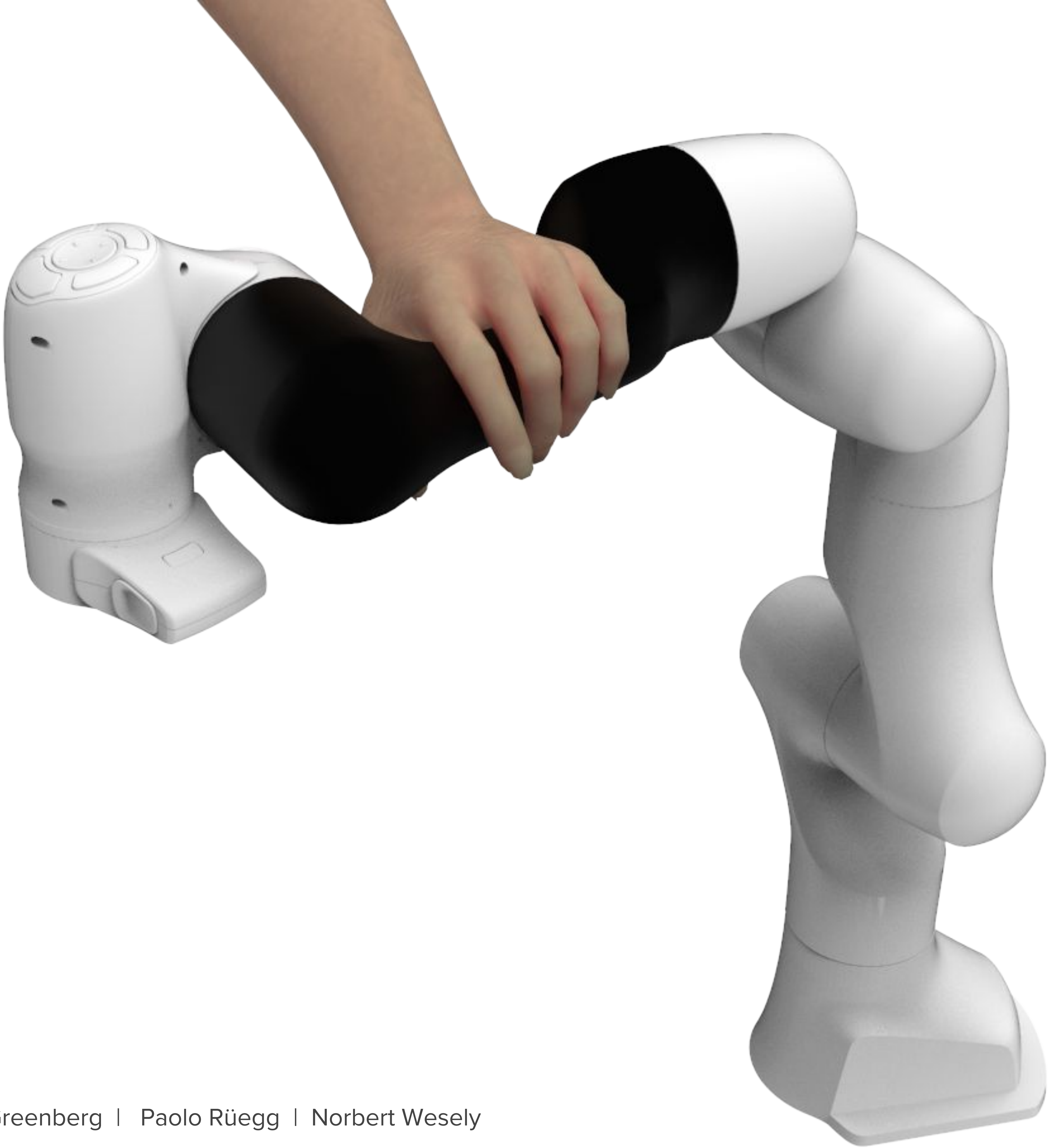
Design Engineering

Futures Portfolio



SIO

Robot Skin

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futurerobotskin.com

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Executive Summary

SIO is an intelligent and versatile skin that makes robots collaborative and allows for organic and predictive interaction between human and machine.

Robots have the potential to solve big problems. They already assemble cars and explore planets far away, but they are usually kept away from us. What keeps robots from helping you clean your dishes or carry the moving boxes? It is the fact that they do not fully understand their environments. Usually dependent on a single vision system, they do not know where you are, which inhibits intuitive interaction and and makes them potentially harmful.

SIO is a skin that gives robots a sense of what is around them as well as a sense of touch, thus making them collaborative. If it senses that a human is in its way, it knows to stops. If a box is slipping out of its gripper, it knows to use more force. Our robot skin works like the compound eyes of a bee, seeing not only through a pair of eyes, but through many more. Because the system can be integrated with the robot’s motion planning system, SIO eliminates the need for particular skills like programming to operate the robot.

We believe SIO has a broad range of applications in the now as well as in the future, and exploiting these will be key to its success. In the next five years collaborative robots are about to revolutionise our industries, but most robots are not equipped with the right hardware. This is where the journey begins.

This portfolio outlines the ideation and development of SIO, both in terms of designing a product service system as well as creating technical prototypes. Firstly, the exploration of the theme is presented, the results of which laid basis for synthesising a concept. The technical development is outlined thereafter, embodied through several prototypes. Finally, the design proposal shows how these technologies add value to the user’s experience of interacting with robots.

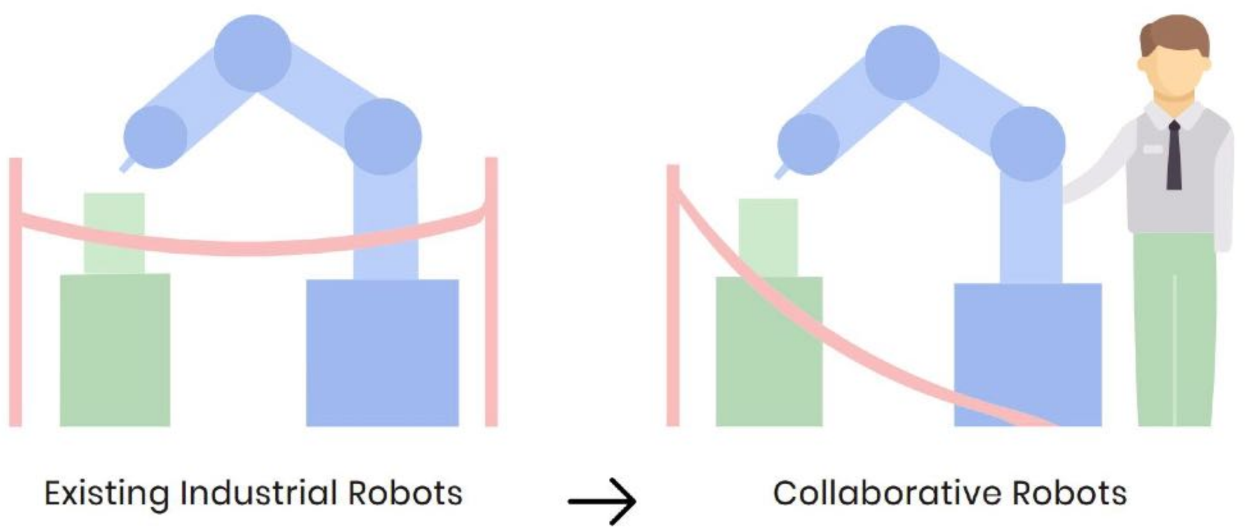


Table of Contents

Acknowledgements

We would like to thank the Imperial College Hackspace for their financial support throughout the development of this project. The ICAH were kind enough to award the SIO early development with a grant along with professional guidance.

We would also like to thank the following people and institutions with their invaluable support in providing feedback to our project.

SIO

Buzzword mind map developed in the early research stages of the project in answering “what might a robot skin be”.

Reconceptualising Robot Skin

How should a robot look and feel? Is the final goal to recreate the human skin? Why might robots need a skin?

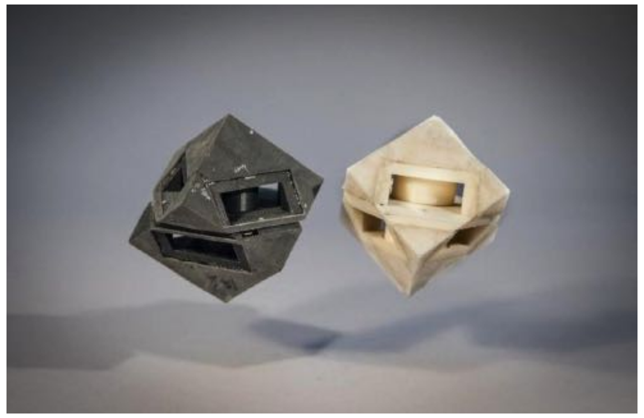
Before we set out to redefine this crucial interface between a robot and its environment, we had to widen our perspective on what robot skin could be. Our initial research was categorised into three main themes as illustrated in the concept video. Firstly, we looked to nature and took inspiration from our own skin and those of other animals, such as a rapidly expanding puffer fish, or a regenerating tail of a salamander. Can the way our skin dissipates heat be reproduced in a robot skin?

Secondly, we looked into existing robots and their markets and users. We had to understand the tasks robots are performing today, and how they interact with their environment. Finally, we looked into the future of robotics; how their environments might change, and how the stakeholders, technologies and markets may expand. Answering these questions brought together the perspectives and ideas displayed in our concept video and yielded two general directions the project could take.

Anthropomorphic Skin - This direction aimed to recreate human skin, primarily in terms of texture and feel, for applications where physical collaboration with people is necessary. Applications could include health monitoring, coaching, rehabilitation or companionship.

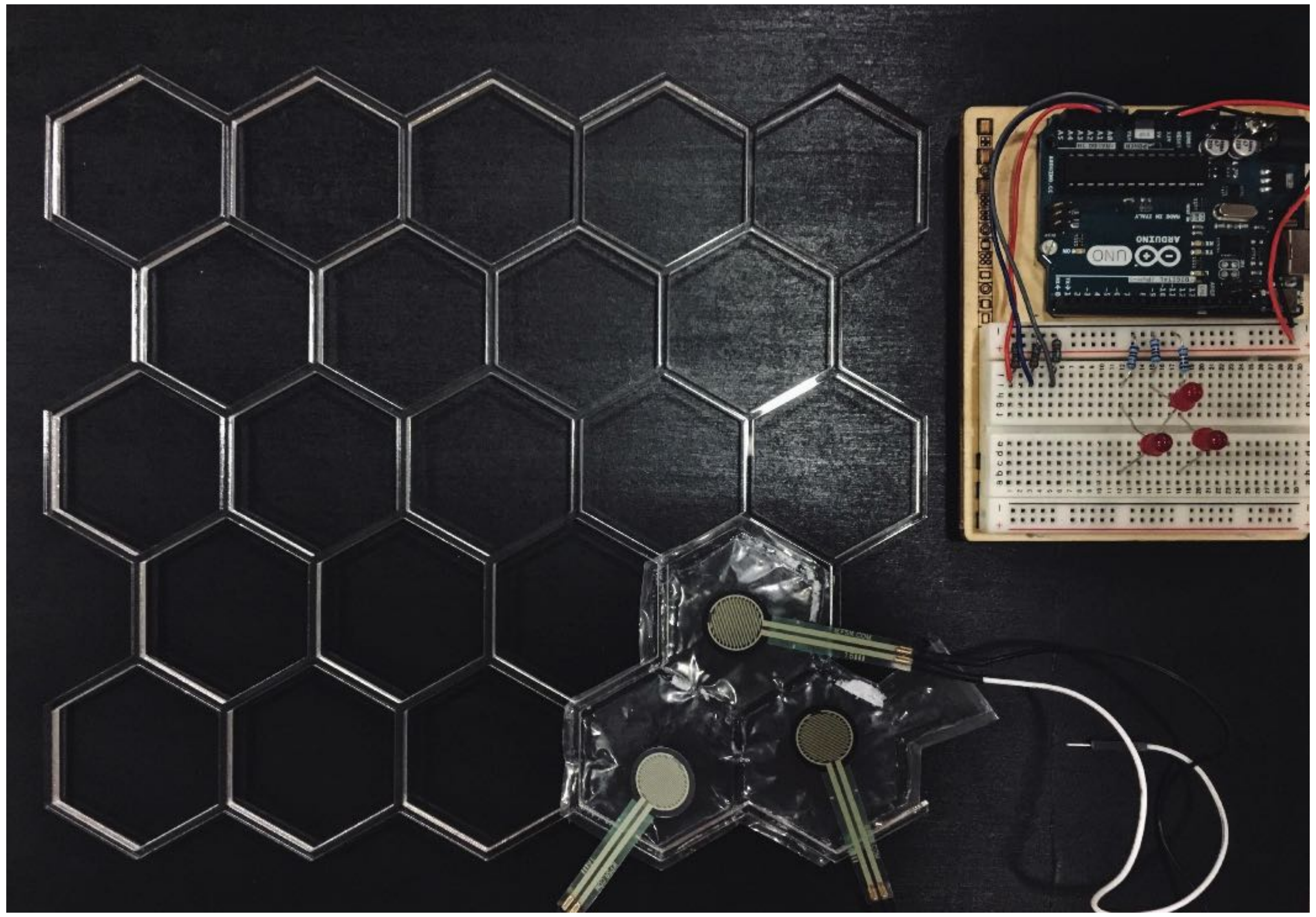
Adaptive Skin - This more futuristic concept transforms the skin into a dynamic system that is ever-changing. Imagine if the skin was only ever where it is needed at a given point in time. Dangerous objects in the environment would be detected prior to impact and the skin would then deform in order to protect that region.

Benchmarking - Examining existing products and research was key to understanding the potential markets and applications. We soon recognised that existing research often focused on only one potential functionality of skin. This revealed that combining the anthropomorphic and adaptive concepts could cover a more diverse market and set of use cases.



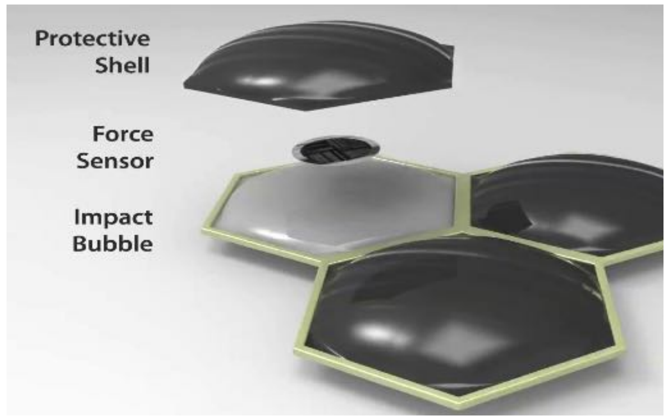
MIT: 3D-printed robots with shock-absorbing skin

University of Glasgow: Hyper-sensitive robot skin

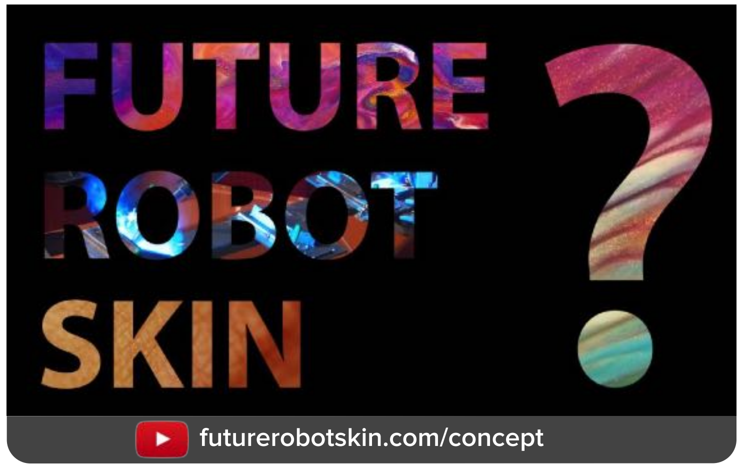


Initial Concept and Prototype
Our initial concept involved a tessellation design (to focus on ease of manufacture) and inflatable air pockets to protect the robot. These pockets would be embedded into a custom exoskeleton to help the skin keep its shape as well as making maintenance and repair easier.

Under the shell of the skin, we embedded force sensors to allow the robot to detect and understand its surroundings. This early concept had two main foci, protection of the robot and repeating manufacturable modules to discretise and miniaturise the product.



Initial concept render



Industrial & Global Drivers

To future proof and validate our concept ideas for 10 to 20 years from now, we built out a technology roadmap of related developments and expected innovations in a select few industries. We believe that with the advent of key technological innovations, such as ultra-high-speed-networking, the functionality that SIO would offer will change likewise.

This technology roadmap informed us throughout our prototyping and proof-of-concept journey. We became aware that we could not prototype the fully-fledged integration of SIO, given its deep roots in advanced technologies, so we used the insights from industry feedback and low-fidelity prototypes to demonstrate the potential abilities of SIO in the future.

	2017	2020	2025	2030	2040
TECHNOLOGY	**Motion Tracking:** Tracking takes place with RGB-D cameras, in real-time. **Proximity Sensing:** Objects are detected using IR and time-of-flight sensors.	**Swarm AI:** Products will think as one organism, allowing for new service experiences. **AR:** Low-cost products come to market allowing for the first augmented technology experience widely available to the public.	**Wireless charging / high-density energy storage:** High efficiency wireless charging is standard use across many industries allowing for untethering of products from traditional power systems/infrastructure. **Nanotechnology:** Physical computing reaches a <10nm scale that allows for more complex calculations in small devices.	**Quantum computing:** Hyper miniaturised electronics allows for smaller CPUs and computing logic in physical products. Complex, dynamic motion planning becomes more viable.	**Biocomputers:** Computational power and processing will be grown and powered sustainably.
CONNECTIVITY	**4G:** Connections between both humans and technology are limited by slow transfer of data.	**5G:** Faster communication networks allows for better computing and AI platforms.	**Constant connectivity:** Majority of all services will be connected and interlinked (Internet of Things).	**Human computational augmentation:** Reduced barriers between human biology and computational augmentation allows for more integrated and natural ways to communicate with machines.	
ASSISTIVE DEVICES	**Virtual Assistants:** Smartphones currently have high level assistive functionality.	**Rehabilitation:** Use of robotics and machine learning is rapidly used in rehabilitation space to aid human recover from illness or injury.	**Assistants:** Robotics adapted to controlled environments where assistance for simplistic tasks allows it to supersede human performance. Human-robot interaction becomes more 'normal'. **Care:** Robots used to assist with the elderly in day to day life in addition to rudimentary rehabilitation.	**Implanted robotic systems:** Human physically augmented by robots interfacing with its natural physique.	
WHERE ARE ROBOTS?	**Industry:** Robotic manipulators used in manufacturing tasks for rapid increase in yield rates. **Military:** Drone technology advanced such that machines are trusted to operate autonomously with minimal commands.	**Education:** Robotics are used in educational environments to augment and improve learning experience.	**Medical:** Robotics used for rudimentary surgery and for assisting in complex long-term surgery.	**Extreme Environments:** Robots are deployed in physically harsh environments and can navigate and perform their tasks autonomously. **Domestic:** Robots can successfully deal with unpredictable varied environments dynamically allowing for deployment into domestic spaces.	

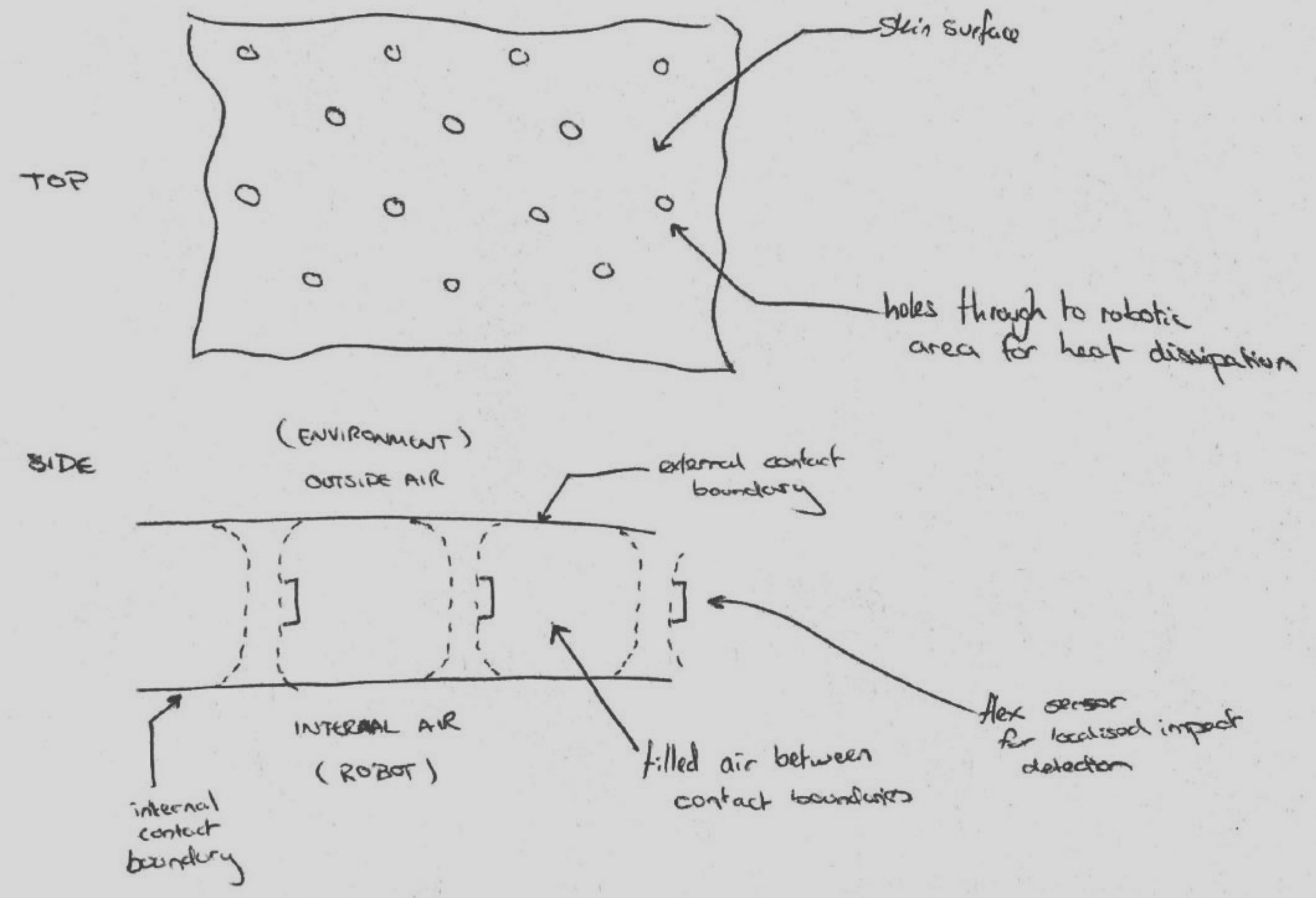
SIO

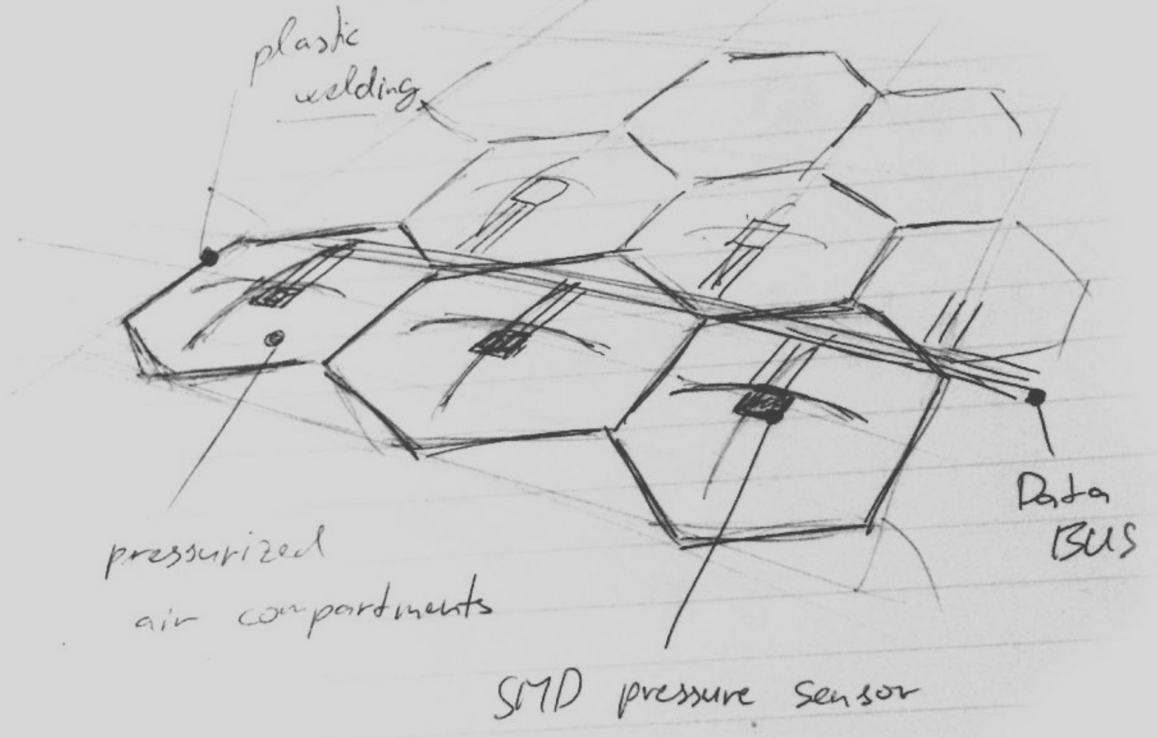
Industry Feedback

Contextual research had shown that Robotic Skin is a very current topic. We understood that it was crucial to tie our design process to industry feedback as early as possible. Through showcases and outreaching efforts, we secured support from a number of high-profile players.

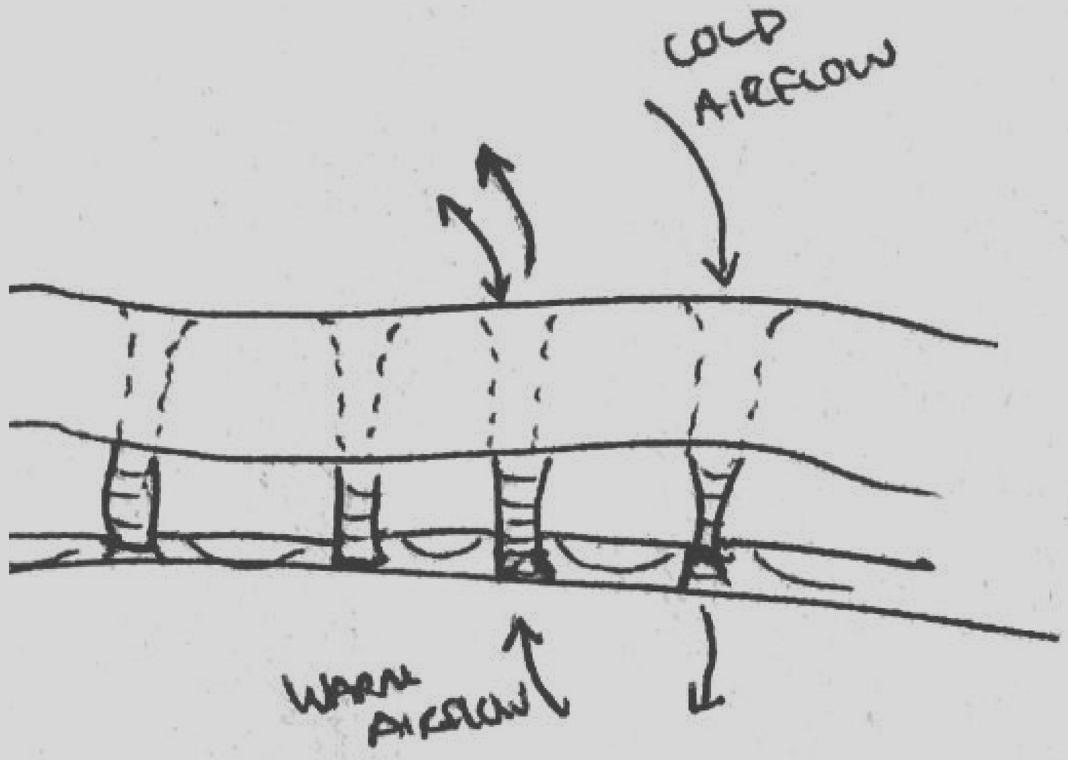
In order to extract design guidances from our interviews, we set up a research framework with three categories. These contained questions for the areas into which we wanted to gain additional insight. Using this framework, we guaranteed comparability between different sources. We have gathered feedback from Cisco, rAndom International, Armourgel, IDEO and many others on an informal basis. We were also able to secure £500 of extra funding from Imperial College Advanced Hackspace to fund our prototyping efforts.

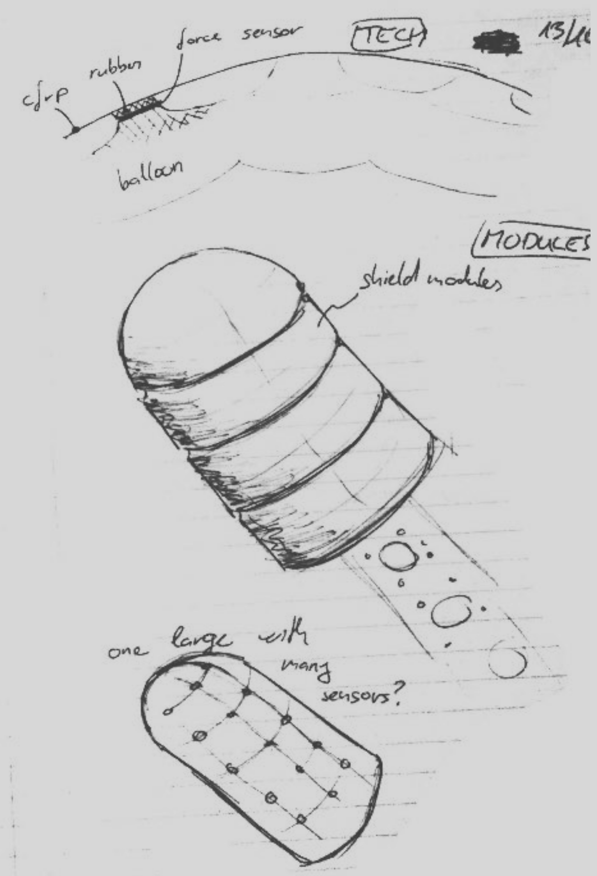
Sample Questions	Selected Responses	Inferred Design Insights
What do you think of the future of robotics? *Where do you think the limitation of robot-human interaction lies?*	*"It will be very hard to convince a user that your skin is alive. How do you make sure that the skin actually gives an animate impression or do you want to avoid that?"*	Design effective narrative and UX Test perception of the skin from a user's perspective
Where do you see value and applications of our concept? *If you were thrown into this project, what would be your first move?*	*"Limit your scope and focus on X"* *"Decouple the sensing and protection subsystem"* *"Find a use case that is strong and explore interactions that emerge"*	Evaluate time window and discard unrealistic goals Minimise interdependencies between technical subsystems
Resources and Facilities *Companies and People* *Inspiration & Technology*	*"We can support you with CAD knowledge for 3D mapping of structures onto complex surfaces"*	Use parametric software to map skin onto a robot Apply for Hackspace Grant to secure additional funding

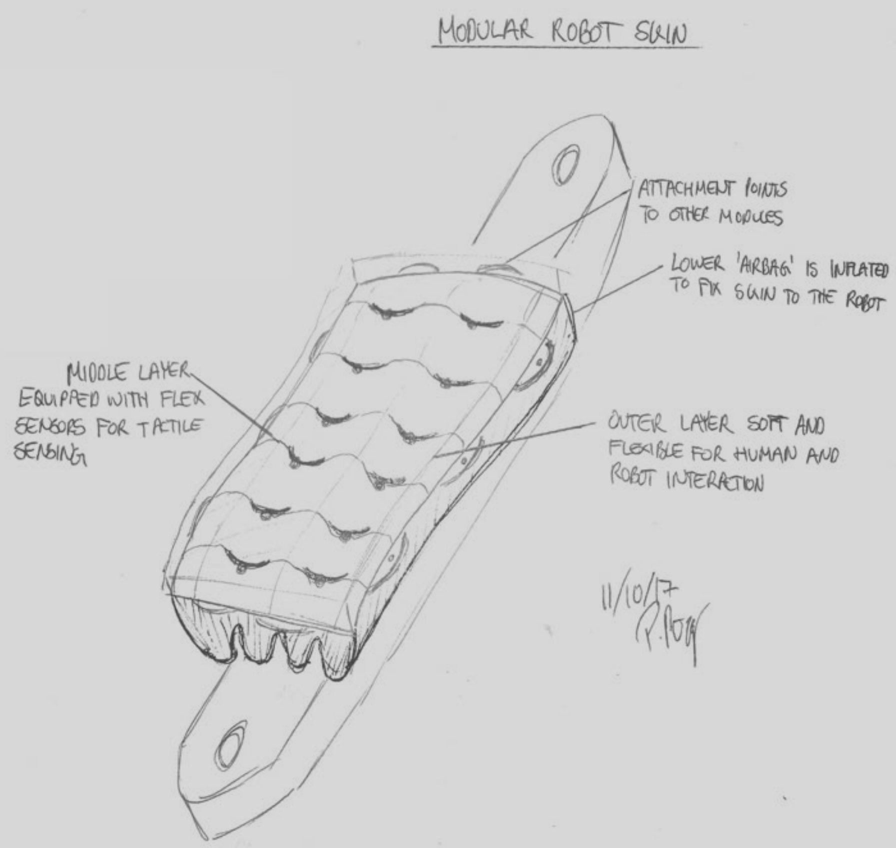




Concept Development





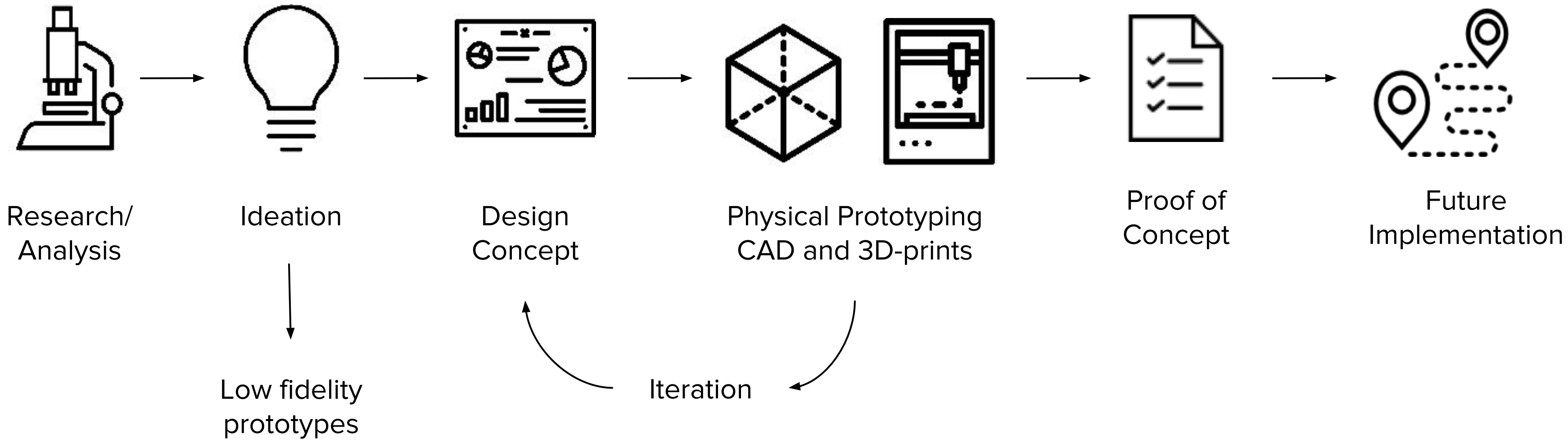


Initial concept sketches around achieving a multi-functional skin.

Ideation

Design Process

Following our initial research we used design tools and frameworks to further develop and iterate our concept alongside the technical developments. A simplified project plan was created to outline our overall approach and design process.



Stakeholder Analysis

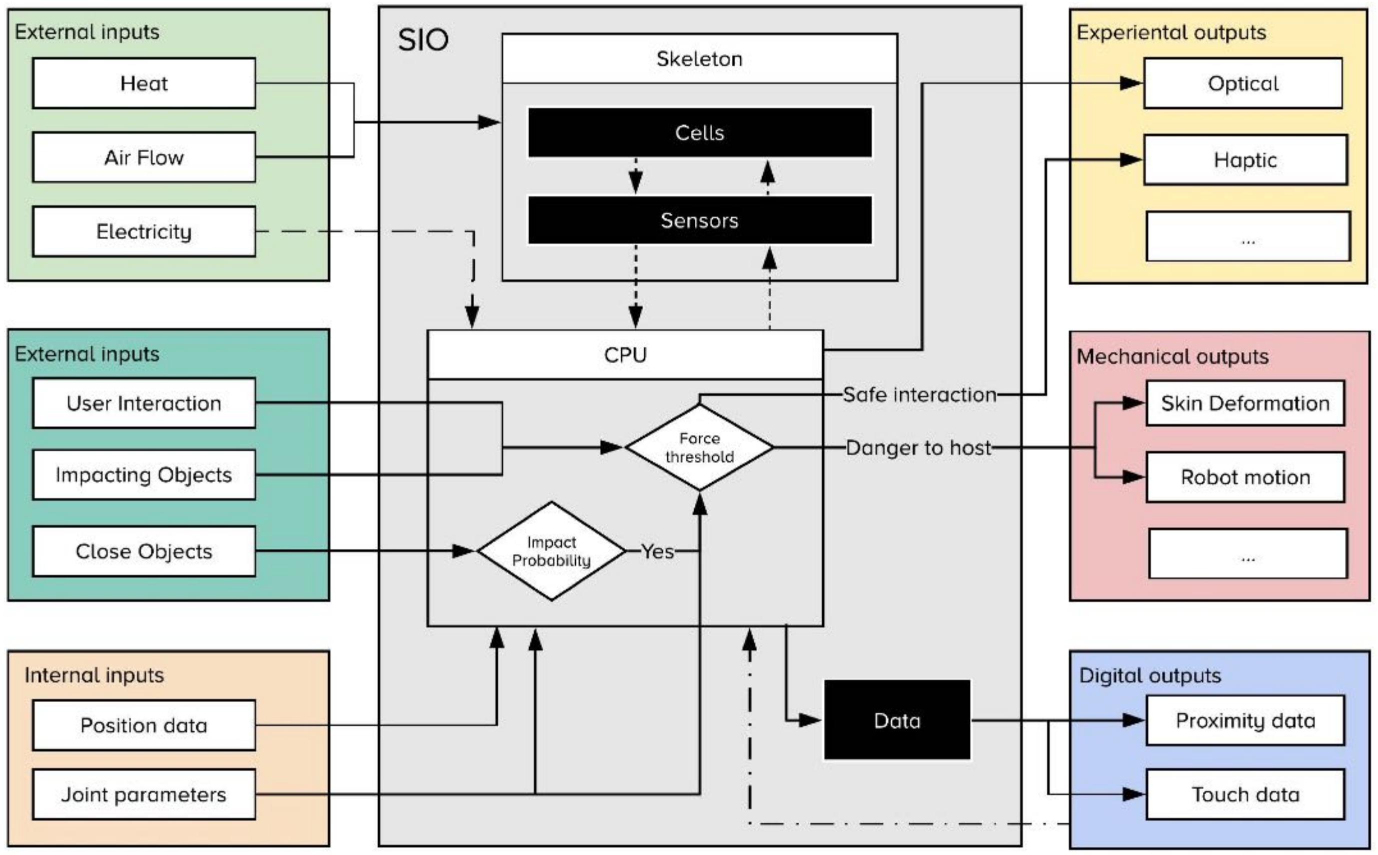
Key Stakeholders	Academia / Researchers *Primary Stakeholder*	Domestic/ personal use, Military, Industrial support, Workers 4.0 *Primary Stakeholder*	Manufacturer (of the robot) *Secondary Stakeholder*	Other Robots *Secondary Stakeholder*	End-of-life operator *Secondary stakeholder*
Stakeholder Needs	Ease of installation, Maintenance and day-to-day operation Accommodates versatile shapes Protection of inner electronics Ease of implementation to robot and its operating system Visual output while operating	Intuitive use and interaction Safety from robot's operation Guidance to robots actions Inference of robots actions Designed for easy repair and maintenance Shatter proof (military) Impact resistant (military)	Simple Designed for manufacture	Robots can detect each other Robots can avoid each other Robots can interact through skin interactions Detects not only touch, but also force and direction	Designed for end-of-life disassembly Reuse of embedded components

SWOT Analysis

Strengths	Weaknesses	Opportunities	Threats
Tactile sense allows safe interaction with humans Improved interaction and collaboration Facilitates robot-to-robot interaction Protects from impact damage Enables touch sensation	Robots can look uncanny to humans A lot of people are opposed / afraid of robots Heat dissipation Adds complexity Reduces robot joint mobility Adds weight	Wide range of industries and applications Likely to become a needed product in the near future Similar product are just yet being developed Potential to disrupt the industry	New designs are created for net robot shape Uncanny valley Other developers are making robotic skin as well Bespoke vs. Generalised solutions People can have adverse emotional reactions to robots and damage them

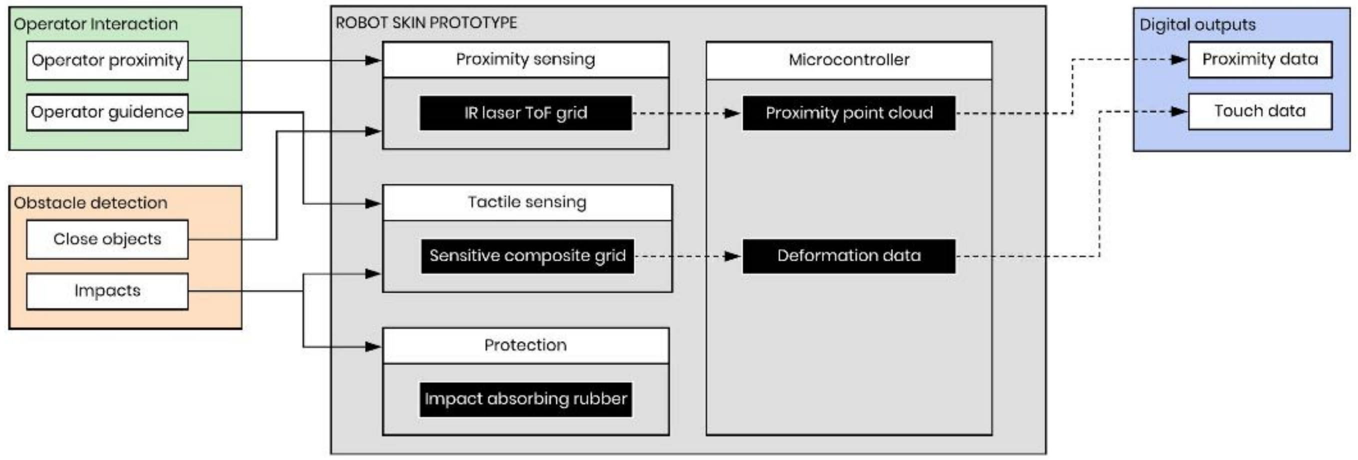
Implementation

Product System Diagram



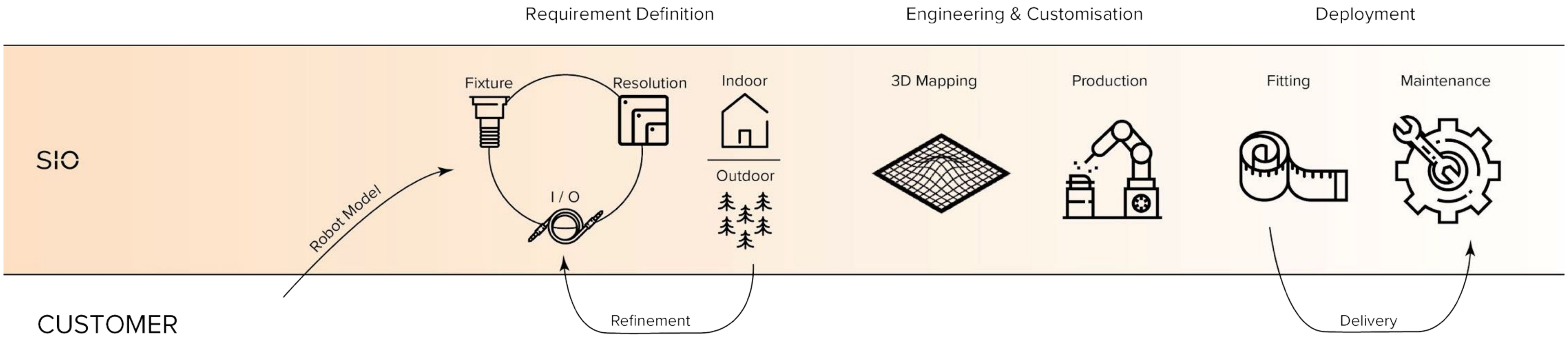
In order to implement SIO as a product we first designed a high-level diagram identifying the inputs and outputs of the system. From this we selected key features that would enter further development; protection, user experience, proximity, and touch. The latter two were technically most challenging, which necessitated developing a separate prototyping flowchart.

Prototyping Flowchart

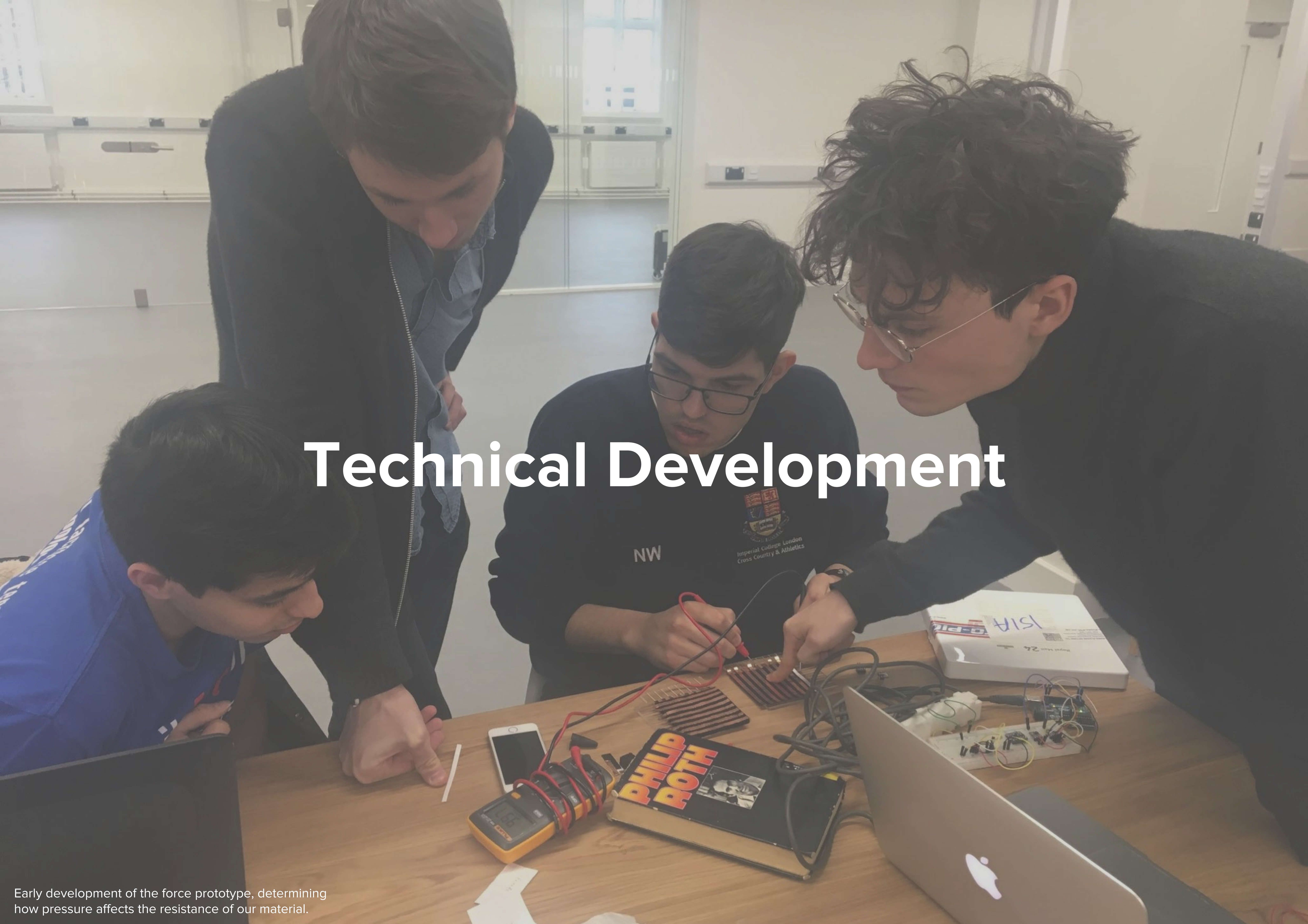


Service system diagram

Our service system diagram allowed us to see how SIO would be implemented into industry today. Using personas and scenarios we developed storyboards to define important touchpoints for SIO's customers. The first market implementation would be to manufacture SIO to retrofit existing industrial robots. This would bring increased safety and allow for industrial robots to become collaborative. This service model entails 3D mapping and tailoring the skin to the robot as well as provide after-sales maintenance. In the future, we predict that robots will enter our lives in environments such as hospitals, workplaces, education, and at home. With these developments the service model would expand to those new industries in order to keep SIO competitive in a fast-changing industry. As robots will get closer and closer to people, the service model would shifts its focus from industry to the general public.



Technical Development



Early development of the force prototype, determining how pressure affects the resistance of our material.

Proximity Prototype

SIO is able to detect an approaching object prior to touching it. This feature was implemented in a self-contained demonstrator inviting people to interact with it.

Low fidelity testing rigs

Arduino and pyBoard rigs to evaluate sensor performance for component selection

Increasing no. of sensors

Interfacing more and more LIDAR sensors

Final proximity prototype

Array of eight VL53L0X sensors with real-time visualisation and interaction

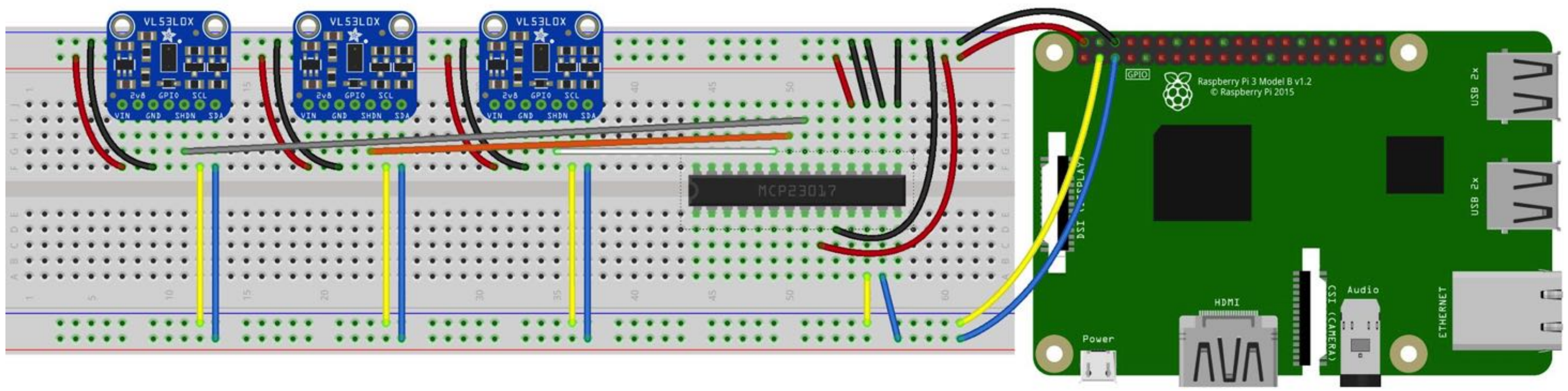
Component Selection

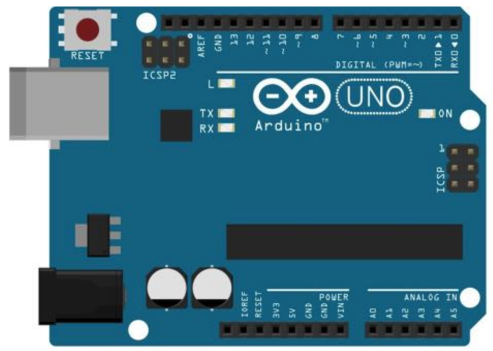
There are a number of well-established proximity measuring devices such as ultrasonic sensors or IR sensors. For the purposes of this project the main requirement was size, accuracy, precision and ease of interfacing to a Raspberry Pi. Selecting the right sensor was therefore not an easy task and meant a trade-off between cost, accuracy and interfacing capabilities. To aid with this decision we performed industry interviews externally, as well as building low-fidelity prototypes internally. After several rounds of testing, we ordered VL53L0X time-of-flight LIDAR sensors straight from the manufacturer in China, helping to keep our costs down.

In terms of processing, the Raspberry Pi was the obvious choice. While we have used Arduino and PyBoard for interim prototypes and testing rigs, added processing requirements called for a stronger platform. The Raspberry Pi is a full computer, not a microcontroller, and so was able to deal with processing and visualising the wealth of data.

Hardware

The diagram below shows a simplified circuit with three instead of eight proximity sensors. The Raspberry Pi only needs four cables to the circuit, power and ground, as well as data (blue) and clock (yellow). The latter two handle all the data transmission between the RPi and the sensors using the I^2C protocol. Furthermore, there is also a GPIO expander that handled initialising the sensors, an MCP23017 integrated circuit. It aided in giving each sensor a unique address, so that the RPi knows which sensor it may be communicating with on the data line.





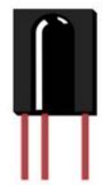
Platforms

Arduino

Used to evaluate suitability of the sensors shown below. Replaced with pyBoard due to reliance on C++

PyBoard

Streamlined testing of sensors and facilitated migration from C++ to Python



Sensors

VL53L0X
Implemented

Small, precise and accurate LIDAR sensor (time-of-flight) at £3.74 per unit

TSAL6200
Discarded

IR emitter with separate receiver. Discarded due bad interfacing capabilities

HC-SR04
Discarded

Accurate and cheap at 74p per unit. Discarded due to bulky size

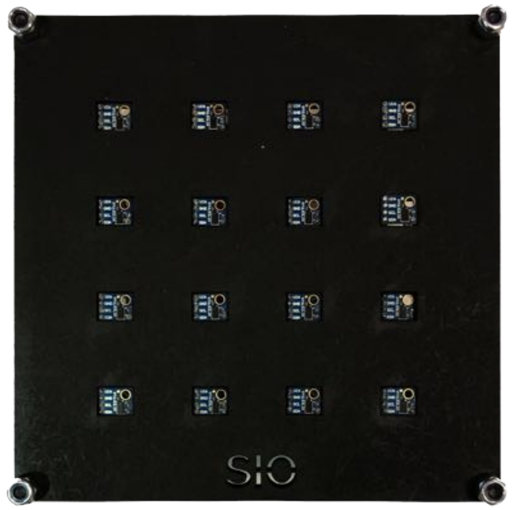
SIO

Proximity Prototype

futurerobotskin.com/proximity

Interactive Prototype

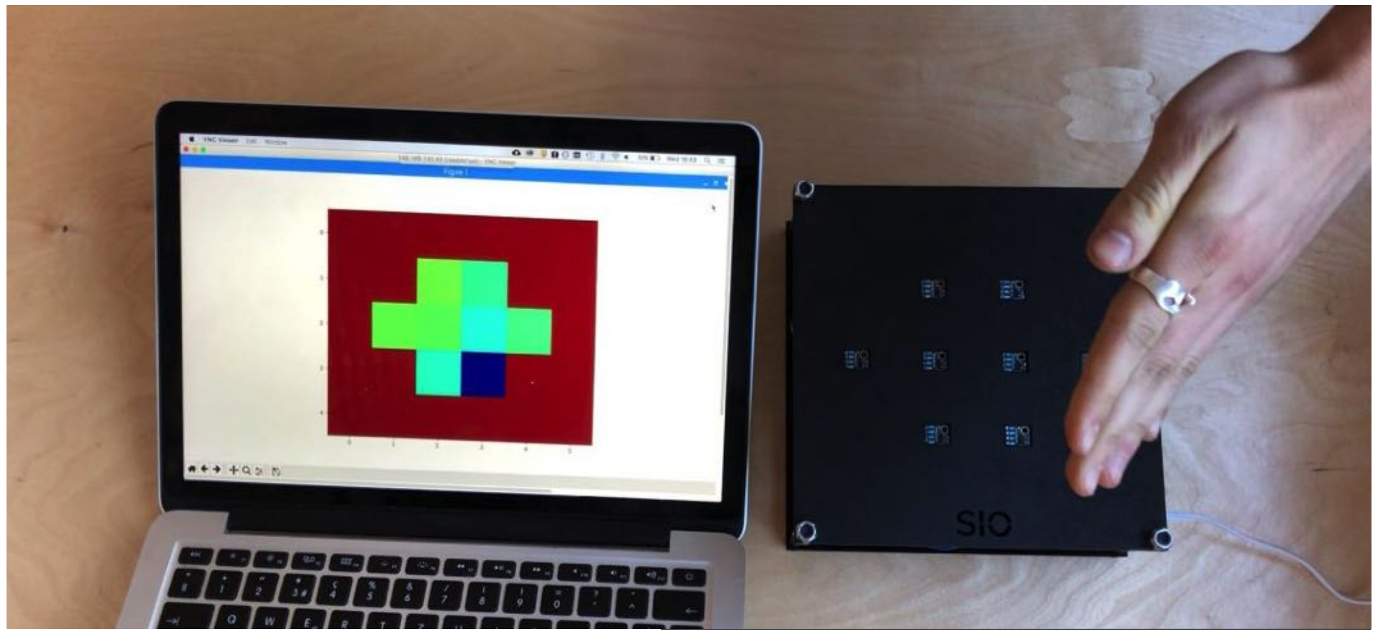
The 16 sensor array was mounted into a laser-cut wood enclosure. A user moves his or her hand above the prototype to interact with it. Finally, the data is shown on a monitor connected to the Raspberry Pi.



simplify

Limitations and next steps

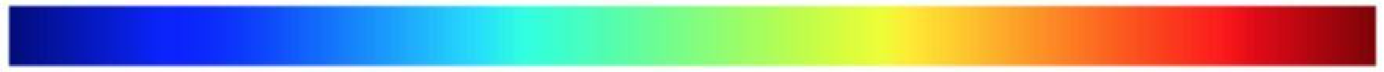
In our final demonstration we are only showing an 8 sensor array due to limitations of our work and hardware. Using I^2C as a data transmission protocol was great in terms of cable management, however, as more sensors were added issues such as bus capacitance and pull-up resistance were identified. Unfortunately, with the sensors we bought, it is not possible to interface more than eight reliably due to the way the chip was packaged. In future prototypes we would have moved to custom PCB design and in the future into more advanced technologies such as image processing.



futurerobotskin.com/proximity2

Processing the data

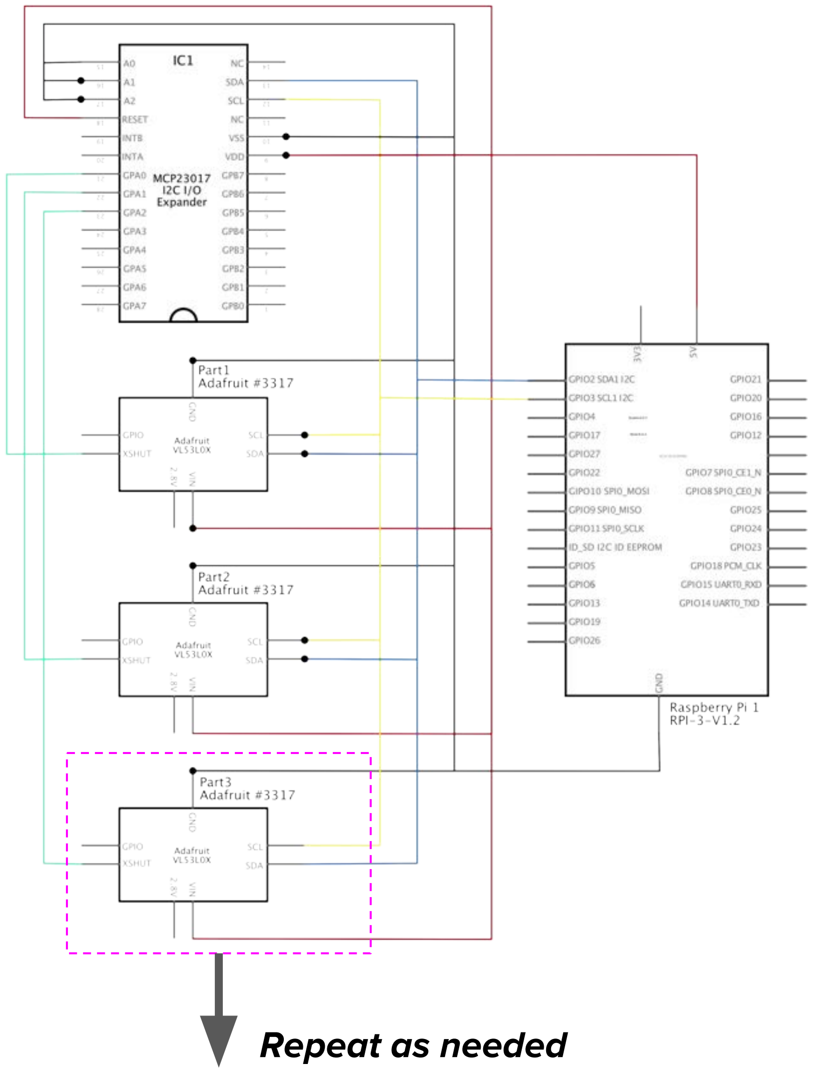
The Raspberry Pi handles instantiation of multiple sensor objects which rely on C++ libraries written by ST Electronics. It requests data over the I^2C data line and the sensor replies with the current distance travelled by its infrared beam. This data is refreshed regularly and displayed using 'matplotlib image show' with a colour map option. The colours are mapped from blue (near) to red (far) as seen in the gradient below.



The code was designed to scale, and can read from a great number of I^2C devices, the only limitation being the number of addresses available through the I^2C protocol.

System Design

The Raspberry Pi was used because it can handle large amounts of data and processing much better than a microcontroller. It also allows us to visualise the data we are receiving from the sensors. The system design reflected the scalability by only relying on power and the two I^2C communication lines available on the Pi.



Repeat as needed

Set up code to instantiate objects and data structures

Request distance from each sensor

Display data as individual coloured squares

Callback after delay

Force Prototype

SIO's second interactive feature is tactile sensation, which detects the exact position and intensity of forces applied on the skin. This is shown in our interactive tactile prototype.

Low fidelity testing rigs

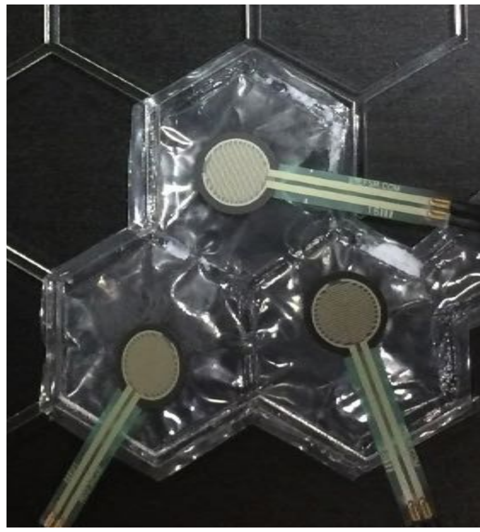
Exploring diverse technologies for component selection

Sensitive material design

Iterative prototyping and development of a force-sensitive, protective and elastic material

Final tactile prototype

A protective elastic skin with a grid of force sensitive spots. Real-time visualisation for human interaction.



Technology Selection

Requirements

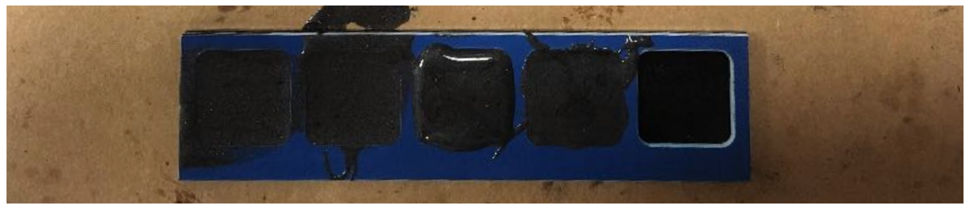
- Thin layer
- Flexible structure
- Identifies nature of interaction
- Accessible and affordable
- Interfaceable with RPi

A range of technologies were considered and force gauges were selected for our initial prototype, as they fitted the above requirements best.. However, experiments showed that off-the-shelf products were not suitable for this application. Sensors were either too bulky or their resolution was insufficient. Moreover, industry feedback pointed out that scaling and mapping our prototype onto a robot would be challenging with standard parts. Thus, the team went back to ideation, aiming to find a better, futuristic solution by eliminating present constraints of technology.

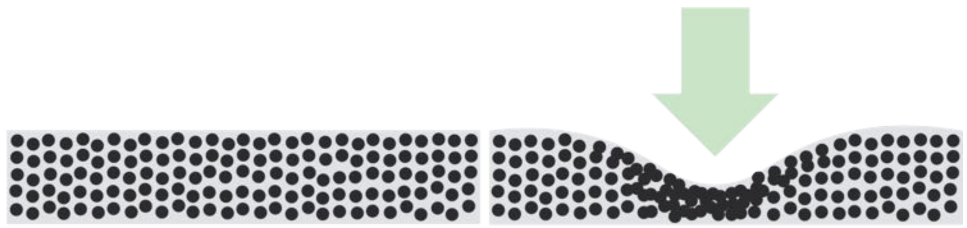
Sensitive Material Design: Carbon Fibre-Infused Silicon Composites

"What if the material would be intelligent enough to sense touch and inform the robot that it has been deformed?"

Sensitive composites have the structure of a non-conductive flexible elastomer infused with rigid conductive particles. Compressing the material results in more particles touching and hence increasing conductivity. After initial tests we decided to develop a completely novel material.



For the prototypes a matrix of Transil40 silicon was used with different levels of carbon contamination. An initial set of samples with graphene particles was unsuccessful, but from the second set with 100 µm carbon fibres some highly contaminated specimens worked really well. Through tests the team realised that a softer matrix (Transil20) and longer fibres would make the skin more elastic and sensitive, enhancing the material for our application. The development was a great success, embodied in a new material that provides information about its current state. It was built into a working prototype.



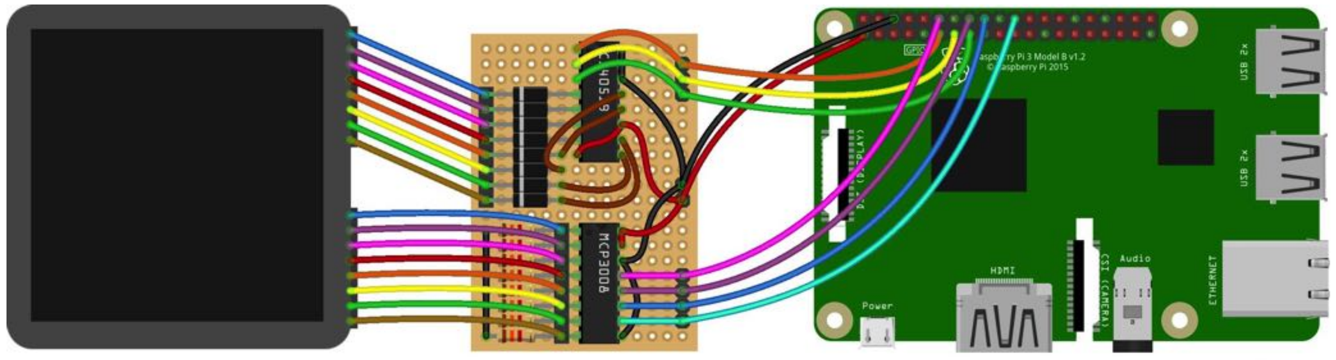
Force Prototype

futurerobotskin.com/force

Final interactive tactile prototype

Tactile sensing was introduced to enhance human robot interaction. Consequently the team also wanted to demonstrate this interaction through works-like prototypes. The final tactile prototype allows users to press the surface of 64 force sensitive pixels, and see their input visualised on a computer screen.

Force exerted on the sensitive material causes a local drop in resistance. In order to measure this a thin layer of copper grid was placed on the two sides of the composite where each node represents a sensitive spot. The resolution of the sensor was determined by the density of the copper grid, and as the approximate size of a human fingertip is 1 cm^2, this area was selected as 1 pixel. The sensitive pad is connected to a custom made interface PCB which allows to loop through the 64 pixels of the pad. Force data then gets sent to the RPi via I^2C.

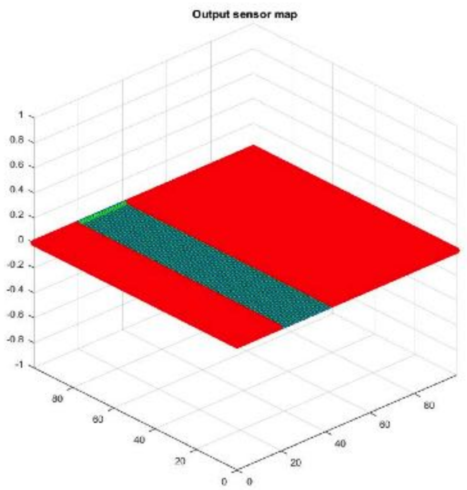


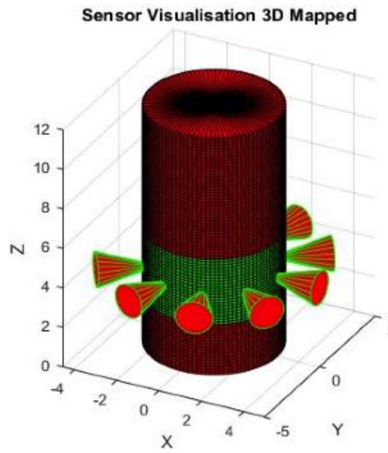
Similarly to the proximity set-up, the RPi works as an embedded controller. It collects and processes data from the prototype, then sends it wirelessly to a computer which displays the visualisation. In the software the pad is represented by a box of 8x8 squares, where colors ranging from blue to red show the increase in force and allows users to experience the tactile feature of SIO.

3D Mapping

The initial aim of SIO was to retrofit industrial robots. A key part of this process was being able to map the skin onto a large variety of surfaces and geometries. The team recognised the need to make different parts of the arm more sensitive than others. This allowed fewer sensors to be used within the skin. The goal of the 3D mapping software was to take in the input sensitivity grid and output a sensor map detailing where the sensors should be located. Initially a 2D net was created and a sensor map was implemented.

MATLAB was used to parse the grid generated by the input sensitivity map and generate the output sensor map. By factoring in the time of flight sensor view an algorithm was generated to ensure that no 2 sensors had overlapping regions over the skin. Once the map had been generated on a 2D surface, the next step was to allow the skin to be mapped to a 3D surface. For this project, robotic arms were modelled as cylinders. The 2D grid that was generated in the 2D mapping algorithm was taken and scaled to be the size of a cylinder net in 2D space. This was then wrapped on a cylinder into 3D space with the sensor field being visible.

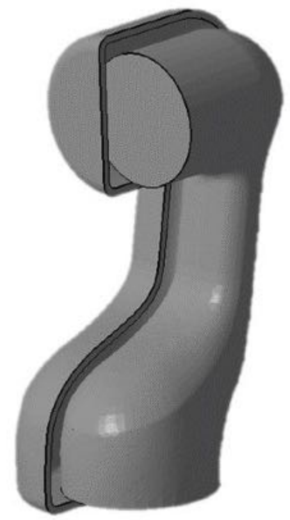




Manufacture

The final prototype was cast in a mould which was 3D printed from PLA . The mould consisted of a solid inner core and a hollow external shell. The skin was created in 2 halves to allow for an easier mould assembly and casting setup.

A Silicon and carbon fiber mixture was cast in this mould and the resulting skin was a touch sensitive and elastic skin which could directly be placed on the robot arm.



SIO

Final Design Proposal

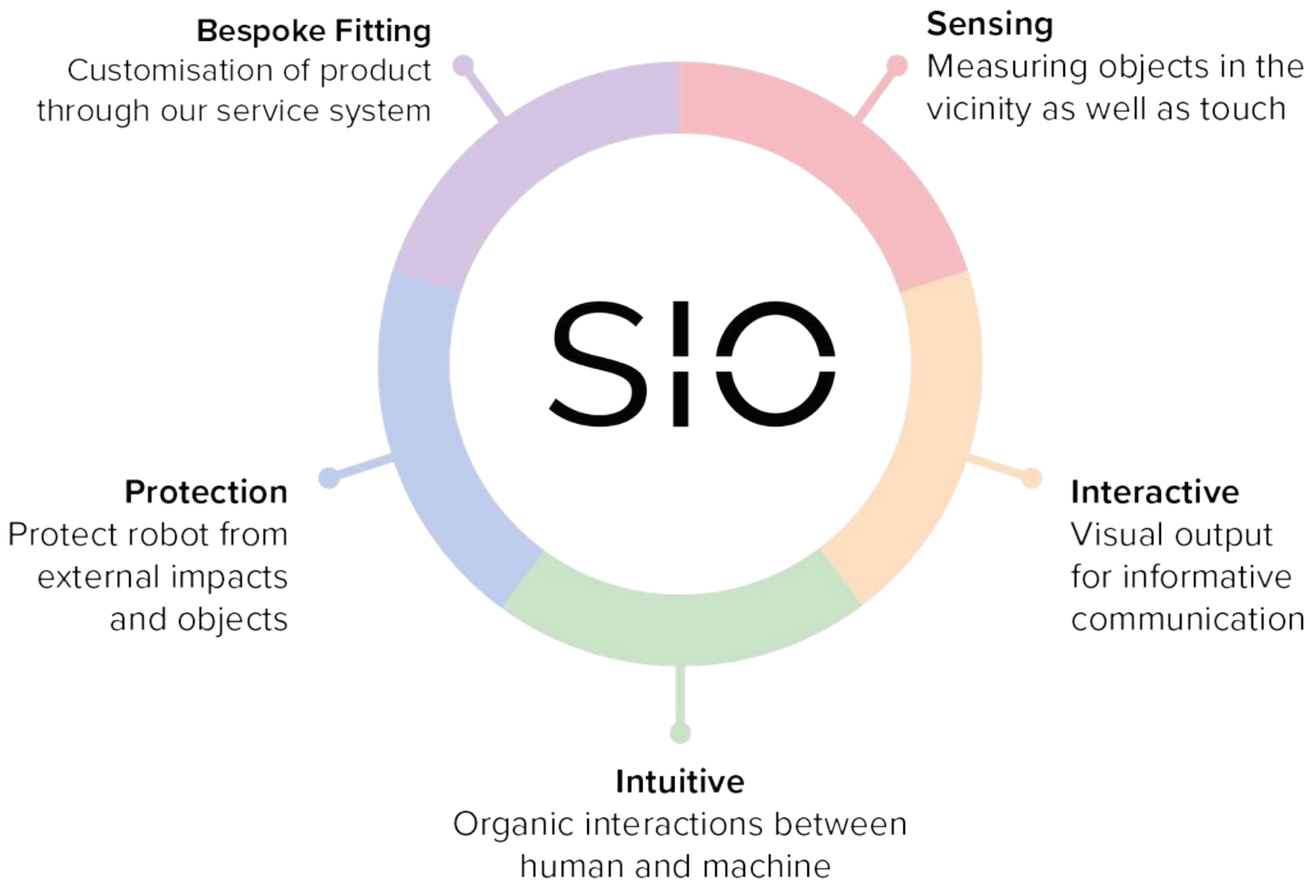
Render of user interaction with SIO mounted onto a FRANKA EMIKA © industrial robot.

Proposal

futurerobotskin.com/proposal

SIO is an intelligent and versatile skin that makes robots collaborative and allows for organic and predictive interaction between human and machine.

The skin will be 3D-mapped and manufactured to the customer's specific needs and aims to move robots out of concealed safety areas and into collaborative workspaces. The two main technical features, proximity and touch sensation, have been prototyped and taken through several stages of technical development showing clear proof of concept. Through innovative material science SIO not only gives the robot perception, but also protection of itself and its surroundings. Equipped with LIDAR sensors it has 360 degrees of vision, adding the level of safety needed for intuitive interaction with humans. The system can be integrated with the robot's motion planning system. In this way, *SIO eliminates the need for particular skills like programming to operate the robot.* The unique selling points are summarised in the SIO circle shown to the right.

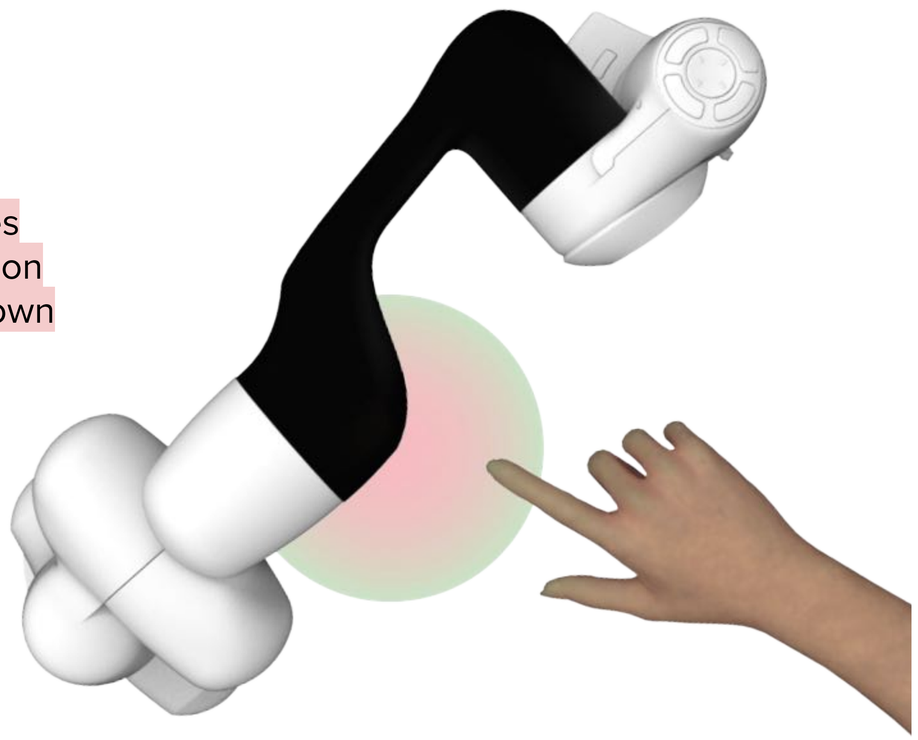


Use Cases
The illustrations below show how SIO allows interaction between robots and people. The platform was built for domestic as well as industrial users. Technology foresight and stakeholder analysis has allowed us to pave a future path for SIO and its applications, evolving with trends and expanding into new market.

Proximity Monitoring

Input Environment
Human
Robots

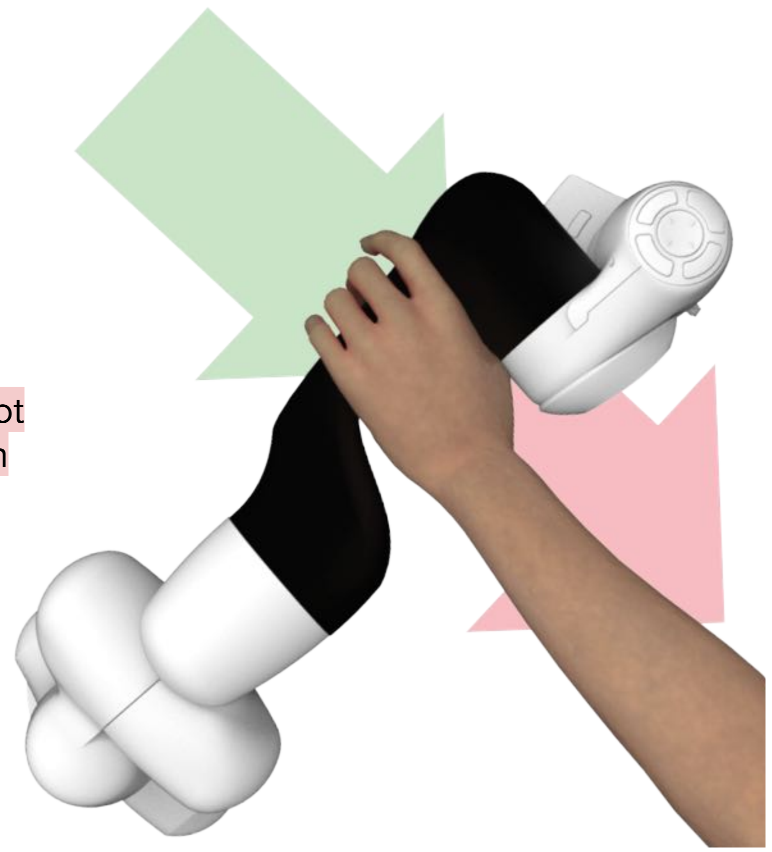
Output Safety Measures
→ Protection
→ Slow down
→ E-stop



Touch Detection

Input Human Touch

Output Robot Movement
→ Guided Motion
→ Teaching the robot
→ Intuitive operation



SIO

Future Considerations

PRODUCT

2017

Early Development: With SIO in early development, the product races through early technology readiness levels using existing technology from various industries.

2020

Capactive Sensing: SIO is developed to understand precise touch interaction using advanced capactive technology.

Roll-out to Industry: SIO begins rolling out to robots in the manufacturing industry to enhance collaboration between human workers and machines.

2025

FPGA & Image Processing: SIO gains more accurate and lower computational load to the host robot by using advanced image processing techniques combined with the high effieciency and power enabled by usng field programmable gate arrays.

Expand to healthcare: SIO's innovative approach to human-robot interaction allows for natural and organic use of robots in the medical healthcare industry.

2030

Biomimetics: SIO draws from nature to augment the experience provided to its human users.

Robot Interaction: With advanced networking capabilities, SIO can provide other robots nearby information about it's host to allow for more efficient and optimised robot-robot collaboration.

2040

Human augmentation: SIO is developed to augment humans, no longer relying on a robotic host.

SIO is a product and service proposal validated through experts and embodied in prototypes. This is just the beginning of the journey however. SIO will change drastically as the narrative, the business model and the technology mature. The above figure outlines the future roadmap for our system.

We have evaluated our prototypes with a number of high-profile experts as well as users. In this way we outlined the next steps that are required in order to arrive at a sellable product.

TECH. DEVELOPMENT

Distributed Sensors

At the moment we rely on a larger number of sensors per area

Visual Imaging

In the future, we would explore the use of visual imaging (pixel-based) techniques. This could be achieved with FPGAs.

MEMS Imaging

Microelectromechanical systems could combine the advantages of LIDAR and imaging techniques

Capacitive Sensing

Explore the use of capacitive touch which provides a high accuracy medium with few components. This is limited to human touch and less so with general objects in the environment.

Nanotechnology

In the future nanotechnology will be more accessible and affordable, This would allow us to decrease the size of our sensors and electronic components and increase the resolution of sensing.

Biocomputing

This technology would allow SIO to do computations locally at skin level. This would allow for faster and more accurate tactile sensing in a thinner and more compact package.

"We are very interested in your proposal and would like to invite you for a meeting with our engineers about developing robotic skin"

Mostafa ElSayed
CoFounder of Automata
London-Based Robotics Startup

"Using MEMS systems with microscopic mirrors can help increase the range of vision with a small number of sensors"

Peter Cheung
Head of EE
Imperial College

SIO

Appendix

Promoting SIO at a showcasing event in the
new Dyson Building at Imperial College London.

Team Reflections

Ina Roll Backe | inarollbacke.com

I have really enjoyed having the time to go in-depth into such a relevant and exciting project. It was challenging to implement design thinking and certain design tools and methods due to the technical nature of the project. However, the latter has shown great importance and allowed us to keep our narrative clear and a strong focus on a human-centered design approach to our integrated product service system. It has been very interesting to have ongoing communication with and feedback from industry, with some key stakeholders following our progress throughout the project.

Shivam Bhatnagar | linkedin.com/in/bhatnagarshiv

We chose one of the more technical futures themed project. By doing so we were able to take a step back from the brief and re-explore the project theme. Being able to expose our work to industry at multiple exhibitions was a very insightful experience that allowed us to validate our project. The team worked well together and we used a variety of project management techniques to ensure that all parts of the project were progressing equally. My contributions to the project have included 3D Mapping, CAD and helping out with the build of the force prototype.

Ben Greenberg | bengreenberg.uk

This was one of our longest projects, and with it came a very thorough development through a number of prototypes. I most enjoyed editing our concept video developed in the early stages of the project and bringing together the data processing of the two technical prototypes presented in this portfolio. My main contribution has been behind Raspberry Pi and programming, but I have also supported other areas such as project management and producing graphics and research into the technology roadmap.

Paolo Ruegg | paolofalcoruegg.com

This project was new to all of us in terms of its length. For the first time we were given time to do proper research, to order in components with longer lead times and therefore to deliver a more refined design proposal. This time frame was very pleasant in terms of the depth we could reach, and has very much allowed to push the boundaries of our abilities. For the first time we reached a depth of technical development where the Internet did not provide answers and we needed to develop the platform completely on our own. The theme of the project, Robotic Skin, turned out to be extremely current and popular and we were able to forge a number of valuable connections to industry through it.

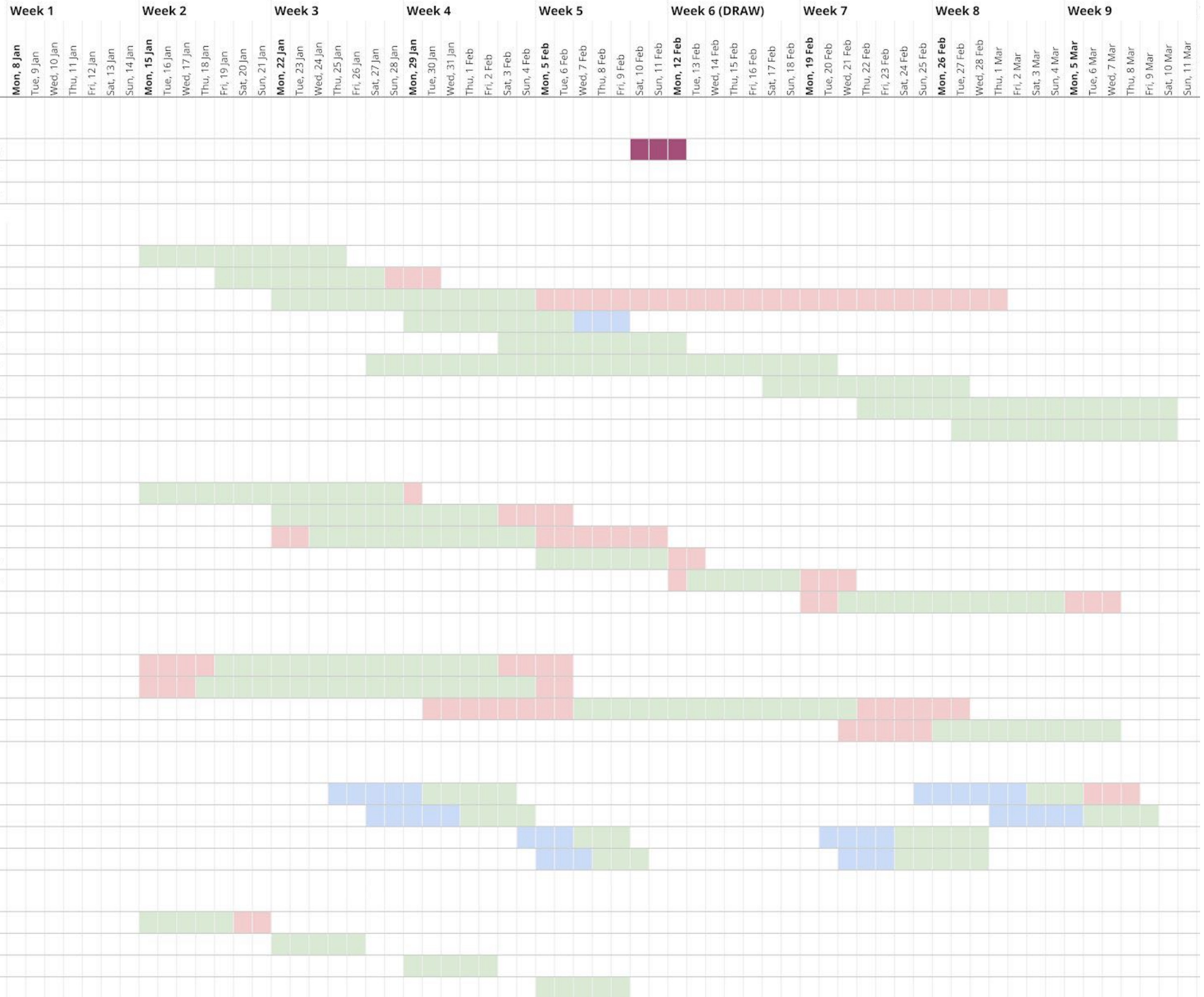
Norbert Wesely | linkedin.com/in/norbert-wesely

I have extremely enjoyed this project for multiple reasons. First, this was one of the longest and most in-depth developments I participated in so far. We had time to thoroughly research various aspects of the project, implementing new technologies and building working prototypes while always keeping future users in the centre of our design process. Secondly, the topic Robotic Skin is strikingly current and possibilities of future application as well as the constant attention of industry kept me excited all along. My main contributions to the project were in ideation as well as overlooking the development of our force sensitive technology.

Project Management

Future Robot Skin - Term 2

No.	Task	Responsibility	Dependency	Complete by
	Milestones			
1	Critical Review Evening (formative poster)			Mon, 12 Feb
2	Report Submission Deadline			Tue, 13 Mar
3	Embodiment demo + Pecha Kucha presentation			Tue, 20 Mar
A	**Touch**	**Norbert**		
1	Prototype Foam: copper grid assembly and wiring	Norbert	-	Sat, 27 Jan
2	Prototype Velostat: copper grid assembly and wiring	Norbert	-	Sat, 27 Jan
3	Prototypes: MUX configuration and electronics	Ben	A1	Mon, 5 Feb
4	Prototype Foam: RPi processing and visual representation	Ben	A3	Mon, 12 Feb
5	Prototype for critical review: working in eclosure	Norbert	-	Mon, 12 Feb
6	Prototype Gel: conductive gel design / test castings	Norbert/Ina	-	Wed, 21 Feb
7	Prototype Gel: copper grid assembly and wiring	Norbert	A6	Wed, 28 Feb
9	Prototype Gel: Look-a-like skin design	Norbert/Sh	A6	Sat, 10 Mar
8	Prototype Gel: mould design for combined touch + proximity	Norbert	A7	Sat, 10 Mar
B	**Proximity**	**Paolo**		
1	I2C set up with sensor, trial multiple sensors	Paolo	-	Mon, 29 Jan
2	Switch to Raspberry Pi, Interface multiple sensors	Ben/Paolo	-	Fri, 2 Feb
3	Design combined circuit for multiple sensor configuration	Ben	-	Mon, 5 Feb
4	Report data on host / Build multiple sensor rig	Ben/Paolo	B3	Mon, 12 Feb
5	Plot data visually on the host controller	Ben	B4	Mon, 19 Feb
6	Improve reliability of >8 sensors	Paolo/Ben		Mon, 5 Mar
C	**3D Mapping**	**Shiv**		
1	2D Mapping - Given a surface how skin can be modelled on it		-	Mon, 29 Jan
2	Input sensitive areas and algorithm will output sensor map		C1	Mon, 29 Jan
3	3D Map - Start with Cylinders		C2	Mon, 29 Jan
4	Output sensor map on 3D surface		C3	Mon, 5 Feb
D	**Looks-like and Visuals**	**Ina**		
1	Renders	Ina	D3-4	Mon, 5 Mar
2	User Interaction	Ina	D1	Mon, 5 Mar
3	Aesthetics - finish/colour design	Ina		Mon, 5 Mar
4	Aesthetics - material choice	Ina		Mon, 5 Mar
E	**Website**	**Ben**		
1	Blog Update for Week 2	Norbert	-	Sat, 20 Jan
2	Blog Update for Week 3	Paolo	-	Sat, 27 Jan
3	Blog Update for Week 4	Shivam	-	Sat, 3 Feb
4	Blog Update for Week 5	Ben	-	Sat, 10 Feb



SIO