**Review of Research Methodology**

**Introduction**

In our modern society, people have become accustomed to simple human-computer interaction (HCI), primarily involving input devices such as joysticks, mice and keyboards. These are commonly used in robotics and automation. However, as technology evolves, these user interfaces (UI) need to advance in parallel. As a result, human-robot interactions (HRI), using hands as input devices. This offers more intuitive control, improves safety, accuracy and responsiveness in complex tasks. This review will explore papers containing research and applications on how the implementation of gesture-based systems can be applied across various industries.

1. **Literature Review of Methodologies**

These papers have been studied to investigate the diverse methodologies used to investigate the gesture-based control systems:

* Sobhani et al. (2022) implemented a mixed-reality robot teleoperation system using VR headsets to control a robotic arm that has three joints (shoulder, elbow, and wrist). The study was measured using the System Usability Scale (SUS) scoring, head tracking and task performance metric using human participants in assessing performance in remote environments that present high-risk conditions as described in the decommissioning of a nuclear facility.
* **Bai et al. (2023)** createdan **automatic control system for a 7-DOF robotic arm,** usingan **RGB camera** and **object pose estimation** powered by neural networks. Their testing involved real-time grasping tasks and robot manipulation in a controlled environment [3].
* **Nguyen et al. (2022)** proposed a **real-time skeleton-based gesture recognition model** utilising **TD-Net architecture** alongside **MediaPipe** for hand pose estimation. They evaluated their system using the **IPN dataset,** measuring recognition **accuracy** and **inference speed** for continuous hand gesture control [2].
* **Gourob et al. (2021)** developed **a low-cost robotic hand** system controlled by **vision-based gesture recognition**. Built using an **Arduino UNO** and five servo motors, the system recognised gestures through a live feed camera and was tested for assistive technology applications [4].
* Yu et al. (2017) implemented a gesture-controlled UAV system using ROS. Hand gestures were recognised through RGB input and translated into UAV flight commands. Drone-operated simulations were conducted to evaluate results [5].

1. **Distinguishing Academic and Non-Academic Sources**

All cited papers referenced are academic, peer-reviewed, and this is because they are published by IEEE. Peer-reviewed sources ensure rigour, replicability and a well-structured methodology. In contrast, non-academic sources such as blogs and or video demonstrations, would lack peer review and scientific validation, and thus are removed from the analysis to maintain research quality.

1. **Recommended Peer-Reviewed Articles**
2. M. Sobhani et al., "Usability Study of a Novel Triple-arm Mixed-Reality Robot Teleoperation System," *2022 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR)*.
3. T.-T. Nguyen et al., "A Continuous Real-time Hand Gesture Recognition Method based on Skeleton," *2022 IEEE ICCAIS*.
4. S. Bai et al., "Automatic Control System for Reach-to-Grasp Movement of a 7-DOF Robotic Arm Using Object Pose Estimation with an RGB Camera," *2023 IEEE ROBIO*.
5. J. Hossain Gourob et al., "A Robotic Hand: Controlled With Vision-Based Hand Gesture Recognition System," *2021 IEEE ACMI*.
6. Y. Yu et al., "ROS-based UAV control using hand gesture recognition," *2017 Chinese Control and Decision Conference (CCDC)*.
7. **Contextualization of Literature**
8. Sobhani et al. investigate HRI in high-risk industrial applications, using VR for safe teleoperation.
9. Nguyen et al. advance continuous gesture recognition, critical for dynamic, real-time systems.
10. Bai et al. address robotic manipulation, bridging prosthetics and automation with precision pose estimation.
11. Gourob et al. emphasise cost-effective assistive solutions for accessibility and healthcare.
12. Yu et al. extend gesture control to UAVS, enhancing flexibility in outdoor and emergency scenarios.
13. **Critical Comparison and Knowledge Gaps**

Strengths

* Rich experimental frameworks: (Sobhani et al., Bai et al.) integrating hardware, VR, and teleoperation metrics. This allows users a better visual of their environment and easier manipulation of equipment.
* Real-time recognition: (Nguyen et al.) with high accuracy and robust model performance. Reduces the possibilities of mistakes or injuries due to an error in operation.
* Practical applications: (Yu et al., Gourob et al.) in UAV control and low-cost prosthetics. Can provide an alternative if manual labour is not available or if there is a shortage of it.

Weaknesses

* Environmental constraints: Many studies (e.g., Sobhani, Bai) were conducted under controlled lab environments, reducing generalizability. Thus, the data collected will be inaccurate when performing in different real-world conditions.
* Hardware-Software Disconnect: Nguyen’s work focused heavily on software modelling without integrating real robotic systems. This can cause problems if the model does not match the robotic system it is applied to, which can lead to orders although correct in the model appearing differently for the robotic hardware.
* Limited user studies: Some projects (e.g., Gourob) lacked extensive user testing or long-term performance metrics. Problems can arise when it comes to the integration of these systems if they are not adaptable to a diverse group of users.

Knowledge Gaps Identified

* Cross-environment testing: Adapting systems for different lighting, weather, or terrain conditions.
* Hardware robustness: Ensuring mechanical durability over extended operation.
* Longitudinal studies: Tracking usability and accuracy over long periods to measure system fatigue and adaptability.

1. **Literature Map**

Gesture-based HRI Methodologies

* Vision-based Recognition
  + Skeleton + TD-Net [2]
  + RGB + Pose Estimation [3,4]
* Interface and Integration
  + VR + Robotic Arms + SUS [1]
  + ROS + UAV [5]
* Evaluation Methods
  + Quantitative (Accuracy, Completion Time) [1,2,3]
  + Qualitative (User Feedback, SUS) [1]
* Application Context
  + High-risk Industry & Surgery [1,3]
  + Assistive Robotics [4]
  + UAV Control [5]
* Research Gaps
  + Environment Robustness
  + Hardware Integration in ML Models
  + Longitudinal Performance Testing

1. **Conclusion**

Gesture-based systems show promise for improving human-robot interaction that requires precision and safety. However, for widespread adoption, further development is essential. In the future, the use of Artificial Intelligence (AI) can be used to assist in the identification and tracking of a person's arm. This role can be further expanded to real-time situations as notifying the user using external sensors and translating it to information that the user can understand. These can range from temperature fluctuation, identification of the structural integrity of a building, and radiation. Sites such as roboFlow allow users to annotate certain parts of an image and name it, for identification, such as a hand. This process requires the processing of thousands of images to train the dataset to identify what a hand is and what it is doing. The dataset can then be given to YOLO to run the program and verify its success. At the same time, the field of robotics will also have to advance to the point where its movement can copy ours accurately to perform said tasks as well as a human could without any of the risk. These robots will have to be built to do these specific jobs, Surgery robots will need to be small, nimble and accurate; construction robots will need strong servos, be resistant to the elements and be durable, etc. They can also be modular, allowing for adaptation to specific situations; these can range from being able to replace tools and equipment, to defence from specific environments, temperatures and hostile environments. This can range from protection from wildfires during firefighting, heating for cold climates, armour to defend from shrapnel and high explosives, radiation shielding and medical robotic arms with modular tools for what is needed in surgery.

1. **References**

M. Sobhani, A. Smith, M. Giuliani and T. Pipe, "Usability Study of a Novel Triple-arm Mixed-Reality Robot Teleoperation System," 2022 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), Sevilla, Spain, 2022, pp. 217-223, doi: 10.1109/SSRR56537.2022.10018630. keywords: {Headphones;Atmospheric measurements;Robot vision systems;Virtual reality;Streaming media;Cameras;Manipulators;Teleoperation;Mixed-Reality;Human-Robot Interaction;Remote presence;System Usability},

S. Bai, J. Guo, Y. Jiang, H. Yokoi and S. Togo, "Automatic Control System for Reach-to-Grasp Movement of a 7-DOF Robotic Arm Using Object Pose Estimation with an RGB Camera," 2023 IEEE International Conference on Robotics and Biomimetics (ROBIO), Koh Samui, Thailand, 2023, pp. 1-6, doi: 10.1109/ROBIO58561.2023.10354531. keywords: {Visualization;Shape;Pose estimation;Robot vision systems;Neural networks;Control systems;End effectors},

T. -T. Nguyen et al., "A Continuous Real-time Hand Gesture Recognition Method based on Skeleton," 2022 11th International Conference on Control, Automation and Information Sciences (ICCAIS), Hanoi, Vietnam, 2022, pp. 273-278, doi: 10.1109/ICCAIS56082.2022.9990122. keywords: {Automation;Gesture recognition;Feature extraction;Skeleton;Robustness;Real-time systems;Task analysis;hand gesture recognition;skeleton-based hand gesture recognition;continuous hand gesture recognition},

J. Hossain Gourob, S. Raxit and A. Hasan, "A Robotic Hand: Controlled With Vision Based Hand Gesture Recognition System," 2021 International Conference on Automation, Control and Mechatronics for Industry 4.0 (ACMI), Rajshahi, Bangladesh, 2021, pp. 1-4, doi: 10.1109/ACMI53878.2021.9528192. keywords: {Service robots;Robot vision systems;Input devices;Human-robot interaction;Gesture recognition;Assistive robots;Older adults;Human Robot Interaction;Hand Gesture Recognition;Robotic Hand},

Y. Yu, X. Wang, Z. Zhong and Y. Zhang, "ROS-based UAV control using hand gesture recognition," 2017 29th Chinese Control And Decision Conference (CCDC), Chongqing, China, 2017, pp. 6795-6799, doi: 10.1109/CCDC.2017.7978402. keywords: {Gesture recognition;Algorithm design and analysis;Drones;Cameras;Robots;Mechatronics;Automation;ROS;UAV Control;Hand Gesture Recognition},