge base system

GROUP MEMBERS

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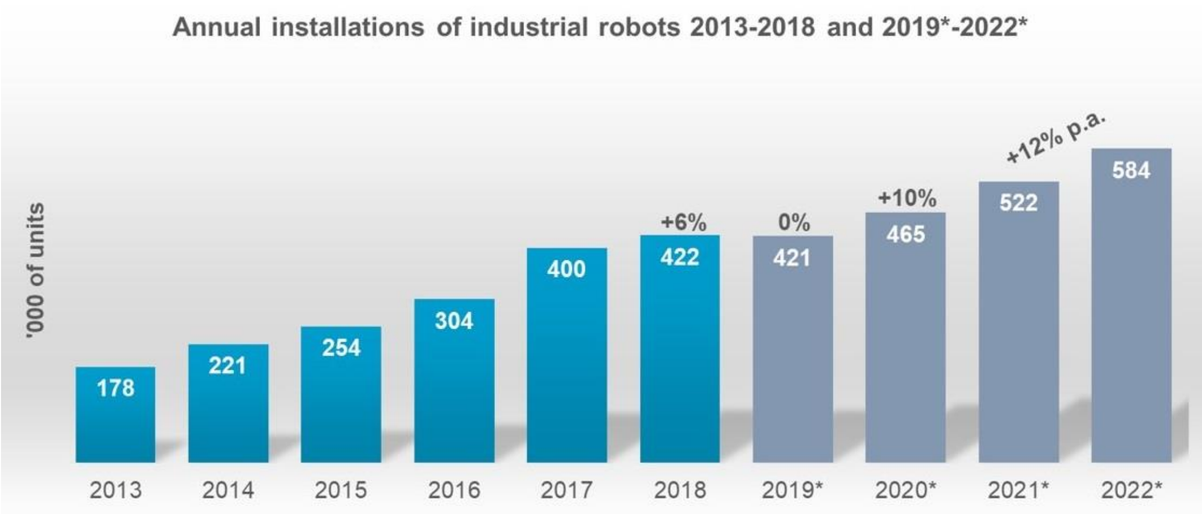
1. Executive Summary

In recent years with artificial intelligence (AI), it has been shown that the usability of machines is enhanced when they become capable to process data, finding patterns, and suggesting proper actions. In this project, a knowledge base for semantic memory is used that allows machines to collect information and experiences to become more proficient with time. By analyzing the video data, the processed information is stored in the knowledge base system which is then used to comprehend the work instructions expressed in natural language. This imparts industrial robots' behavior to execute the required tasks in a deterministic manner.

2. Market Research

Smart robot system needs to cover a large spectrum of applications. Industrial robots are made to do complex tasks in factories. A typical industrial robot application, robots include welding, painting, assembly, disassembly, placing for printed circuit boards, labelling, palletizing, product inspection, and testing; all accomplished with high endurance, speed, and precision. In the year 2020, an estimated 1.64 million industrial robots were in operation worldwide according to the International Federation of Robotics. Robots are a kind of technology that had entered into each and every field such as Agriculture, industry, medicine, technology, and traveling.



3. Business Justification

A lot of research is based on the use of neural networks and especially deep learning methodologies. These methods allow the robot to learn tasks in a way close to human learning but only for specific purposes. In an industrial environment, robots need to process work instruction, extract information and execute requested tasks consistently. The problem considered is to give a robot the ability to process a work instruction for an operator, extract information and execute the requested tasks.

Programming these robots or replicating their tasks onto another robot requires a lot of effort. A typical robotic application requires a specialist to break down the complicated task into smaller sub-tasks and actions. The expert writes detailed instructions in the form of robot programs to make the robot accomplish the desired task. This process needs a high level of expertise and is time-consuming. With the shortages in skilled manpower and resources to train the workforce, it is important we need to capture the factory process into a knowledge base system. The future factory automation process will depend on the task-oriented knowledge graph.

Traditionally robots are good at doing repeatable jobs at high precision – jobs which can bed classified as low mix – high volume(fig 3-1). Semantic Knowledge base in useful in case of high mix – low volume or high mix - high volume(fig 3-2) situations.

Fig: 3-1 High Mix Low volume scenario

Fig: 3-2 Low Mix High volume scenario. Robots packing same type of chocolates into boex

4. Project Objective

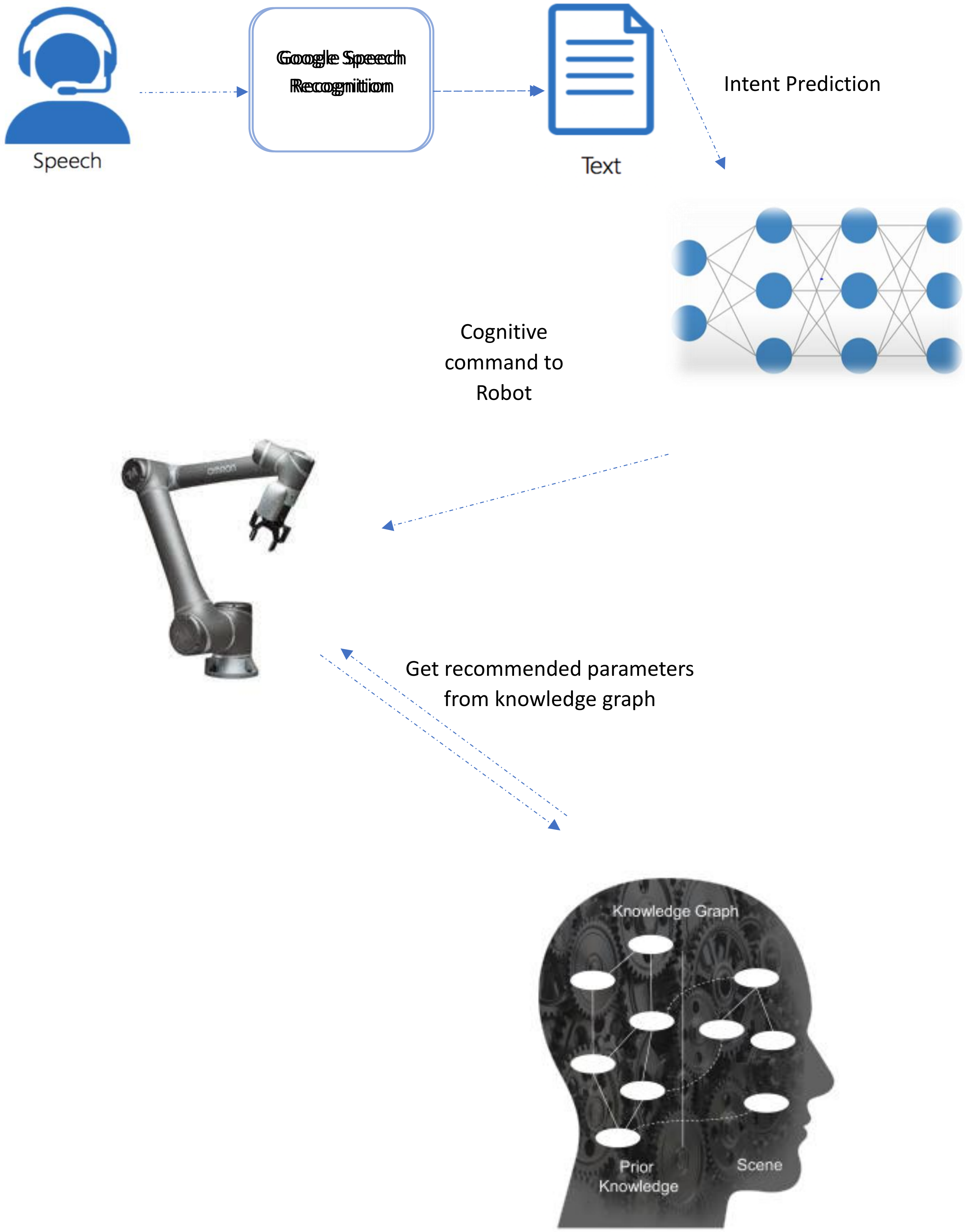
The project focuses on making use of machine reasoning and cognitive reasoning methods to create a knowledge base for articulated robots. At the end of this project my target was to demonstrate the use case of knowledge base system in programming of industrial robots. Demo has to be shown that robot accepts voice commands, get the intent from trained models and query the parameters for identified task from knowledge base system. The knowledge base will be built on certain predefined conditions and new knowledge will be expanded by analyzing the video of human actions for the same job.

4.1 System Design

The system will be listening to the user vice input using google speech recognition. The recognition speech text is sent to a trained neural network model to predict the intent and the predicted intent is sent to the robot to perform the requested task by the user.

Example: If the user says, "please pick red coins". The robot will pick the red-coloured coins available in the vision window.

To complete the action requested by the user, robot needs to query the knowledge base for gripper width to be used for picking up the object and placement location.

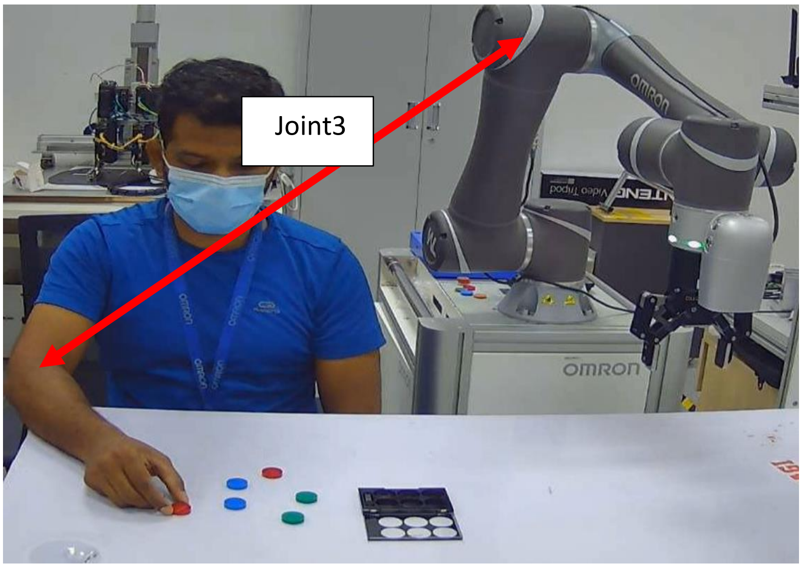

Speech
Google Speech Recognition
Text
Intent Prediction
Cognitive command to Robot
Get recommended parameters from knowledge graph
Knowledge Graph
Prior Knowledge
Scene

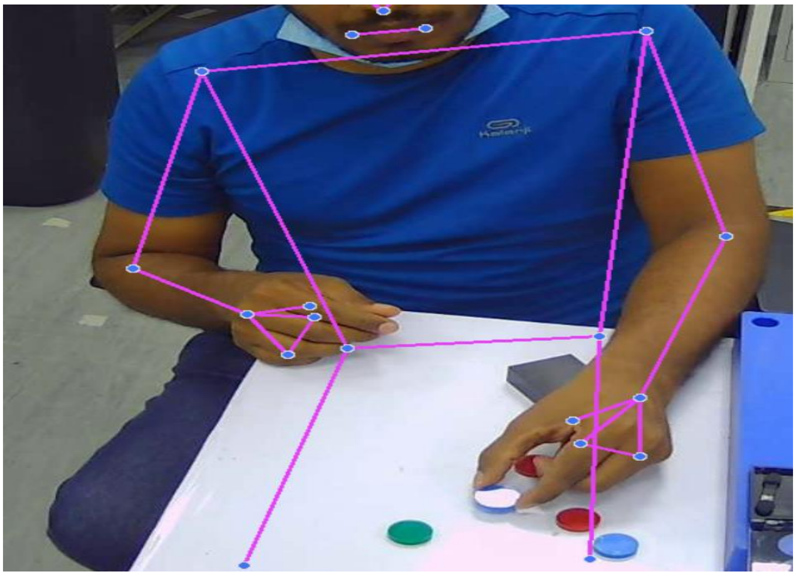
4.2 Knowledge base from recorded video

Below is the list of data items which will be added to the existing knowledge graph.

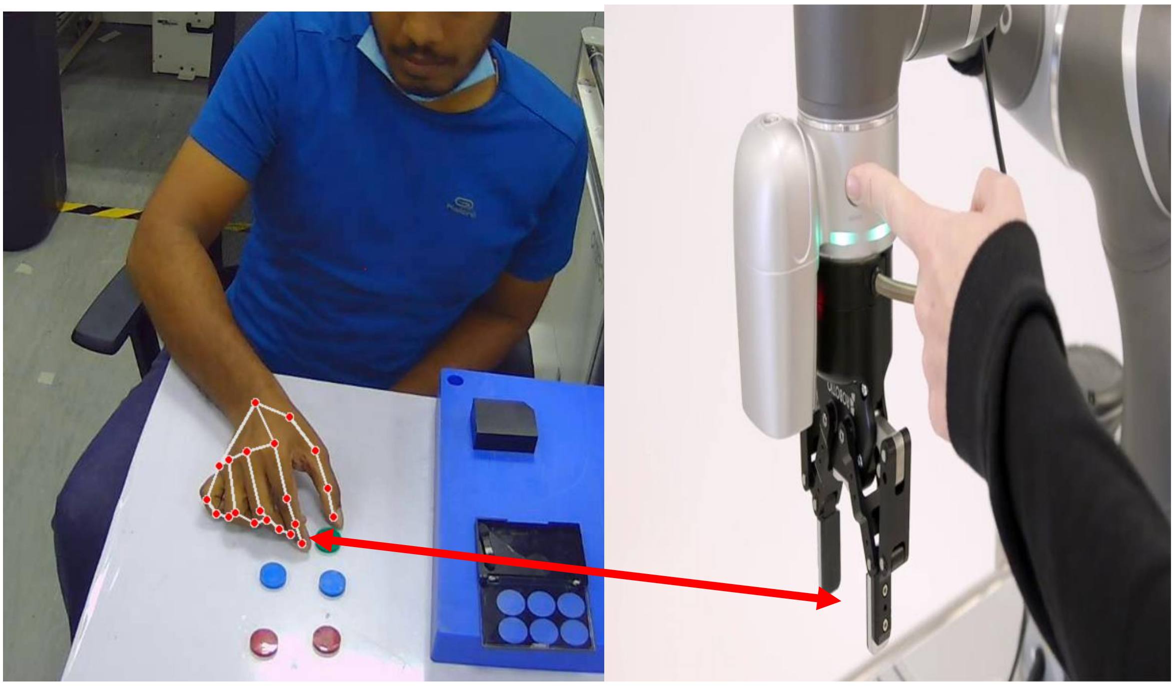
- Color of item
- Final drop-off location by human (finalX, finalY)
- Total distance the object has been moved by human (distance)
- Time taken by human to move object to its destination (cycletime)
- Speed at which object is moved by human(speed)
- Finger gap maintained when moving the object(gripper_wdith)
- Right hand elbow angle (in degrees)
- Left hand elbow angle (in degrees)

Both the elbow angles are used for positioning the joint 3 of the robot.





The gripper width to pick the object is determined by analyzing the distance between index fingertip and thumb tip.



Media pipe framework is being used to process the video files and get data points which will be later added to the knowledge graph system based on neo4j.

4.3 Intent Prediction

For speech recognition google speech engine was used. Google speech recognition has lower word error rate. Dataset is created manually considering the use cases of robot. Total of 16 intents classes is created with 700 words in 55 sentences. Data set containing the json file is manually created.

During data preprocess, first step is tokenization of each words. After tokenization and lemmatization of words are then documented according to intents. With extracted key words after preprocessing they are vectorized for neural network training.

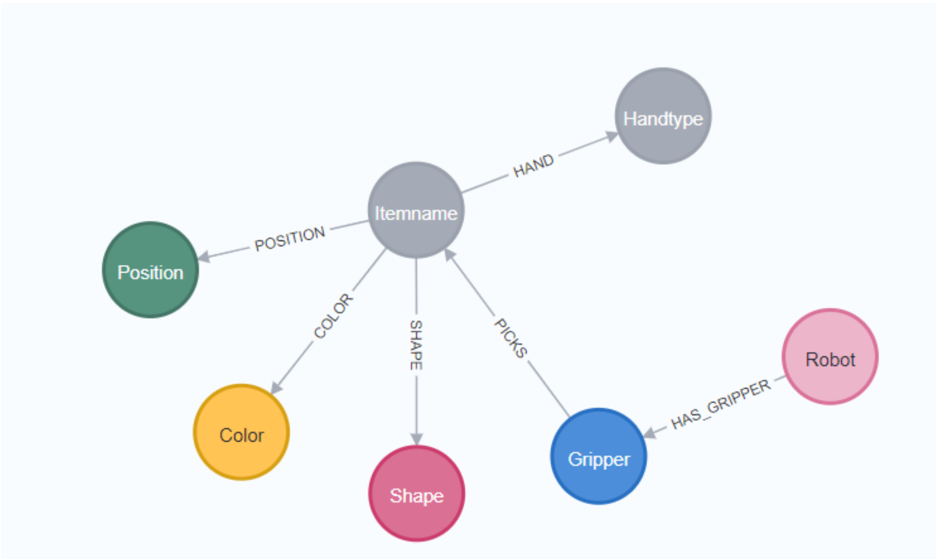
```
},
{"tag": "pickredcoins",
 "patterns": ["please pick red coins", "get the red  coins", "please take red coins"],
 "responses": ["will pickup redcoins"],
 "context": [""]
},
{"tag": "analyze_body",
    "patterns": ["please do body pose analysis", "get body pose", "analyze body pose"],
    "responses": ["will do analysis for bodypose"],
    "context": [""]
},
{"tag": "updatedb",
    "patterns": ["please udpate database", "update the data base"],
    "responses": ["will udpate database"],
    "context": [""]
},
{"tag": "analyze_hand",
"patterns": ["please do hand pose analysis", "get hand pose", "analyze hand pose"],
"responses": ["will do analysis for handpose"],
"context": [""]
},
{"tag": "analyze_all",
    "patterns": ["please do full object analysis", "get full analysis done", "analyze all full video"],
    "responses": ["will do analysis for all items"],
```

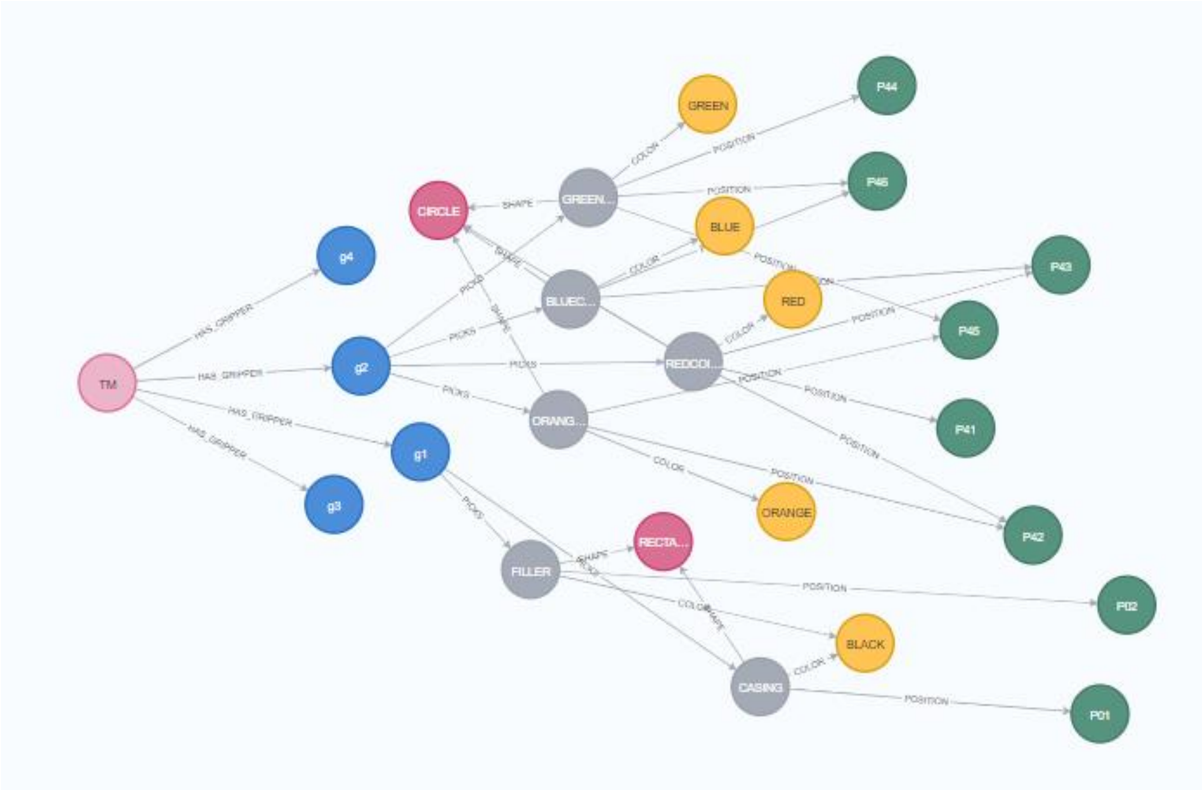
Fig : 4.3 – Dataset for training

5. System validation

5.1 Knowledge graph from expert

Below is the screenshot from neow4j graph data base which shows the node labels and relation types created in the knowledge base by field engineer.





5.2 Knowledge graph after video analysis

Sample data extracted from knowledge graph.

Item Name	Relationship	Value
Redcoins	Cycletime	2 seconds
Redcoins	Grippergap	30 mm
Redcoins	Position	F100F200
Redcoins	Rightelbow	135 degree
Redcoins	Distancemoved	120 mm

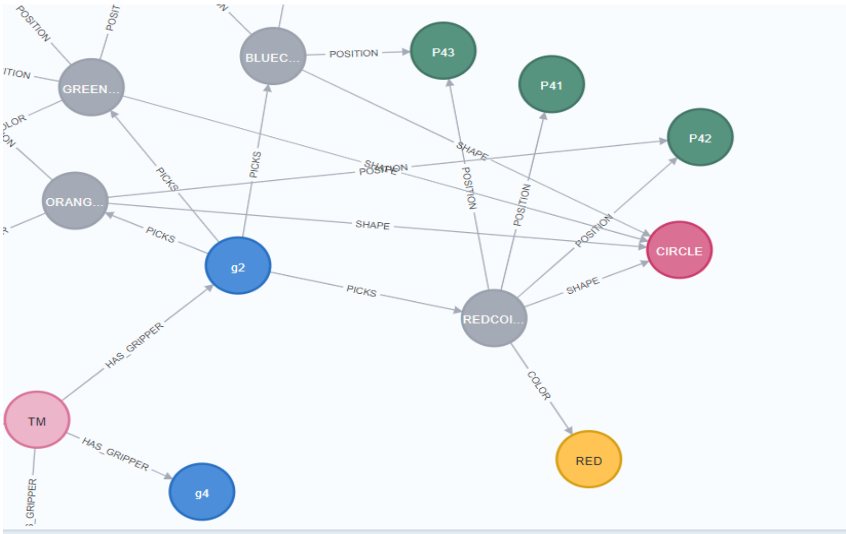


Fig 5.2.1 Old data created by factory engineer

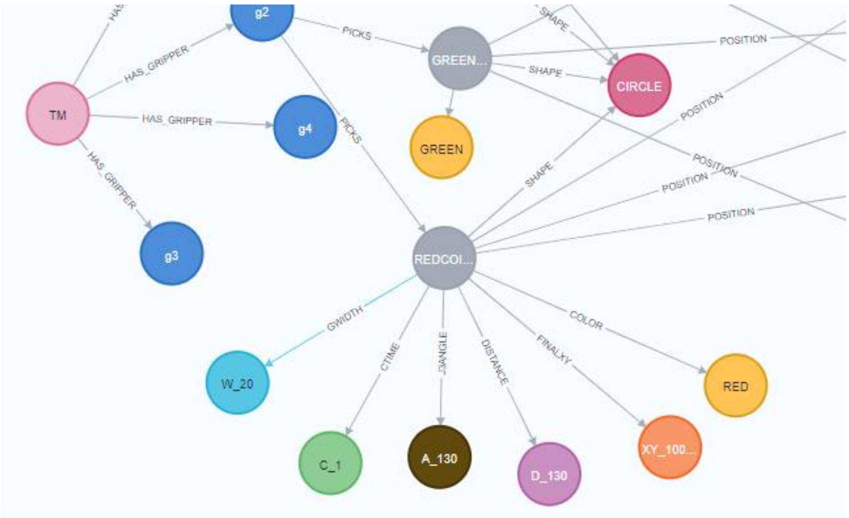


Fig 5.2.2 – New data added to knowledge base by analysing video

5.3 Resulting output – demo

Here is the demo example where the voice command is given to the robot to pick red coins. Once the colour is identified by the robot it sends back the message “Found matching color”.

IP - > 192.168.1.3 is the robot connected to the system

```
----Starting system
Waiting for client...
Connected by  ('192.168.1.3', 56192)

----waiting for voice command
Speak now
please get the red coins
pickredcoins
----Found matching color
----Getting recommendation from database for drop location and gripper position
position for color: P43
Gripper width is : W_20
---sending data to robot
----waiting for voice command
Speak now
thank you goodbye
thanks
```

Fig: 5.3.1 – Screenshot of terminal output

For the given colour red, the system queries the database to get the recommended grip width and distance to be maintained.

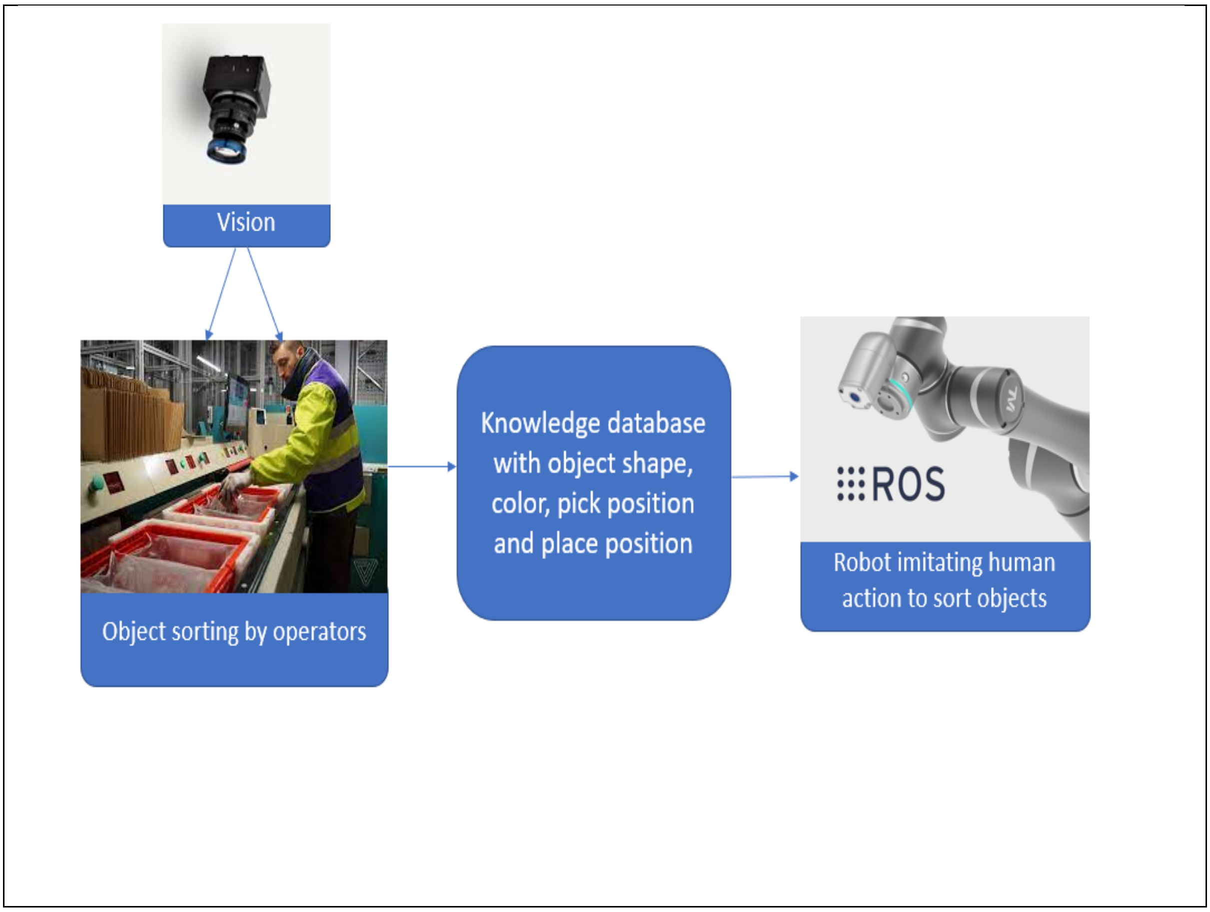
6. Conclusion

The demonstration was successfully done in the lab with actual robot. This method of adding a knowledge base for robot deployments can help to minimize the time required by skilled robotic programmer in the factory floor. This particular proof of concept and demonstration paved for a opportunity to implement similar knowledge base in Singapore based factory. This method will change the way factory automation is approached – “Buy the machines then look for knowledge, but now we will capture knowledge first and then look for machines”

Appendix 1: Proposal

Date of proposal: 28 January 2022
Project Title: Intelligent Cognitive robots learn by imitating human action
Sponsor/Client: *(Name, Address, Telephone No. and Contact Name)* Jayaraman Rajaram Omron Asia Pacific Pte Ltd 438B, Alexandra Technopark, 08-01/02, Alexandra Road, Singapore - 119968 Email: jrajaram20@gmail.com

Handphone: +65 86084217
Background/Aims/Objectives: The proposed system will make use of various reasoning methods to create a knowledge base for the robotic arm to imitate human action. The system will reduce the programming and training time required when deploying new robots in the factories.
Requirements Overview: • Research ability • Programming ability • System integration ability
Resource Requirements (please list Hardware, Software, and any other resources) Hardware proposed for consideration: • GPU, Intel i7 notebook • Omron TechMan collaborative robot • 2D color camera Software proposed for consideration: • Neo4j • Mediapipe • Python



Appendix 2:

Mapped System Functionalities

Module Courses	System Functionality / Techniques Applied
Machine Reasoning (MR)	Knowledge Representation, Rule Based System
Reasoning Systems (RS)	Analytic and Synthetic tasks
Cognitive Systems (CGS)	NLP Chatbot

Appendix 3:

Installation and User Guide

Installation:

The code can be executed from python environment. Below is the software requirement

- mediapipe
- pyttsx3
- nltk
- speechrecognition
- neo4j
- opencv-python
- tensorflow
- pyaudio
- python 3.8

Steps to run the system:

1) Download the files from GitHub.

   Here is the file Structure
   - main.py
   - bodypose_analyze.py
   - handpose_analyze.py
   - socketserver.py
   - tp_final.py
   - graphdb.py
   - chatbot.py
   - findpose.py
   - intentpredict.py
   - video.mp4

   speech
     - train.py
     - chatbot_model.h5
     - classes.pkl
     - words.pkl
     - intents.json

2) Install anaconda and neo4j desktop in your PC.
3) Create a new conda environment with python 3.8
4) Activate your conda environment and install the below packages

   mediapipe
   pyttsx3
   nltk
   speechrecognition
   neo4j
   opencv-python
   tensorflow
   pyaudio
   python 3.8

5) Make sure the neo4j database is active and running on your pc
6) Communication to the robot is through TCP Socket, so it's easier to implement the code for any robot.

```
uri = "neo4j://localhost:7687"
user = "neo4j"
password = "admin"
host = '192.168.1.3'
port = 5000
file = "video.mp4"
```

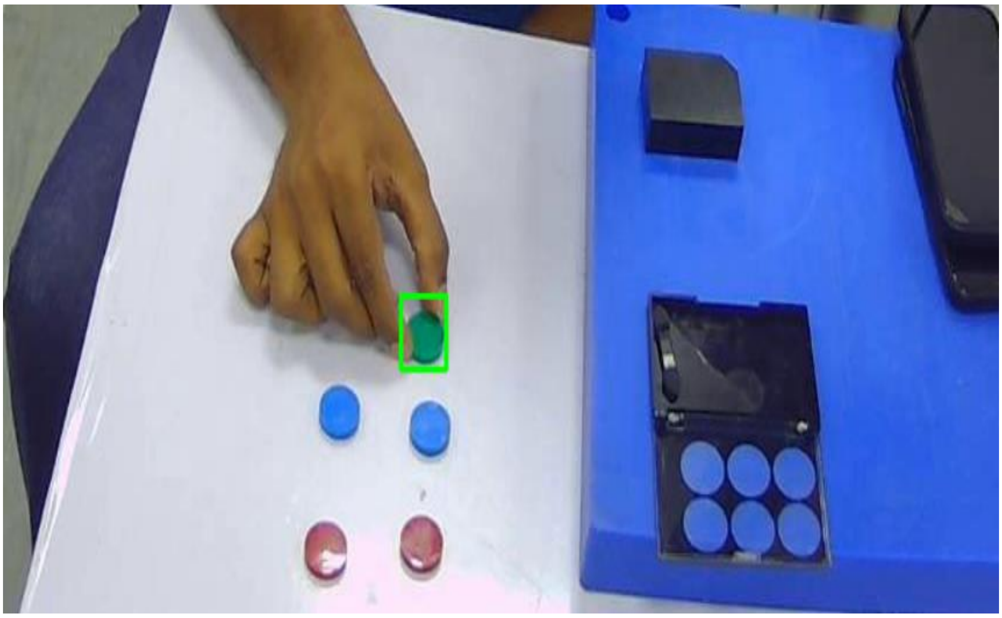
7) Run the main.py program from your anaconda environment. Next run the robot so it will start communicating to the python program
8) You can give voice commands to the system,

   Example : "Create new database", "update database from video"

   "pickredcoins", "pickblackbox"

9) If you want to update the database from the video there will be a prompt to select the region of interest at the beginning of the video. After selecting the item hit enter key.

   Data will be captured only when the selected item is moved in the video.



10) Data captured will be updated to the knowledge base. For reference purpose the same data will be saved to robot.csv file.

Appendix 4:

Reflection on project journey

Lessons learned:

As this is an individual project, I learnt on how to work on a new project which has a wide variety of applications and be focused on the target to be achieved. Due to confidentiality reason need to implement this project on a mock-up system.

The key takeaway from this project is how and where the reasoning system will be useful in the robotics industry.

Second, to understand how the future of robotics knowledge will be moving towards semantics rules-based systems.

Explored a few knowledge-based systems in the market and learned the differences between them.

The most important lesson – is situations where semantic knowledge base may not be useful for factory automation.

Future:

This project helped me to familiarise myself with the knowledge base system. I will be extending this project to the real-world factory application in Singapore. This project gave me a lot of recognition for me in my department, as the project is a mock-up of real-life events in a factory environment.