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Fowl, **Fuzzy** Logic and **Frugality**: A **Better** approach to **Bipedal Robots**.

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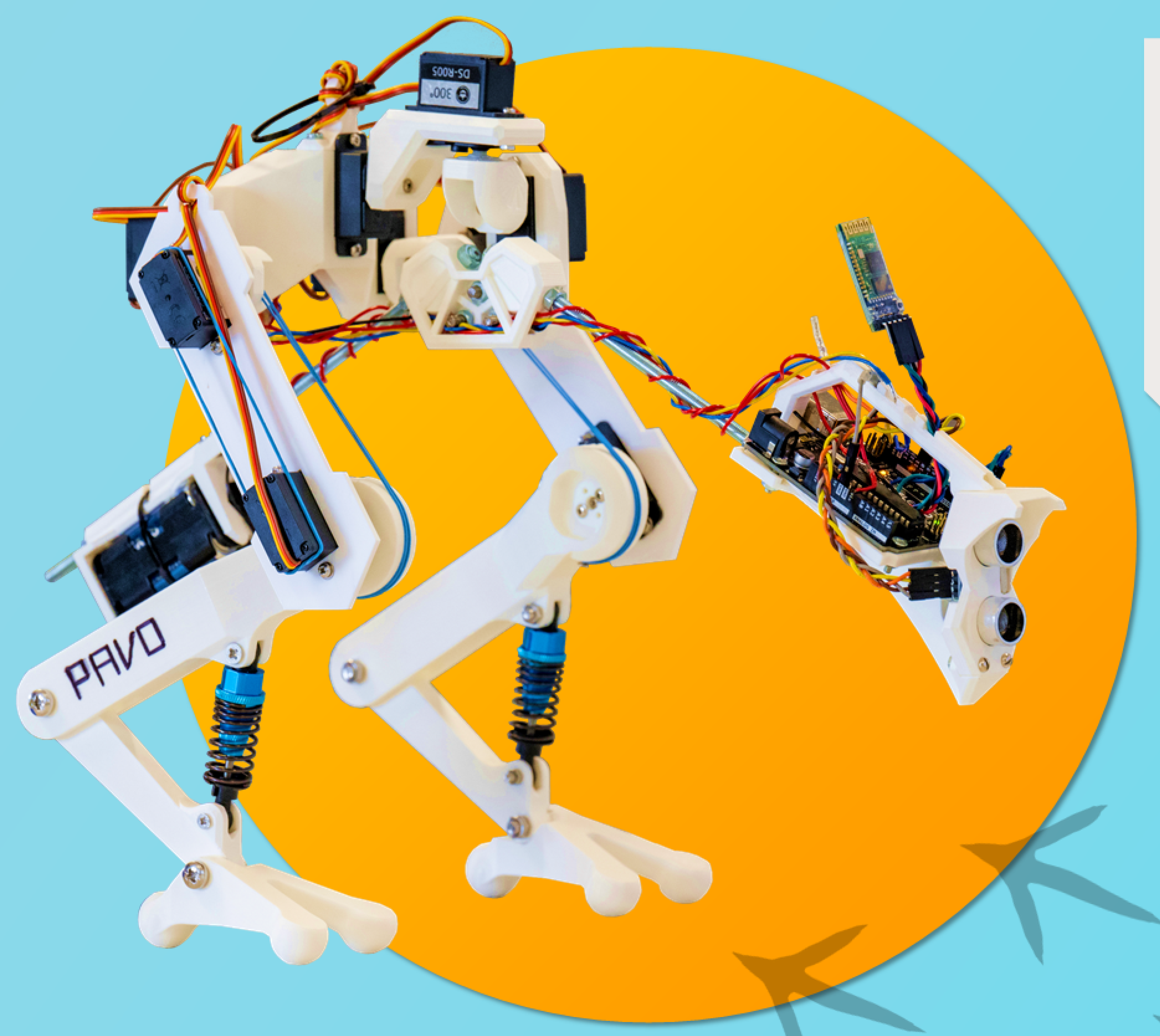

Motivation & Aims

Robots that move are **vital** for many modern processes. However, many of these robots are **limited** to specialised environments designed around them. A better approach may be **robots** designed around **existing environments** instead. As most environments are already designed around bipedal humans, **bipedal robots** are uniquely poised to fill this niche.

Existing bipeds are **expensive**, **computationally intensive** and inherently **unstable**. This report **aims** to address these issues and develop a **small**, **upgradable** robot capable of semi-autonomous **walking**.

Design

Birds began walking on two legs over **150 million** years before us, studies show that the lower centres of mass resulting from the “couched” build of birds **improve stability** over upright human configurations.

- The robot (Pavo) is designed from the measurements of a **European Quail** at a scale of 2.5:1 and mimics its **low centre of mass** (see Fig. 1)
- Pavo is 3D printed and laser-cut, it utilises **cost-effective** off-the-shelf parts to achieve all the joints required for walking within £200

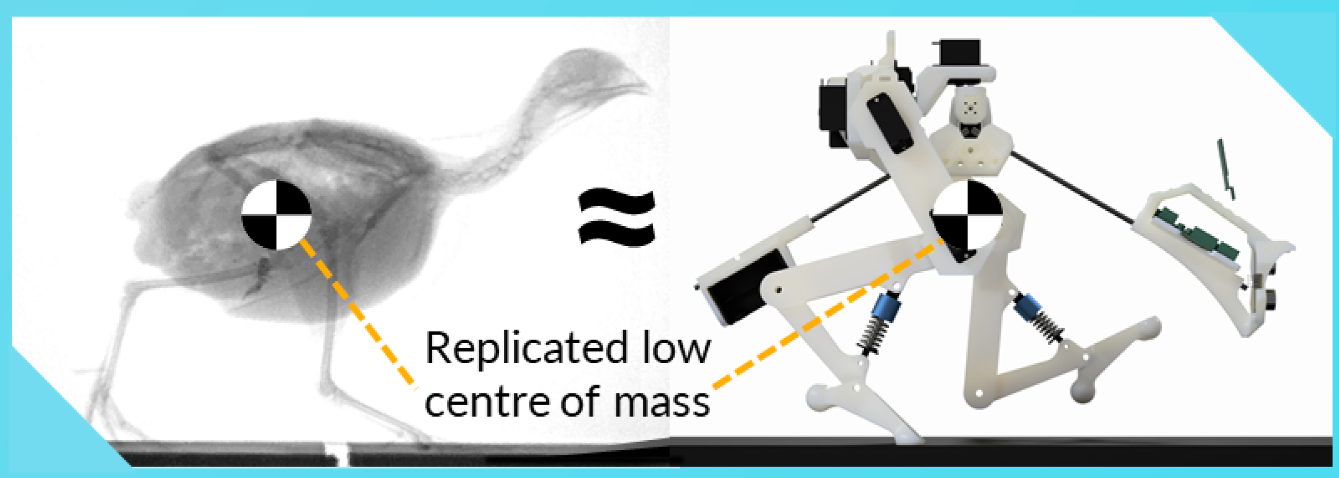

Fig. 1: An X-ray of a walking quail and Pavo (Nyakatura et al., 2011)

Control

- **Cost-effective** Arduino boards are used to control Pavo
- Pavo can be **wirelessly** controlled over Bluetooth
- An experimentally obtained quail gait cycle (Fig. 2) is broken into discrete **states** and coded into the Arduino memory
- Pavo uses the stored footstep cycles to **walk in the direction of a fall** to prevent falling, an onboard inertial measurement unit (**IMU**) enables this
- **Traditional** control methods are computationally **expensive**, intuitive **Fuzzy logic** is utilised to **off-load** these calculations onto a computer
- Pavo takes into account: **balance**, **obstacles** and **user input** to decide how to move

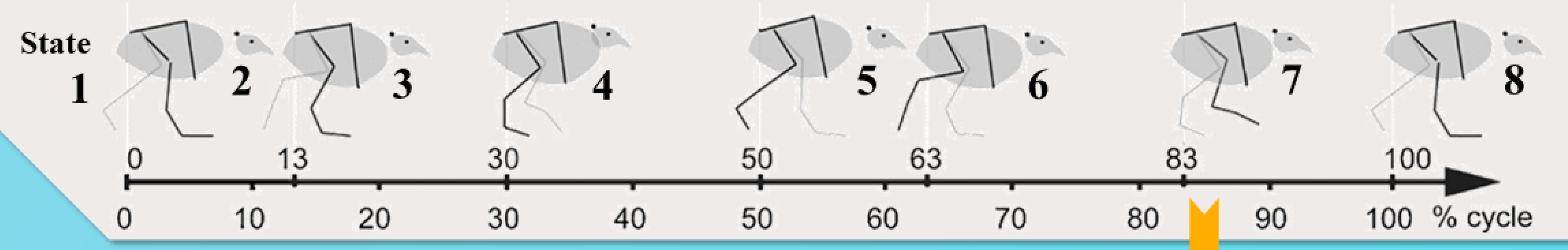

Fig. 2: The discretised gait cycle of a quail (Abourachid et al., 2011)

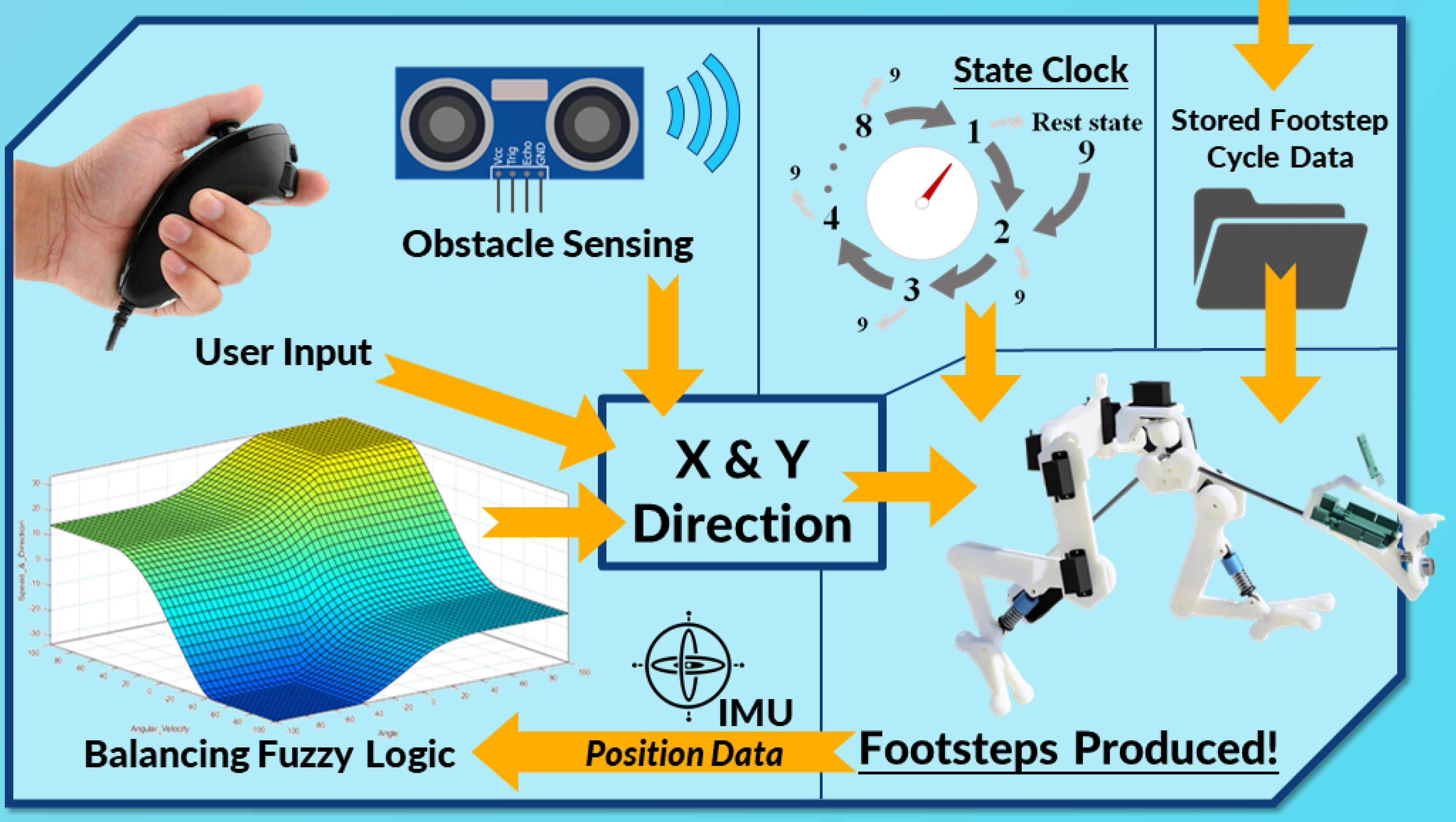

Fig. 3: A diagrammatic representation of how the control theory functions

Results

After code refinements and the addition of an elastic system that reduced servo torque requirements, Pavo was **successfully** able to:

- Combine the fragmented footstep states into a **controlled**, **cohesive** gait cycle
- **Respond** appropriately to angular positions/accelerations and return to **rest** when in balance
- Begin **backwards** movement upon sensing an **obstacle**
- **Receive** wireless directional user input from the **controller**
- Walk forward at an average speed of **30mm/s**

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Conclusion and Future Work

- The low centre of mass **improved stability**
- The control theory was implemented **successfully**
- Underpowered servos resulted in **reduced footstep** capacity
- Low Arduino **RAM** and **clock speeds** limited code function

Many aspects that could be **further developed** were identified:

- **Upgrading hardware** (i.e. servos, power solutions and processors)
- Improving **rigidity** and reducing **weight** without sacrificing size/functionality
- The Fuzzy logic and gait cycle could be **further refined** to better mimic that found in nature

References:

- Abourachid, A., Hackert, R., Herbin, M., Libourel, P. A., Lambert, F., Gioanni, H., Provini, P., Blazevic, P., & Hugel, V. (2011). Bird terrestrial locomotion as revealed by 3D kinematics. Zoology, 114(6), 360–368. https://doi.org/10.1016/J.ZOOL.2011.07.002
- Nyakatura, J. A., Andrada, E., Blickhan, R., Blickhan2, R., & Fischer, M. S. (2011). Avian bipedal locomotion. https://www.researchgate.net/publication/233757966

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