A pick-and-place, for *rapid* prototyping.

p4p.jamesnzl.xyz

PROBLEM SPACE & BACKGROUND

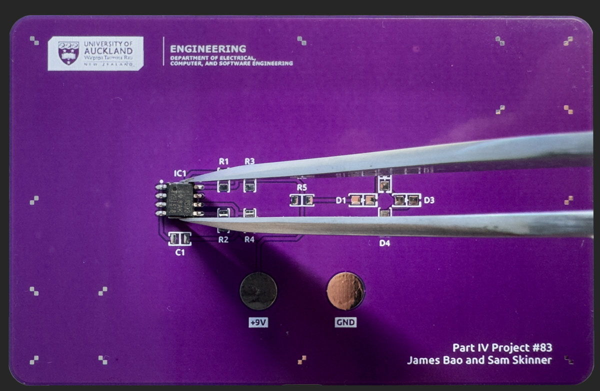
Entirely human
Fully manual

our project

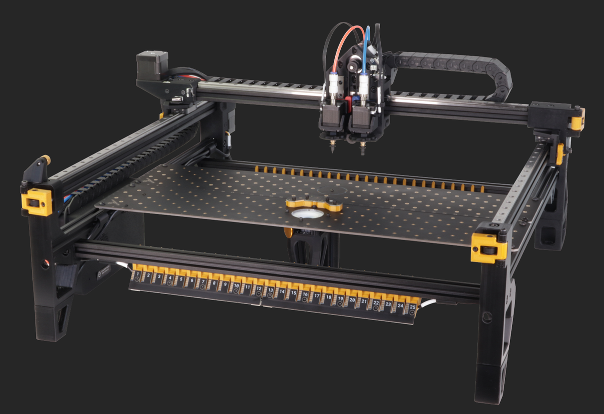
Entirely numeric
Fully automated

Humans and robots have complementary abilities [1] — **why can't these be combined?**

Our aim was to profile a method with the same **top-down vantage point** that a user would have with tweezers and the **accuracy of a machine,** using existing technology.



Manual assembly with tweezers — clear view from **overhead** with **no parallax error**

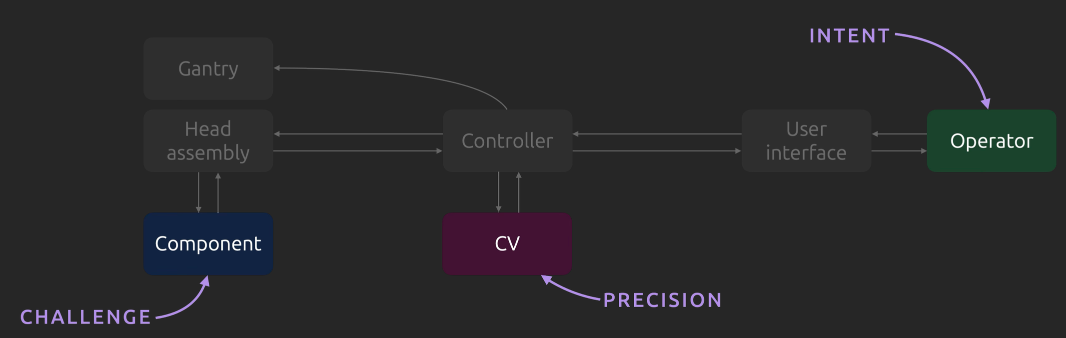


Existing technology — gantry with vacuum nozzle [2]

RESEARCH OUTCOMES & METHOD

Our project sets out to determine whether a solution exists to the problem, and the engineering reasons and requirements for this. Our aim was to put the problem into more definite terms and do so by constructing a **physical prototype** — we wanted to know if there was anything unexpected that would happen in practice.

RESEARCH DIRECTION



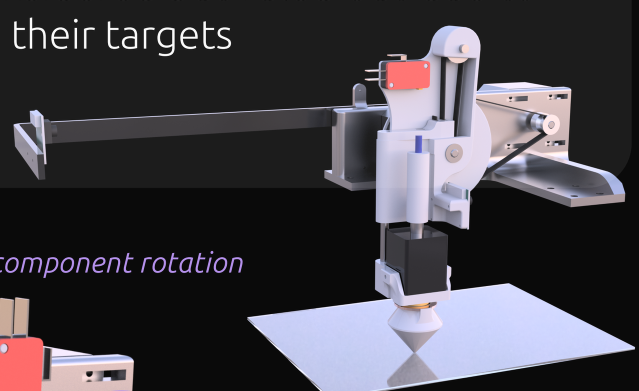
Machine architecture

Several approaches exist to address the issue — with varying levels of software and mechanical work — but we've chosen a **mostly-mechanical architecture** which provides **two real-time video feeds to a user interface**. We've done this to keep the positional control loops as tight as possible.

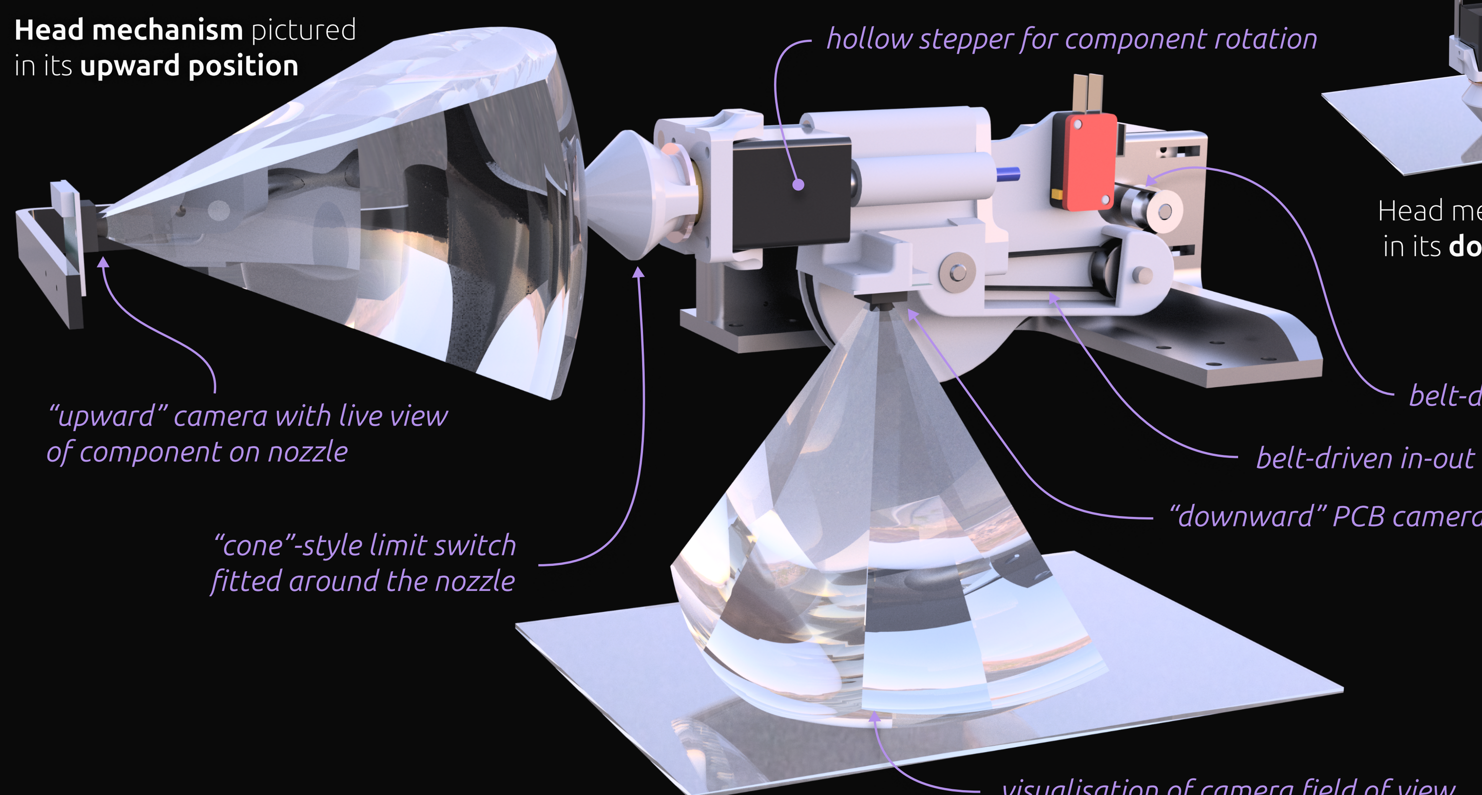
HEAD DESIGN

Our approach trialled a **compound head movement** that could place components with its vertical stroke, and bring components to a second camera with its horizontal stroke. This permits a real-time video feed **without obstruction by the nozzle**.

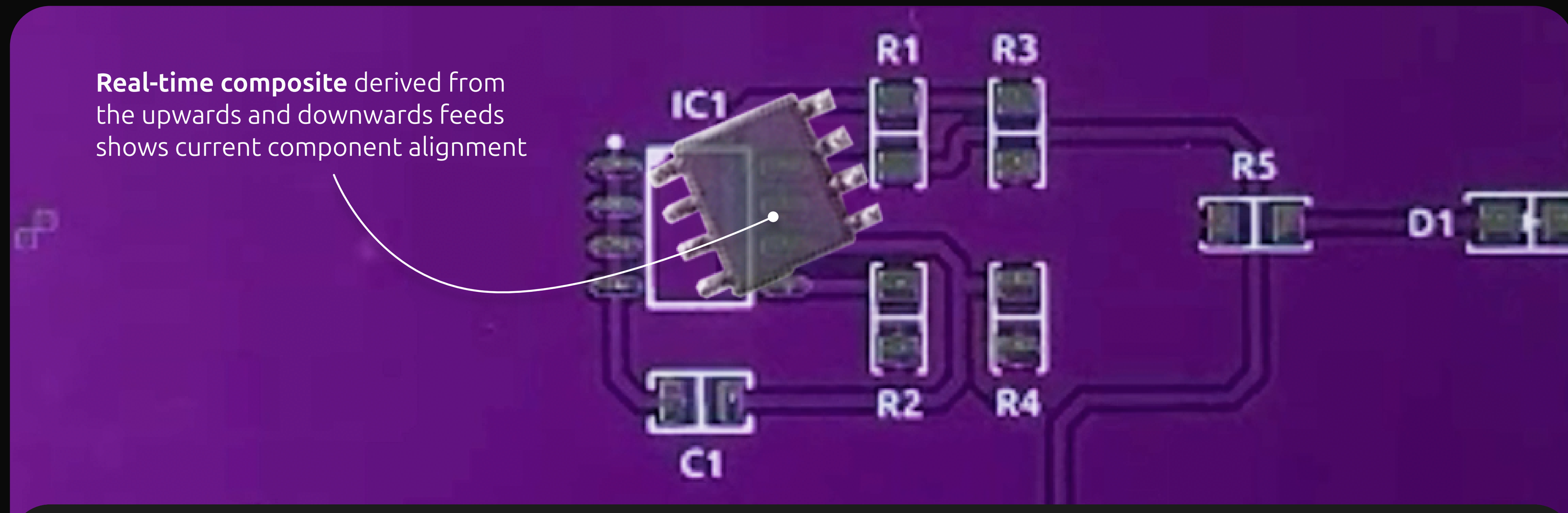
Many prototypes of the head were needed to get the mechanism right — providing adequate precision with the additional constraints imposed by the compound motion isn't trivial. Our best design uses two stepper motors and belt drives to achieve the 'folded' *z*-axis motion. Other, 'unfolded' options were considered but ruled out due to complexity — getting the cameras far enough away from their targets to achieve focus required overly long nozzle travels.



Head mechanism pictured in its **downward position**

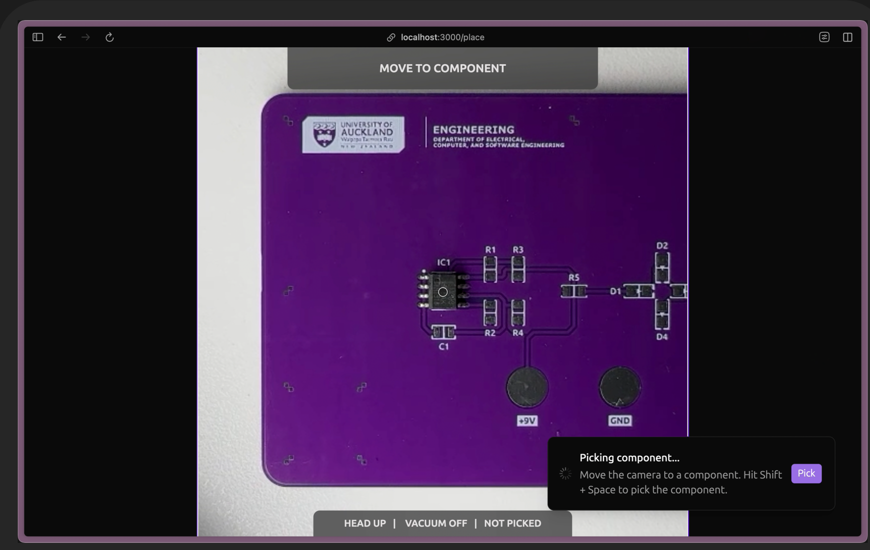


Head mechanism pictured in its **upward position**



Real-time composite derived from the upwards and downwards feeds shows current component alignment

USER INTERFACE



User interface with heads-up display

Compositing is achieved in real-time in our machine controller software, and is streamed to the web front-end using **WebRTC**.

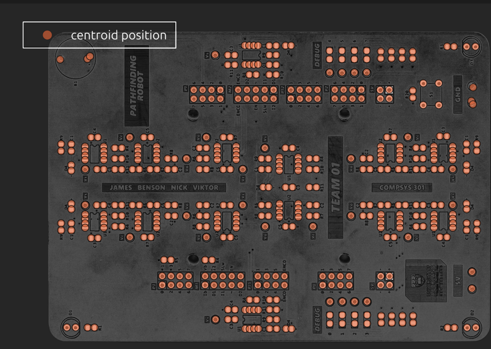
Click navigation is provided to the user with status indicators on a heads-up display, allowing **real-time, accurate control**.

Low-latency data exchange [3] is achieved with **Protocol Buffers** and **WebSockets**.

COMPUTER VISION (CV)

Research in the field of teleoperation suggests that **computer vision assistance is worthwhile** to allow operators to more effectively use computer input devices to navigate space [4].

While our project doesn't fully implement a computer vision scheme, we hypothesised that a true implementation would require this and **treated CV-compatibility as a requirement**.



Centroids are identified based on pixel luminance and chrominance values

RESULTS

- We have succeeded in picking and placing components, so the aim is technically possible. However, the accuracy and usability are not as good as we hoped.
- The mechanical approach proved not to be an efficient engineering solution — the head design becomes significantly more complicated by the additional action.
- Computer vision, while never implemented, looked promising and would be generally applicable to this problem — even with a different head design.

RECOMMENDATIONS

Based on our findings with the computer vision, and the existence of good desktop pick-and-place machines, **we believe our initial aim is not unachievable**.

We have demonstrated that the **compound-action head is not the answer**, but a more **software-based solution might be**. Future research should be undertaken to understand whether the same CV algorithm and user interface we developed could be applied to an existing machine to more squarely achieve the original aim.

REFERENCES

[1] Y. Li *et al.*, "Continuous role adaptation for Human–Robot Shared Control," *IEEE Transactions on Robotics*, vol. 31, no. 3, pp. 672–681, Jun. 2015.
[2] Opulo-Inc, "opulo-inc/lumenpnp," GitHub, https://github.com/opulo-inc/lumenpnp (accessed Sep. 21, 2024).
[3] I. I. Lysogor, L. S. Voskov, and S. G. Efremov, "Survey of data exchange formats for heterogeneous LPWAN-satellite IOT Networks," *2018 Moscow Workshop on Electronic and Networking Technologies (MWENT)*, Mar. 2018.
[4] J. Amat, A. Casals, L. Muñoz, and M. I. Heras, "Dexterity improvement in teleoperation through Computer Vision based automatic correction," *IFAC Proceedings Volumes*, vol. 35, no. 1, pp. 473–478, 2002.

UNIVERSITY OF AUCKLAND
Waipapa Taumata Rau
NEW ZEALAND

ENGINEERING
DEPARTMENT OF ELECTRICAL, COMPUTER, AND SOFTWARE ENGINEERING

2024 Project 83
James Bao and Sam Skinner
Supervised by Dr. Nitish Patel