Advanced Research + Invention Agency ARIA

Smart machines need smarter bodies

Opportunity space

v1.0

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CONTEXT

This document describes an early opportunity space from which we believe one or more funding programmes can emerge. We've sketched out some of our early thinking to spark your interest, and invite you to imagine relevant potential programmes with us, or suggest new directions.

We'll publish updated versions of this document as our thinking evolves. Sign up **here** to receive those updates and learn about any funding opportunities that emerge from this opportunity space.

An ARIA Opportunity Space should be

+ important if true (i.e. could lead to a significant new capability for society),
+ under-explored relative to its potential impact, and
+ ripe for new talent, perspectives, or resources to change what's possible.

SUMMARY

Throughout history, humans have used tools and machines to reduce the burden of physical labour. We are entering a new era with robots smart enough to act independently in complex and dynamic environments. But smart machines with dumb bodies will only get us so far – to reap the transformative benefits of intelligent machines, we need better bodies.

BELIEFS

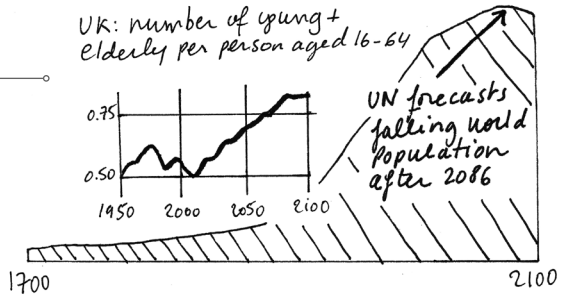
1. A world where robots free humanity from physical labour is not only possible ⟶ **it is imperative if we wish to boost longevity and prosperity.**
2. Advances in sensing and computation are improving robot brains, but that alone won't enable ubiquitous robotics ⟶ **limitations of robot bodies will soon be the critical obstacle.**
3. Progress in AI, control, materials, and manufacturing opens up previously inaccessible design spaces ⟶ **we can exploit these to build robots that approach or even exceed the capabilities of living bodies.**

OBSERVATIONS

Some signposts as to why we see this area as important, underserved, and ripe.

Humanity is approaching an **extraordinary turning point**. People alive today will see the end of 10,000 years of world population growth. Between 2000 and 2100, the proportion of the UK population aged >65 is set to double; worldwide, it will triple.
We can expect increasing labour shortages especially for unskilled and physically demanding work.

Fig 1



For our children, the concern is not so much that robots will take their jobs, but that robots won't have developed enough to fill the gap

Embodied intelligence aka morphological computing is a distinctive feature of biological systems. In flying insects, the wingbeat frequency reflects the body's resonant frequency, while muscles inject energy each beat through their mechanical properties. Control is simplified because signals do not need to be timed precisely.

Could we make a material with the stress/strain relationship of active insect asynchronous flight muscle?

Fig 2

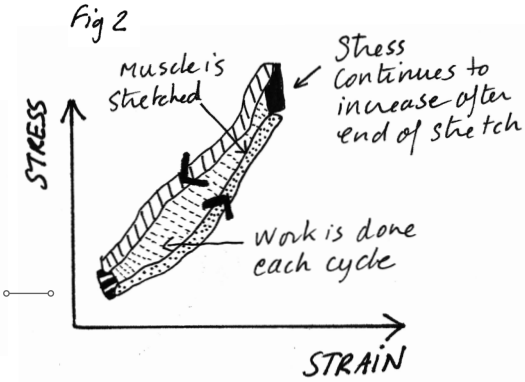
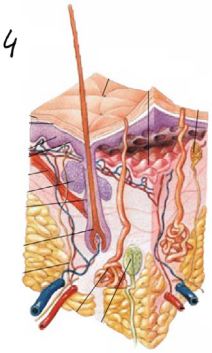


Fig 4



intelligent sensing + actuation

Animal bodies have a protective, flexible, waterproof, washable, self-healing covering densely studded with sensors for pressure, temperature and tissue damage – skin.

Muscle has incredible properties: tunable stiffness, variable recruitment, and the ability to absorb as well as generate work, enabling it to switch between roles such as actuation, structural bracing and shock absorption.

What would it take to create something similar for robots?

The next bottlenecks will be the affordability and reliability of robotic hardware, the amount of compute required for complex control, + energy consumption.

Currently, humans tele-operating robotic hardware outperform autonomous systems on complex tasks in unpredictable environments, showing that inadequate control algorithms are the current bottleneck.

Why do ~all motor systems lie on just two force/mass lines?

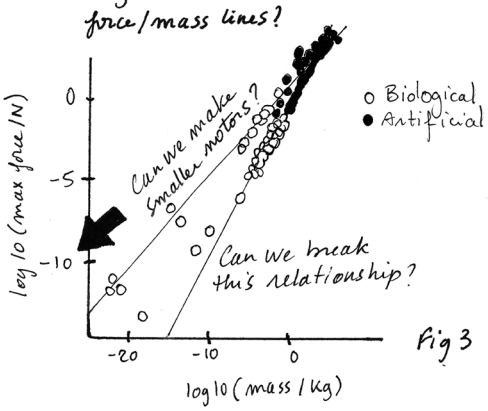
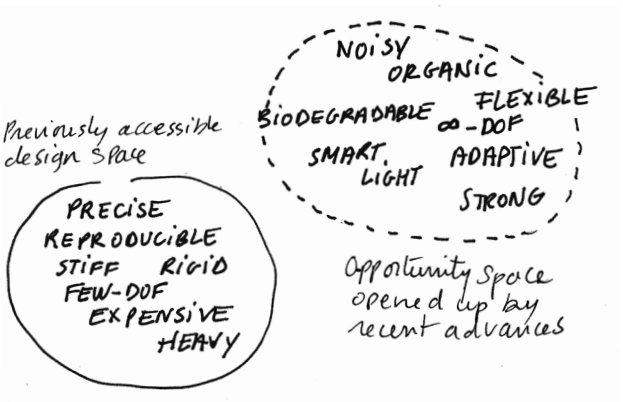


Fig 3

Advances in control are opening up design spaces involving materials and structures which would previously have been unfeasible, e.g. due to noise, low manufacturing tolerance or complexity.



SOURCES

A compiled, but not exhaustive list of works helping to shape our view and frame the opportunity space (for those who want to dig deeper).

Humanity has long dreamt of robot servants and guardians

Our grandchildren will inherit a world where the population is falling (Figure 1)

Dependency ratios will approach 1 by the end of the century (Figure 1 inset)

Today's robots lack the adaptivity, robustness, versatility, and agility of biological organisms

Insect intelligence offers an alternative to classic methods in robotics

What can robotics learn from neuromechanics?

Currently-available soft actuators are very different from muscle

Insect asynchronous flight muscle has remarkable properties (Figure 2)

There may be universal scaling laws applying to all motors (Figure 3)

Insect flight motors are extraordinary natural structures that maintain near-perfect resonant energetic optimality over significant wingbeat frequency range

Animal integumentary systems are highly sophisticated (Figure 4)

ENGAGE

We invite you to shape our efforts by providing feedback and surfacing breakthrough ideas related to this Opportunity Space. Our next step will be to formulate a programme that directs funding across research disciplines or institutions toward a focused objective. We also plan to open up seed funding for researchers whose bold aspirations are unlikely to be funded elsewhere.

Sign up for updates and share your feedback **here** – we will read anything you send.

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