Using a Dexterous Hand for Automotive Painting Quality Inspection

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- Professor at the Faculty of Engineering of the University of Porto
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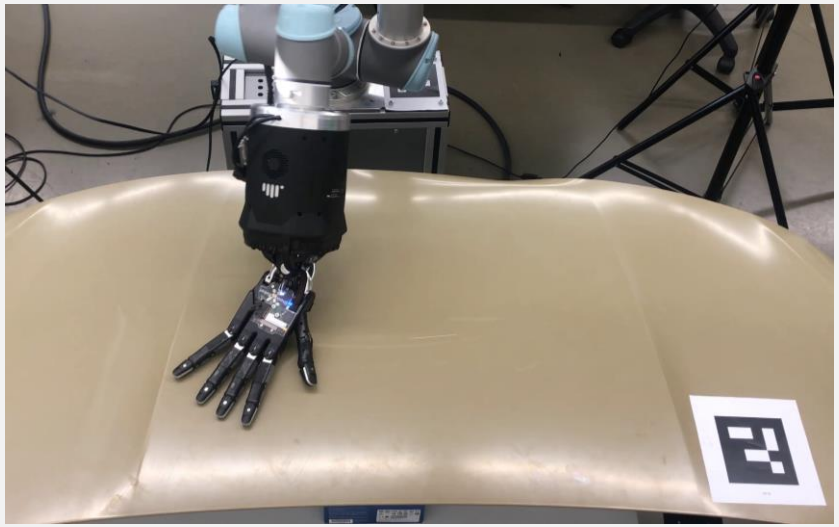
- Research interest areas:
  - Robotic Hybrid Locomotion Systems
  - Manipulation with Robotic Hands
  - Educational Robotics
- 40+ Publications

Contents

I. Introduction

- Since the 1960s, with the improvement of technology, industrial-level processes performed by human operators have gradually been replaced by industrial robots.
- Industrial automation has become imperative for companies striving to attain competitiveness in the contemporary marketplace, owing to its inherent advantages, such as increased productivity, improved product quality and cost savings.
- There are still tasks that are not yet automated, typically because they require a high level of sensitivity to touch and/or dexterity.

- **Goal Task**



- Automotive Painting Quality Inspection

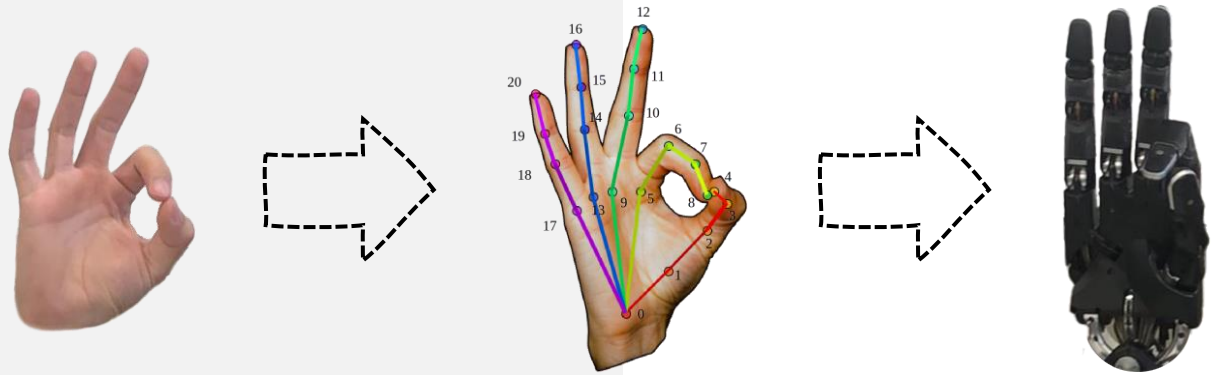
II. Literature Review

A. Data Acquisition

- OpenPose
  - Full body detection
  - Robust performance
  - Open-source
- MediaPipe
  - High-fidelity hand tracking
  - Low computational footprint

B. Kinematic Retargeting

- BioIK
  - Optimisation algorithm
  - Flexible user-defined weighted goals
  - Hand and Arm control
- TeachNet
  - Neural network
  - High-fidelity hand pose replication



III. Implementation

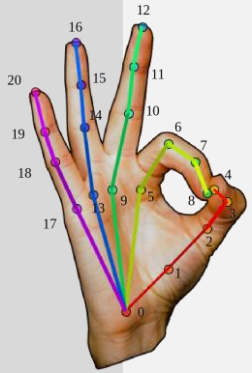
A. Data Acquisition

- OpenPose

RGB D

OpenPose

2D Keypoints + Depth



3D Keypoints

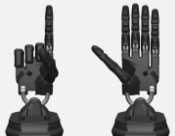
- MediaPipe

RGB RGB

MediaPipe MediaPipe

2D Keypoints + 2D Keypoints

disparity

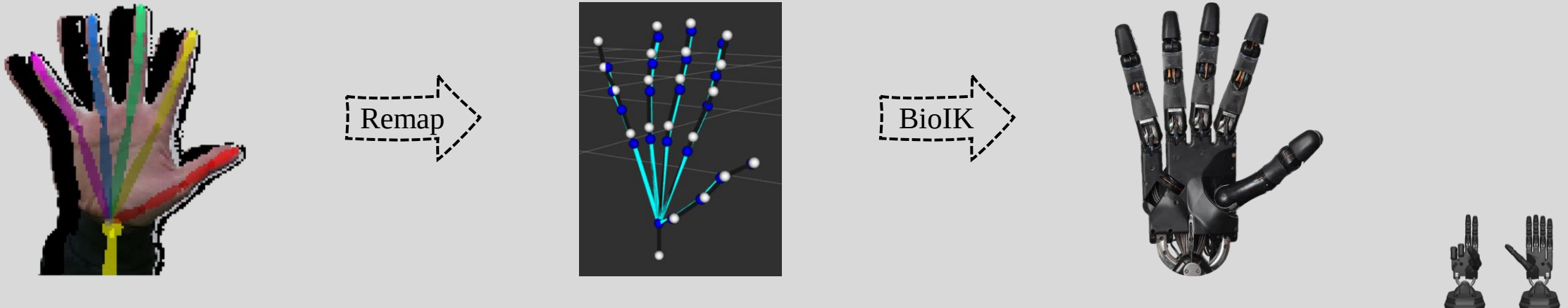


III. Implementation

B. Kinematic Retargeting

- BioIK

- Simultaneously control Shadow Dexterous Hand and UR5
- Utilised Goals: position, direction, centre joints, minimal displacement, joint function
- Prior to being utilised by BioIK, the keypoints were remapped to match the dimensions of the Shadow Hand

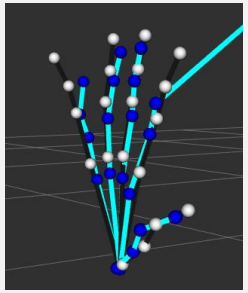


IV. Results

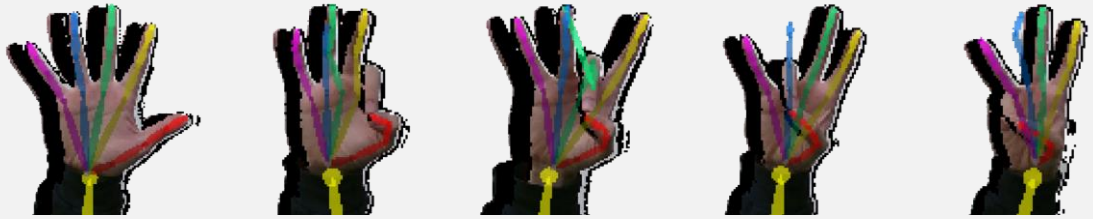
○ OpenPose

- Keypoints frequently detected incorrectly

  (mainly fingertips)

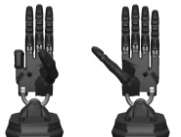


- Highly unstable keypoints detections



○ Chosen Algorithms

- MediaPipe (data acquisition)
  - Accuracy and stability
  - Low computational power required
- BioIK (kinematic retargeting)
  - Faithful human movements replication
  - 200 milliseconds execution time



IV. Results

- Final Global Algorithm

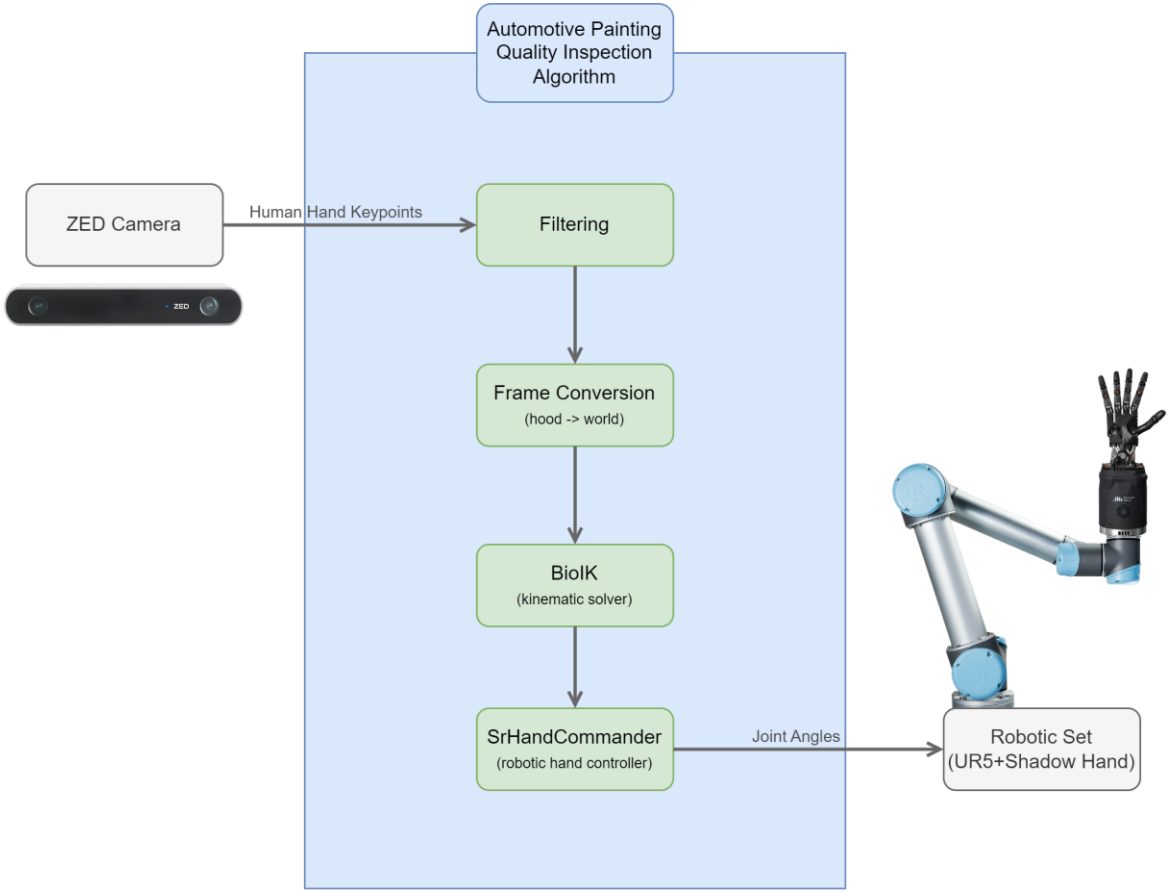
i. Human hand capture by ZED camera;

ii. 3D hand keypoints acquired via MediaPipe and stereo-vision techniques (car bonnet referential frame);

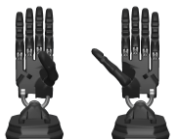
iii. Conversion from the car bonnet referential frame into the robot frame;

iv. Robotic set joint angles calculated via BioIK;

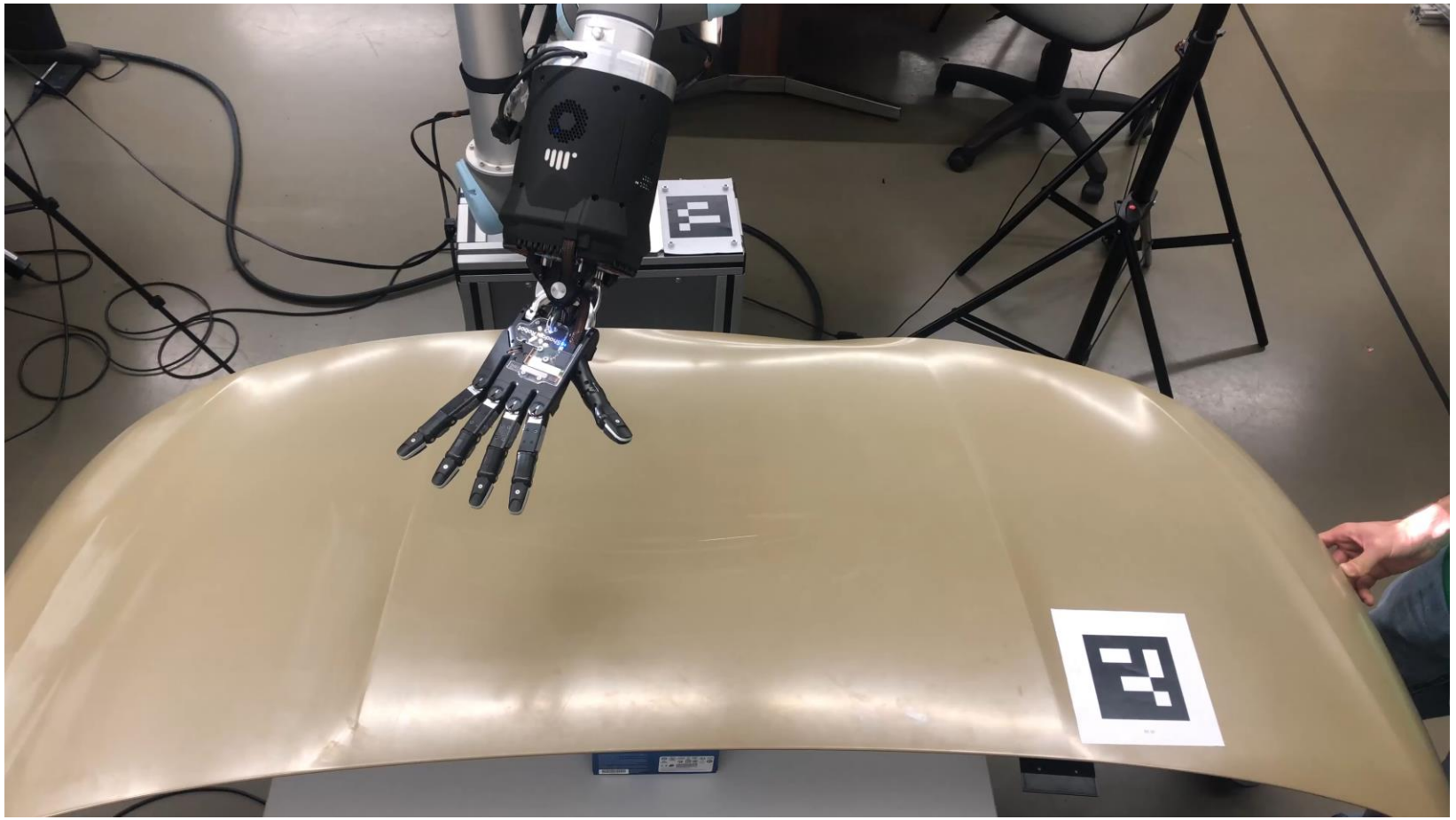
v. Joint angles sent to the robotic set.



(1 second end-to-end delay)



IV. Results



Demonstration Video

https://youtu.be/lpxIPF_6WYc

V. Conclusion and Future Work

○ Conclusion

- Challenges and lessons from OpenPose
- Successful integration of MediaPipe
- Efficient kinematic retargeting with BioIK
- Accurate replication of human-like movements
- Successful accomplishment of the proposed task

○ Future Work

- Integration of tactile sensors
- Enhanced sensory feedback
- Exploration of advanced techniques

Acknowledgement

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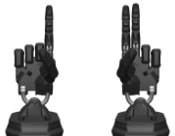

Thank You