# James Verco

Mechatronics Engineering Portfolio

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## Professional Summary

Mechatronics engineering graduate with hands-on experience in mechanical design, prototyping, and computer vision systems. Demonstrated ability to design, build, and validate integrated engineering systems through academic and personal projects spanning robotics, automation, and biomedical applications. Strong interest in practical problem-solving and iterative engineering design.

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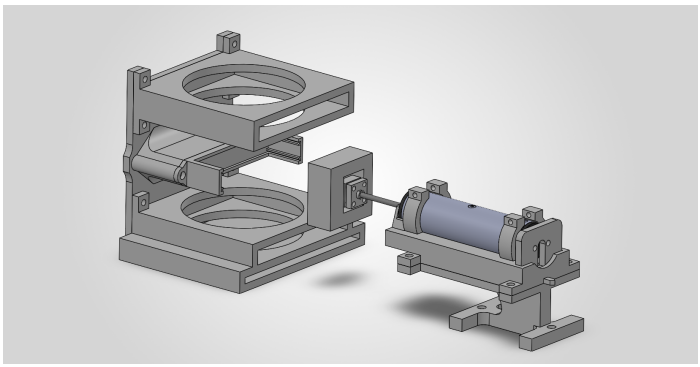
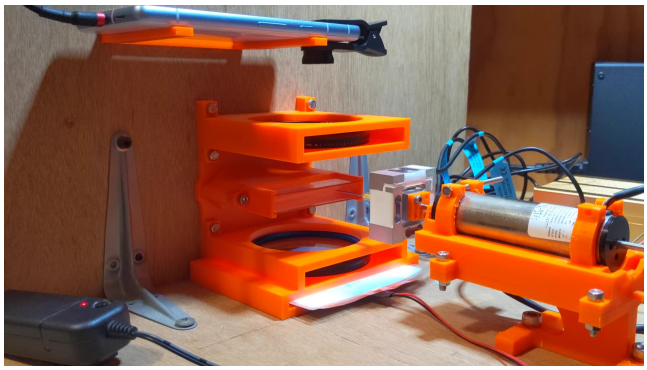
## Thesis: Experimental Platform for Studying Needle–Tissue Interaction

**Overview:** Undergraduate honours thesis investigating the effect of needle insertion speed, angle, and gauge on tissue stress and deformation. The project also explored methods to reduce vein rolling during intravenous procedures through controlled mechanical insertion.



(a) CAD Assembly View



(b) Physical experimental setup

Figure 1: Experimental rig

**Design Highlights:**

- Designed and constructed a custom experimental rig to visualise stress distributions in tissue surrogates during needle insertion.
- Utilised clear carrageenan gel tissue surrogates in a glass mould with polarising filters used to exploit birefringence principles, enabling visualisation of internal stress patterns captured using a high frame rate camera (see Fig. 2).
- Developed modular 3D CAD components mounted to a rigid base using threaded inserts and fasteners for repeatable assembly.
- Designed an adjustable motorised needle insertion fixture allowing precise control of insertion angle and speed.
- Integrated force sensing from three axis load cell to synchronise mechanical force data with visual stress footage.
- Created a rolling vein surrogate using silicone tubing covered in silicone lubricant embedded within multi-layer carrageenan gels of varying concentrations to simulate skin and subcutaneous tissue.


(a) Needle at initial piercing (b) Needle fully inserted

Figure 2: Experiment sample

**Outcome:**

- Demonstrated distinct tissue stress distributions resulting from variations in needle angle, insertion speed, and needle type.
- Generated force sensor data that correlated with observed stress patterns in the tissue surrogate.
- Showed that higher insertion speeds reduced vein rolling but increased surrounding tissue stress.
- Delivered a modular experimental platform enabling rapid replacement of tissue samples and needles for fast repeatable testing.

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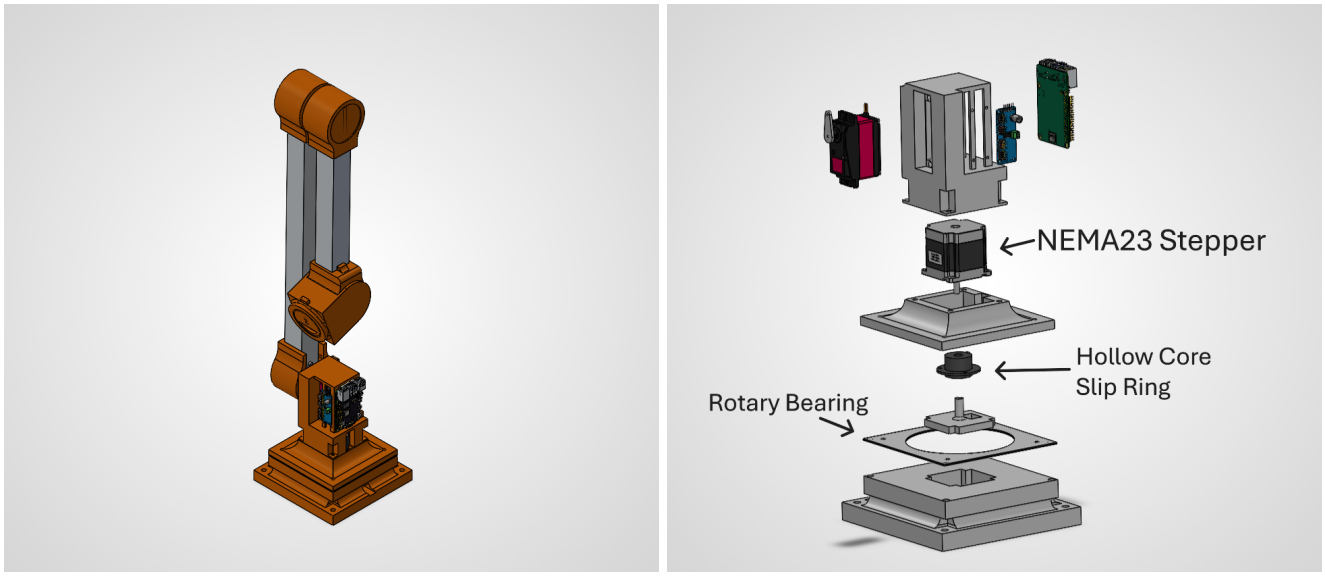
## 5-DoF Robotic Arm (Personal Project)

**Overview:** Designed and constructed a 5-degree-of-freedom robotic arm as a personal mechatronics project to develop skills in mechanical design, electronics integration, and system prototyping. The project focused on creating a modular, low-cost robotic arm using a combination of 3D-printed components and machined aluminium links, with an emphasis on iterative design and physical validation.




(a) Full CAD Assembly Isometric (b) Exploded View of Base CAD Assembly

Figure 3: SolidWorks Assembly of the Robotic Arm

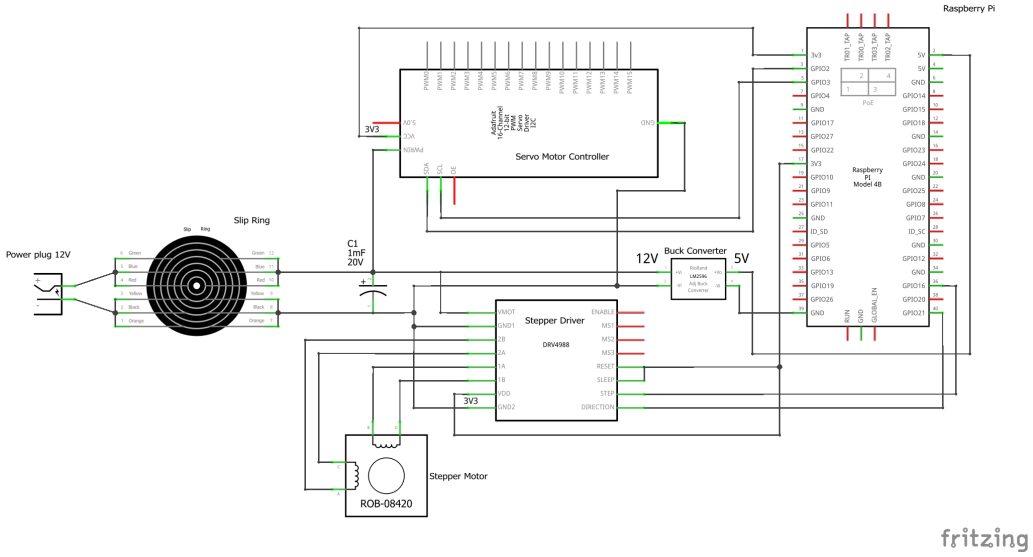
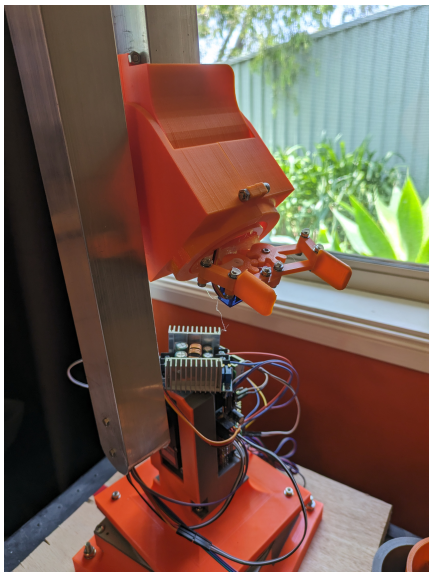



Figure 4: Circuit Diagram

**Design Highlights:**

- Developed a complete 3D CAD assembly of the robotic arm, including base, joints, arm links, and electronics enclosures.
- Structural components were primarily 3D-printed, while the longer arm links were machined from aluminium using SolidWorks drawings handed off to a contact for machining.
- Designed a motorised base with a rotary bearing to support rotational motion, with a later redesign incorporating a slip ring to enable continuous rotation without twisting wires and improved overall cable management.
- Integrated servo motors at each joint, with custom housings designed to support alignment, fastening, and accessibility.
- Electronics were packaged within the base assembly, enabling a compact footprint and simplified wiring to the arm.
- Utilized a Raspberry Pi 4B as the central controller, integrated with an A4988 stepper driver for the base motor and an Adafruit 16-Channel PWM/Servo driver connected to the I2C Raspberry Pi pins to manage the four joint servos and one servo for the grabber.
- An initial physical prototype was assembled and tested to validate joint motion, structural layout, and overall system geometry prior to further refinement.

(a) Initial Physical Prototype



(b) End effector capable of 180° rotation

Figure 5: Physical Constructions

**Outcome:**

- Successfully demonstrated coordinated motion across multiple joints in a physically constructed robotic arm.
- Validated the mechanical design through real-world assembly and functional testing, highlighting areas for iterative improvement.
- Produced a revised base design incorporating a slip ring, reflecting lessons learned during prototyping.
- Project provided practical experience in mechatronic system integration, design-for-assembly, and iterative development.

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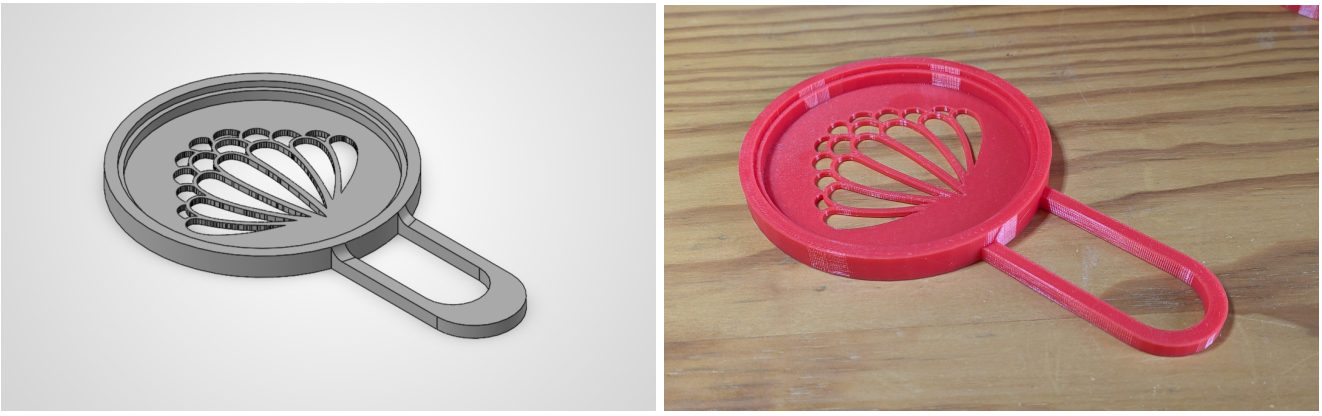
## Coffee Stencil Design for Club Cafe

**Overview:** Designed and manufactured a custom coffee stencil for an RSL club café to allow baristas to apply the club logo (Waratah flower) onto coffees using chocolate powder. The stencil was required to be easy to use during service, food-safe, and compatible with standard café dishwashing procedures.

**Design Highlights:**

- Geometry designed to sit on the rim of the cup, with the central stencil surface raised to prevent contact with milk foam.
- Designed to fit the café's specific cup dimensions, ensuring repeatable placement.
- Company logo converted into a DXF vector format to be used in SolidWorks to ensure accurate reproduction of the logo geometry.
- PETG selected for improved thermal resistance, dishwasher durability, and improved suitability for food-contact applications, as compared to PLA.



(a) Isometric CAD model of the custom coffee stencil (b) Stencil cup fit view

Figure 6: 3D-printed PETG stencil

**Outcome:**

- Successfully produced and delivered six functional stencils for use in the café.
- Stencils were deployed in daily service and used by multiple staff members over a period of time.
- Design demonstrated durability under repeated washing in a hot commercial dishwasher, with no warping or deformation occurring.
- Project resulted in tangible value to the café and validated the design through real-world use.

Figure 7: Example coffee prepared using the custom stencil

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## Scrabble Score Tracker

**Overview:** Developed a computer vision system to automatically detect and digitally reconstruct the state of a Scrabble board from a live camera feed. The project focused on robust board detection under real-world conditions, including variable lighting, glare, rotation, and perspective distortion. The system identifies the board in-frame, geometrically normalises it to a fixed reference, and enables reliable tile recognition.

**Design Highlights:**

- Implemented feature-based board detection using SIFT keypoints, matching features between a Scrabble board template and live camera images.
- Applied Lowe's ratio test and RANSAC-based outlier rejection to reduce thousands of raw feature matches to a small, high-quality inlier set suitable for geometric estimation.

- Estimated a homography transformation using OpenCV to map the camera image plane to the template plane, correcting for rotation, scale, and perspective distortion.
- Used reprojection error thresholding within RANSAC to further improve robustness and eliminate incorrect correspondences.
- Warped and reoriented the detected board to exactly match the template's size, shape, and orientation, enabling consistent downstream processing.
- Partitioned the rectified board into individual tile squares for per-cell analysis.
- Integrated a deep learning tile classification model (trained by a project partner using PyTorch) as a downstream component of the system pipeline.

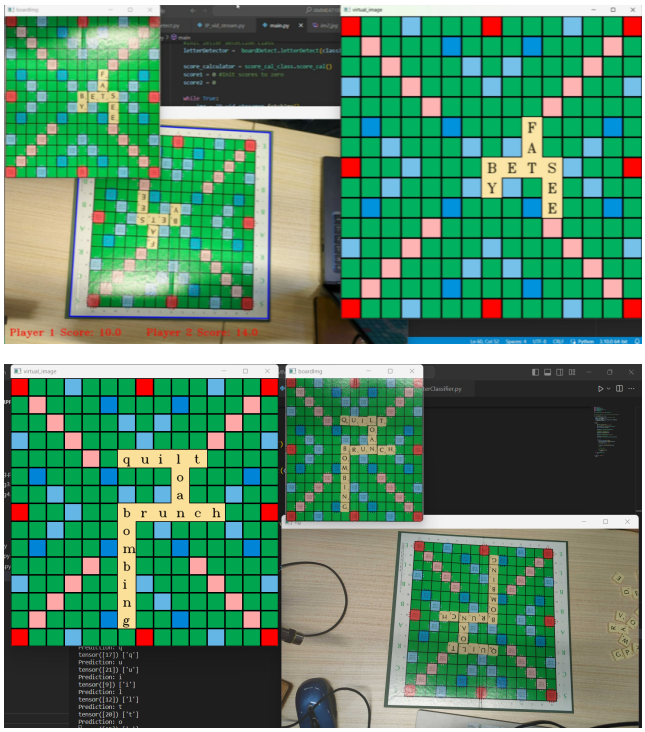


Figure 8: Example games with board state visualisations to verify success

**Outcome:**

- Successfully demonstrated reliable Scrabble board detection and rectification across a wide range of conditions, including glare, uneven lighting, arbitrary orientation, and perspective distortion.
- Reduced initial feature match counts from thousands of raw correspondences to approximately 15–100 high-confidence inliers, enabling stable and repeatable homography estimation.
- Enabled accurate digital reconstruction of the board state by standardising the board geometry prior to tile analysis.
- Integrated a turn-based scoring system allowing two players to have their scores automatically tracked throughout gameplay.
- Validated system performance through live visualisation of the detected board state and score progression, confirming correct localisation and system operation.

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