Fellow	<Zahid / **Iqbal**>
Host Organisation	<Fraunhofer Institute for Integrated Circuits>
Scientific coordinator	<Martin / **Dehmel**>

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During the fellowship period, we developed the work around the following tasks.

- The first task involved the development of a preliminary approach that uses classical computer vision techniques and available software libraries for pose estimation of workspace objects. We establish a world reference frame using Aruco markers and find a point in the object's bounding box in the camera reference frame. Finally, we use a transformation to locate objects in the world reference frame. We developed modules for Aruco marker detection and RealSense camera manager in this exercise. This approach, however, has limited scalability to different objects. While it gives the complete translation in 3D, it provides one component of the rotation, i.e., rotation around the z-axis.

- In the next exercise, I reviewed recent pose-estimation techniques in literature that rely mostly on deep-learning methods. We studied the following popular methods: PoseCNN, Deep Object Pose Estimation (DOPE), Dense Fusion, FS6D, BundleSDF, FoundationPose, and Point-pair features. Here, all but the last method relies on a deep learning-based technique for pose estimation. All the studied methods report a success rate of pose estimation. At the end of this study, we generate a comparison table summarising the different approaches around various performance metrics such as the type of input data, output of prediction, pose estimation accuracy, and implementation difficulty. This exercise led to further investigation and deployment of FoundationPose. Currently, FoundationPose supports the perception component of the pipeline in robotic motion and control.

- In the final task, we carried out developments regarding LEAP Hand, a dexterous and anthropomorphic robotic hand. We developed a ROS-based control interface (CLI) for the robot hand and a digital twin in a state-of-the-art physics-based simulation engine, Isaac-Sim. CLI lends capabilities to perform individual or grouped joint control and saving and reloading of poses, thus providing a handy tool for debugging purposes. With long-running tests, we read and logged data from the hand, which we analyzed to characterize its performance. These aspects include movement precision and accuracy in reaching and following a given motion target. Additionally, we examined the hand's temperature profile during operation.

  Further, we created a simulation model for the hand in the state-of-the-art simulator Isaac Sim. We simultaneously controlled the simulation model and the robotic arm, creating a virtual twin. As Isaac Sim is a physics-based simulation engine, our work provides a preliminary basis for creating learning-based skills which are deployable to the hand.

  A paper is in progress based on our work regarding LEAP Hand.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

I am involved in the following papers which are still in progress and will be submitted in the coming weeks.

1. The developments regarding LEAP Hand. (Principal author) (Pending)
    a. Tentative title: "Performance Characterization of the LEAP Hand with a ROS-Based Control Interface and Digital Twin Integration"
    b. authors: Zahid Iqbal, Martin Dehmel, Konstantin Wrede, Sebastian Zarnack

2. I was part of the general group working to deploy a sim-to-real policy transfer for robotic arms. My role involved initial studies in the perception pipeline and a review of the written drafts. (minor contribution) (Pending)
    a. Tentative title: blind-review submission
    b. authors: Konstantin Wrede, Sebastian Zarnack, Martin Dehmel, Vladimir Fokow, Yibo Di, Robert Lange, Zahid Iqbal and Dirk Mayer

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

The LEAP Hand demonstrator was presented at the following two local events.

- Long Night of Science
  Lange Nacht der Wissenschaften, 14.06.2024 online link
  Fraunhofer IIS, EAS, Dresden

- Community Event
  ReAIllize Wettbewerb, 20.06.2024 online
  Fraunhofer IIS, EAS, Dresden

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Concerning the research exchange programme, I visited INESC TEC Porto, Visual Computing & Machine Intelligence (VCMI) Research Group from September 30th to October 4th, 2024. My main point of contact was prof. Jaime Cardoso. During the brief visit, I presented my research work, mainly on ROS-based control of robotics with the team at VCMI, and discussed the work being done at Fraunhofer robotics group. Fraunhofer mainly works with industrial manipulators. One of the lines of investigation at Fraunhofer is reinforcement learning and the use of Isaac-related frameworks from Nvidia. On the other hand, VCMI's focus area is the perception of autonomous driving. In this case, they are particularly investigating uncertainty suppression techniques. Also, they use OpenMMLab which allows the development of open-source deep learning-based perception systems. It was a valuable opportunity to learn about the work at VCMI.