Applying 5G and Edge Processing in Smart Manufacturing

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***Abstract*— This paper presents a concept for next generation collaborative assembly stations for manufacturing industry. It applies a collaborative mobile platform, AI and 5G technologies. Feasibility of the 5G and Edge processing was studied in this paper. Remote operations and data processing were realized with 5G New Radio wireless connection together with edge processing in order to support low latency communication for data transfer.**

Keywords—Edge computing, 5G, robotics, AI

I. Introduction

A tendency in manufacturing has been towards short production series, one-of-kind production, which requires high flexibility from assembly stations. The high flexibility can be achieved for instance by using mobile robot platforms equipped with a robot arm (manipulator), vision sensors and AI techniques.

Highly flexible assembly cells are characteristically dynamic environments where constant changes occur. The mobile platforms must be robust against such environments. This requires use of 3D vision sensors and high computational power for object detection and identification in order to control tasks of the mobile platforms. High bandwidth with 5G New Radio (NR), the fifth generation of mobile communications systems defined by 3GPP, [1] with Multi-access Edge Technology (MEC) technology [2] can provide scalable computational power with bounded communication latency. Vision based control software of a mobile robot platform can be moved from on-board computer to the edge.

In this paper we present a concept of the next generation assembly cell. Fig. 1 illustrates the concept. In following sections, setup, scenarios, requirements, and outcome of the demonstration are given.

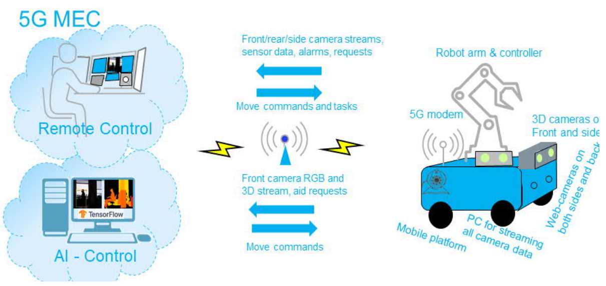

Fig. 1. Concept of the next generation assembly station

II. Setup and Scenario Description

A. Setup

The demonstration consists of a mobile robot platform (MiR 100) equipped with a robot arm (Universal Robots UR10), two 3D cameras (MS Kinect v1&v2) and three 2D web-cameras. In Fig. 2, the demonstration platform is shown. Both the remote control software and the object detection software are running at the 5G network MEC platform, a onboard laptop streams the video and sensor data for remote use. The onboard laptop also handles locally cognitive information sensing human presence and responding to voice-activated actions. The mobile robot and the manipulator have their control software running in their control systems.

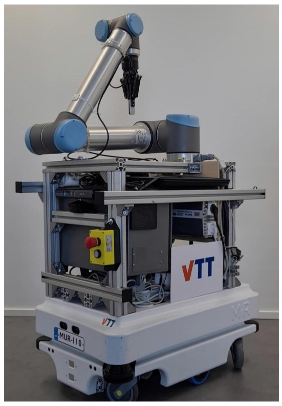

Fig. 2. The demonstration platform

The mobile robot platform is connected to VTT's 5G test network. Wireless connectivity is provided with a 5G Non-standalone (NSA) network deployment. In Fig. 3, the high-level network architecture with main components of the 5G setup are shown.

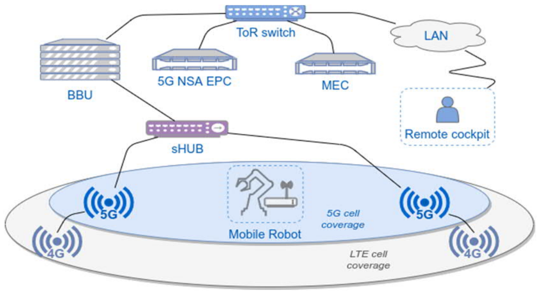

Fig. 3. The high-level 5G network architecture

The 5G network includes several indoor remote radio heads (RRH), both LTE and NR, to provide sufficient coverage to the indoor lab environment. The NR radios are using 3.5 GHz frequency band with a 60 MHz bandwidth. Here, a 5G NSA capable Evolved Packet Core (EPC) is used. The radio network (RAN) consists of an indoor radio solution including several pico RRHs, a radio aggregation point (sHUB), and the 4G and 5G baseband units (BBU).

The 5G network setup is equivalent to a private network likely to be used in manufacturing industry. One key enabler in private networks is the possibility for a local break out function enabling data processing at the local.

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B. *Scenario*

High level scenario is as follows: A mobile robot platform is moving in a dynamic environment and serves an assembly worker; it assists the worker in assembly tasks by carrying parts or tools and delivers them to the worker, who can work in different locations in an assembly cell. There can be several such platforms in multiple locations performing equivalent tasks. The demonstrated scenario has three subscenarios.

Scenario 1: When the mobile robot platform is unable to navigate autonomously to its destination, it raises a message in a remote cockpit after which a remote operator can then use video streams and sensor information remotely and guides the robot to avoid the problematic area. The remote cockpit, shown in Fig. 4, displays real-time video streams for monitoring the platform and surroundings. A navigation map is embedded with 360° sensor data and a joystick for controlling the platform.

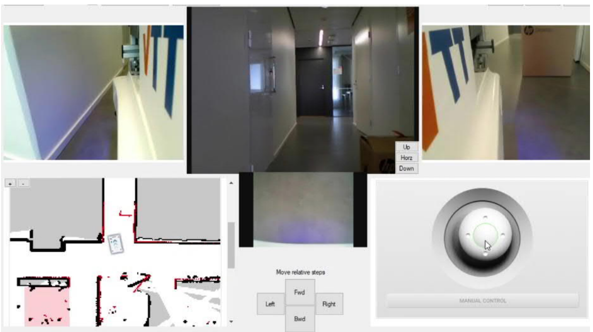

Fig. 4. User interface of the remote cockpit

Scenario 2: The platform can be requested to fetch an item from an arbitrary position e.g. “fetch screwdriver from the trolley in the room 544”. The trolley may have been moved within the room, the platform needs to request AI-control, powered by Tensorflow [1] to take over to drive to the previously unknown position. Same functionality is utilized while delivering the item to the worker, who may have moved around the working area. The platform uses the AI-control to locate and drive to the worker. The AI-control receives a video stream from the platform. Objects (tables, chairs, persons etc.) are identified utilizing a Convotional Neural Network (CNN) [4]. The AI control analyses distance from the 3D-data to the target object, drives the platform next to it, and instructs the platform to continue the original task. Fig. 5 displays the object detection with corresponding depth data in action.

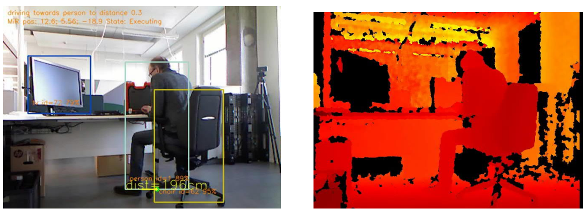

Fig. 5. The object detection (left) and corresponding depth data (right)

Scenario 3: When the platform is in a location where the robot arm needs to reach over, a 3D-sensor is utilized to detect workers or other objects in the work area. The robot arm can then wait until the area is free, warn the worker or request help before performing the actions. In addition to the 3D-sensing functions, the cognitive sensing software handles the voice-activated actions for all of the scenarios where the worker could request the robot to make an action, e.g. pick or place, or complete a task, e.g. deliver or fetch. Fig. 6 shows the cognitive sensing software GUI**Error! Reference source not found.** It displays the working area of the robot-arm as a bounding box highlighting objects breaking the zone. The software also displays available commands and speech detection state with confidence value.

Fig. 6. User interface for cognitive sensing

III. System Requirements

5G-connection requirements: for the remote driving to work like clockwork and safely, the video stream delay may not be more than 30 ms; maximum delay of 90 ms delay is possible with slow driving speeds. The minimum bandwidth using 640x480 MJPEG-video streams is 70 Mbit/s, using several full HD-cameras the requirement would rise to 475 Mbit/s.

IV. Outcome

The setup and implementation of the concept were realized with a real industrial mobile robot platform and standard 5G technology. The realized use cases and tests showed very promising results. A lot of experience was gained about the feasibility of the 5G and Edge processing for industrial robot use cases. Bottleneck of current wireless connection has been the limited performance considering the latency and bandwidth capacity in the wireless networks. The first experiences were made with 5G NSA setup optimized for broadband downlink use cases. With the edge processing and the private network setup we were able to realize a proof of concept for collaborative robots. With future enhancement for 5G connectivity solution, it is foreseen that technology will boost industrial cases further.

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