Trim3D

Development of an Automated Hair Trimmer

Graduate

Thomas Rüegg

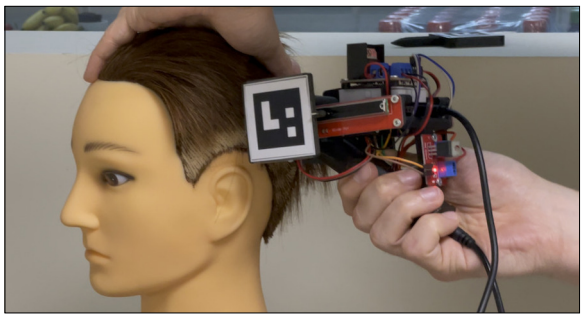
Patrick Wissiak

Introduction: This bachelor's thesis presents the development of Trim3D, a prototype for an automated hair-trimming system. Starting from the observation that hairdressing remains mostly manual, the project aims to make the first step into automating the haircutting process and addresses core challenges, such as accurate 3D head measurement, intuitive haircut definition and precise real-time control of a hair trimmer with an extendable comb.

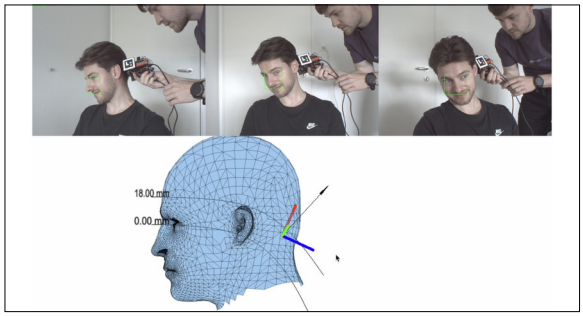
Approach / Technology: The developed system integrates a three-camera network for synchronous multi-view capture (requiring intrinsic and extrinsic camera calibration, and triangulation to determine 3D positions from the different camera angles), ArUco marker-based pose estimation for head measurement and trimmer pose estimation, and MediaPipe facial landmark detection for head pose estimation. After rigorous systematic evaluation and testing, often using Blender to ensure a controlled environment, the biggest error sources were spotted and mitigated. Through targeted improvements such as multi-threaded image grabbing, triangulation reprojection error thresholds, ArUco marker pose ambiguity correction by global marker rotation-alignment, thin-plate-spline head morphing, exposure correction for more robust facial landmark detection, stability-enhancing mechanical redesigns, and 10 Gbps networking with jumbo frames, the system's accuracy and robustness were greatly enhanced. Similarly, the performance increased, doubling the frame rate from around 10 to 20 FPS.

Result: End-to-end tests of Trim3D in a simulated environment verify the detected trimmer position to be accurate with errors below 5 mm, and predicted hair length versus ground truth hair length with errors below 0.5 mm at different positions. Unifying all underlying components, a web interface enhances usability and guides users seamlessly through extrinsic calibration, head measurement and morphing, haircut definition, and real-time trim execution. The final prototype demonstrates feasibility, accuracy, and user-friendliness, laying the groundwork for future visions such as smartphone-based head scans, sensor fusion, and an actively tilting trimmer comb.

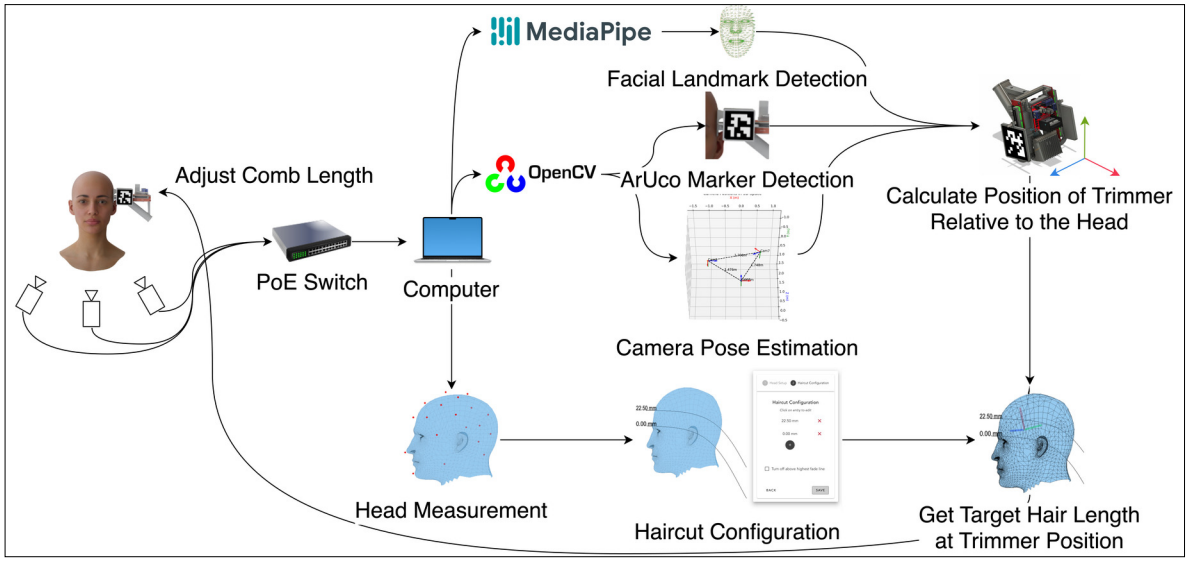
The Trim3D Hardware in Action
Own presentment



Web Interface Showing Camera Live Feeds, Haircut Configuration and Trimmer Pose During Trim Execution
Own presentment



Overview of the Trim3D System
Own presentment



Advisors
Hannes Badertscher, Simon Walser

Co-Examiner
Gabriel Sidler, Teamup Solutions AG, Uster, ZH

Subject Area
Artificial Intelligence

Project Partner
Institut ICAI, OST, Rapperswil, SG