Using the Intelligent Edge for Real-Time Teleoperation System

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ABSTRACT

Industry is moving rapidly towards human and robot collaboration. An example of this would be Teleoperation, which is the remote control of a machine or a robot. However, one of the major challenges in teleoperation is the latency introduced due to the time taken to transfer large volumes of data. This problem can be solved using Intelligent Edge computing which analyses and processes the data at the edge i.e. where the data is generated. Intelligent edge computing enables near-instantaneous responses and actions.

In this paper we propose a real-time, easy to use and reliable teleoperation system, that combines ADI Time of Flight technology, high precision AI and intelligent Edge computing. This system is being developed, controlling a UR5e Universal robot, and is tested and verified at ADI *Catalyst* in Limerick.

BACKGROUND

Teleoperation has seen a massive development in recent years, especially in the area of autonomous vehicles (teleoperated cars), delivery drones and in mining. Teleoperation reduces the risk of human injury by keeping the human away from a potentially dangerous situation. For example, in mining a teleoperated robot can be sent to inspect a mining cave where it is dangerous for humans to enter.

In ADI we are working on applying the same concept in industrial automation. Using teleoperation in Industry will increase human safety in complex tasks including inspection and repair. It has the potential to effect great societal change by widening the job market for less physically capable workers. Furthermore, it has the potential to improve the shortage in labour skills by making it possible for one person to monitor the flow of several production lines simultaneously, with the added ability to remotely correct for any obstructions on those lines.

For this reason, ADI joined the IMOCO4.E Research project where 46 different consortium partners are working together to deliver a reference platform consisting of AI and digital twin toolchains and a set of building blocks for resilient manufacturing applications. Within IMOCO4.E, ADI is working closely with Tyndall National Institute and Emdalo Technologies on a tactile robot teleoperation use case. The use case will be enabled with high performance AI embedded at the edge. The main challenge for this project is the latency that will accompany teleoperation over large distances.

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PROJECT DESCRIPTION

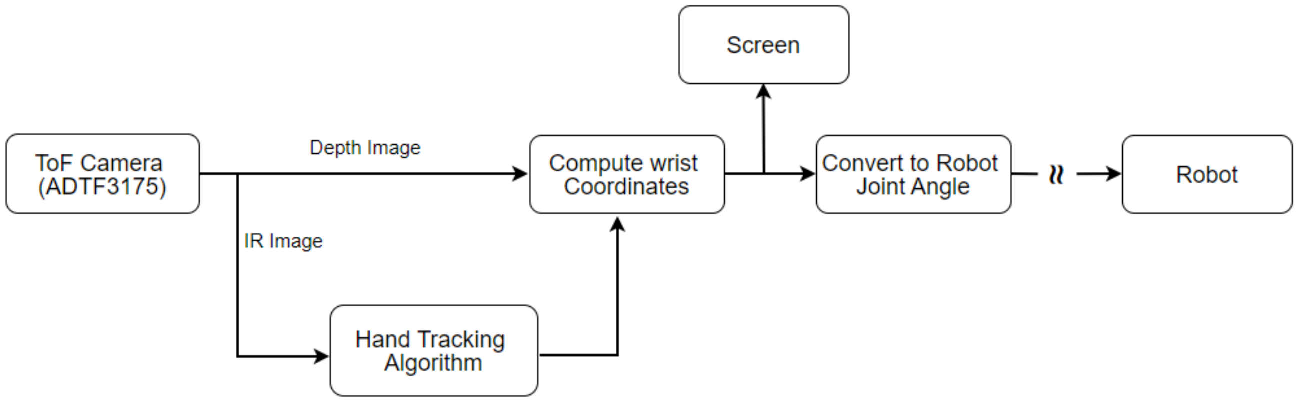

Figure 1. System Diagram.

The ADTF3175 Time-of flight module is used to generate Infra-Red (IR) and depth images. Using machine vision, you can train an algorithm to detect a person's hand and follow its movements. This training can be done by feeding the algorithm with thousands of images of humans each with the key points of a hand labelled, so that the algorithm can learn to detect when a hand is in an image. There are many pretrained models already developed for use with RGB images. However, the number of pretrained models available for either IR or depth images is extremely limited. This makes the use of IR/depth images for hand tracking challenging. However, a key advantage of IR/depth is that it requires less computational power compared to RGB, which makes it more suitable for use at the Intelligent edge.

Multiple hand tracking algorithms were developed and tested to find which created the best model to suit our application. These included looking at pretrained models as well as developing our own models, trained internally using available datasets. We also used a combination of RGB and IR datasets to train a new model.

The most successful approach tested to date has been using IR images with a pretrained RGB hand tracking model. This provided a successful detection rate of 89%. Additional work in this area will be to train a new model with IR images and compare the level of accuracy and processing times achieved with current performance.

As mentioned, IR images require much reduced computational power to process, they can be used in darker lighting conditions than more standard RGB images. In addition, IR sensors are preferred if there are privacy concerns in recording people's faces.

The IR image together with the depth image are used to find the position of the wrist in space in X, Y and Z coordinates, where X and Y are obtained from the pixel location of the wrist in the IR image and Z is the depth obtained from the depth image as shown in Figure.1.

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To begin the remote control of the robot (teleoperation) the user would position their hand in front of the camera (ADTF3175), with their wrist centered in the middle of the screen. The system will detect the position of his wrist and save its coordinates, then it will start to calculate the teleoperator's wrist movements across the frames and convert it to robot joint angles used to move the robot.

The robot is preprogrammed with an initial starting position. When it receives the joint angle co-ordinates it will move to the requested position. This will allow the robot to continuously track the movements of the operator's wrist. As part of the development work several options for real time robot control were tested, the optimum in terms of latency for this project was found to be Real Time Data Exchange (RTDE). For safety, maximum boundaries are set for the robot motion which the robot cannot exceed. These boundaries can be set for different tasks to define a virtual bounding box for the robot to move inside.

Visuals have been included within the system to make it easier for the operator to see from where he started and how he is moving the robot. The initial point will appear at the middle of the screen and a line will be drawn to show how much and in which direction the robot moved from its initial position as shown in Figure 2.

Figure 2. Wrist Tracking in the Teleoperation system.

The next step will be to add gesture recognition to the system, which will allow remote control of the gripper. This will include two commands, closed fist to close the gripper and open fist to open the gripper.

RESULTS, LEARNINGS OR TAKE-AWAYS

The system is currently working on an Intel® NUC 10 Performance kit (NUC10i7FNH), which is an edge computing device. The system shows reliable results for real-time teleoperation with minimum latency. To put it into context, a latency of 0.3 secs is considered safe for teleoperation for precision surgery [4].

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For our system we are currently achieving:

- Overall system Latency: 0.3 secs for the total latency measured from the operator movement to the equivalent robot movement.
- Frame rate: 30 fps for the Hand tracking algorithm.
- Detection rate: 89% for the wrist.
    - A new IR hand tracking model under development should increase detection rate.

This results in a teleoperation system which works in real time i.e. the robot moves almost instantaneously with the hand. This makes it simple and intuitive to use, avoiding the need for specialized operator training.

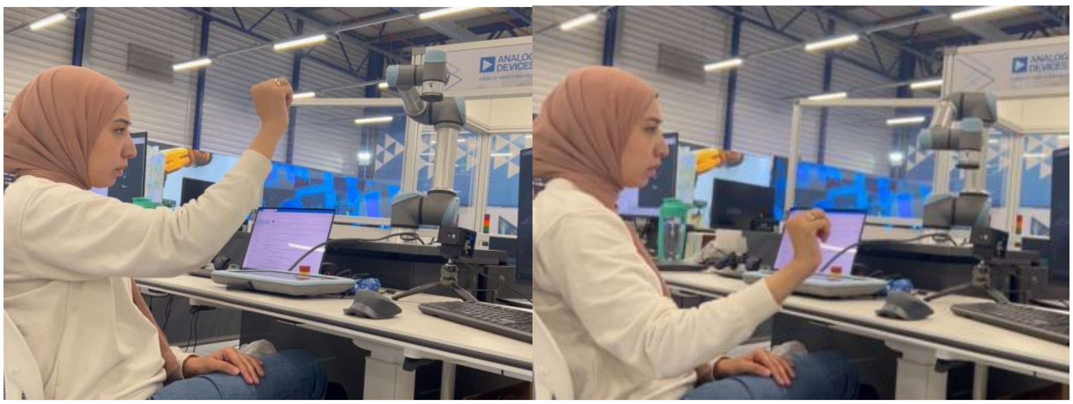

Figure 3. Teleoperation Demo at ADI Catalyst Limerick.

CONCLUSION

The proposed teleoperation system using ADI ToF and Intelligent edge computing shows minimum latency and high accuracy teleoperation. It is easy to use and does not require any training, unlike most of the available teleoperation systems. The limitation in this system is that it allows the robot to move in the X, Y and Z directions but does not currently allow rotational movements for the robot joints. This can be addressed in future development work. The system is now working for short distance teleoperation where the robot is directly connected to the system. We are working on operating the system for longer distances between the operator and the robot.

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