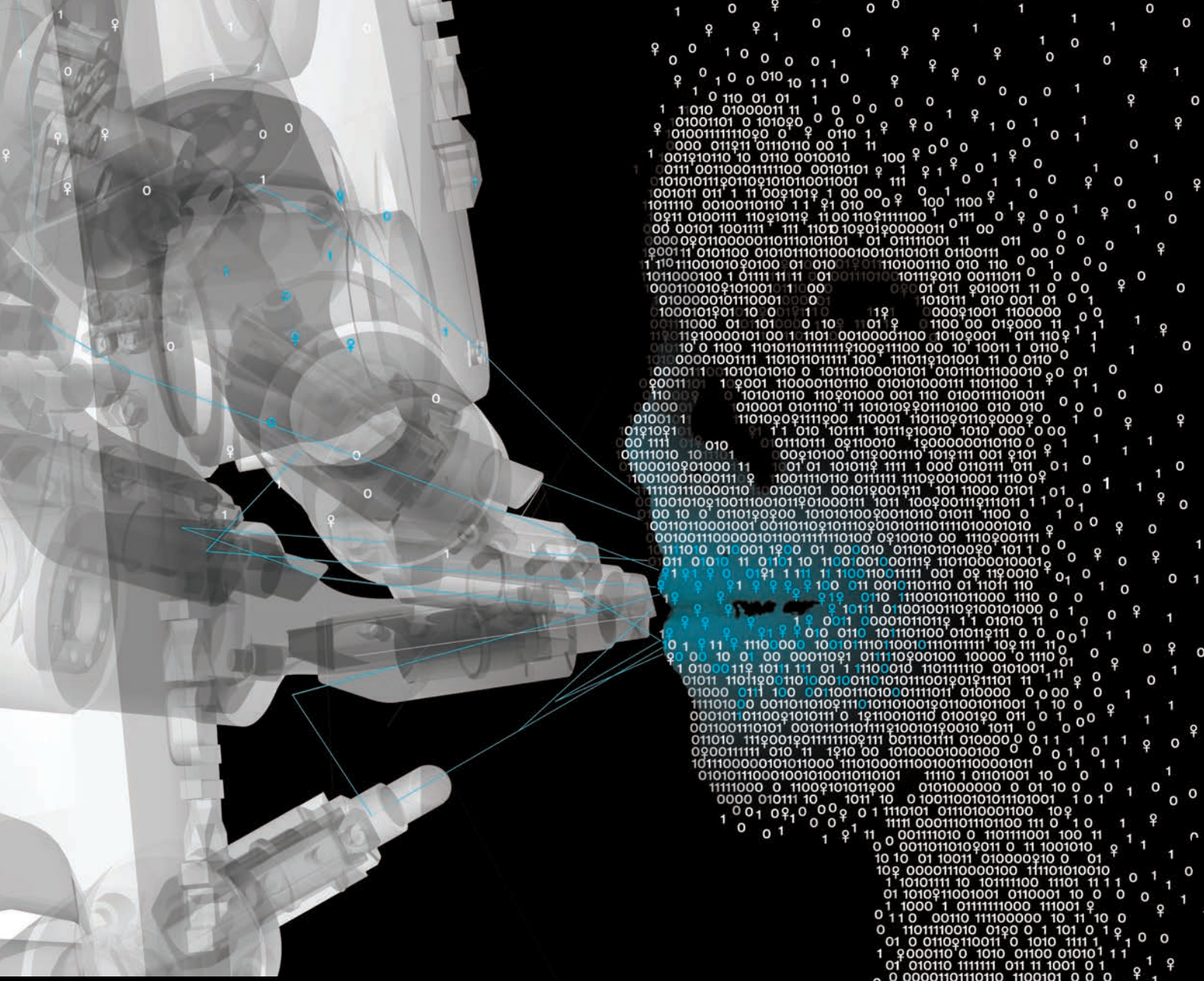


SHErobots

tool:toy:companion

AN EXHIBITION HELD AT TIN SHEDS GALLERY
148 CITY ROAD, DARLINGTON NSW 2008
THE UNIVERSITY OF SYDNEY
20 OCTOBER – 10 DECEMBER 2022

SHErobots: Tool, Toy, Companion

Dagmar Reinhardt, Lian Loke, Deborah Turnbull Tillman

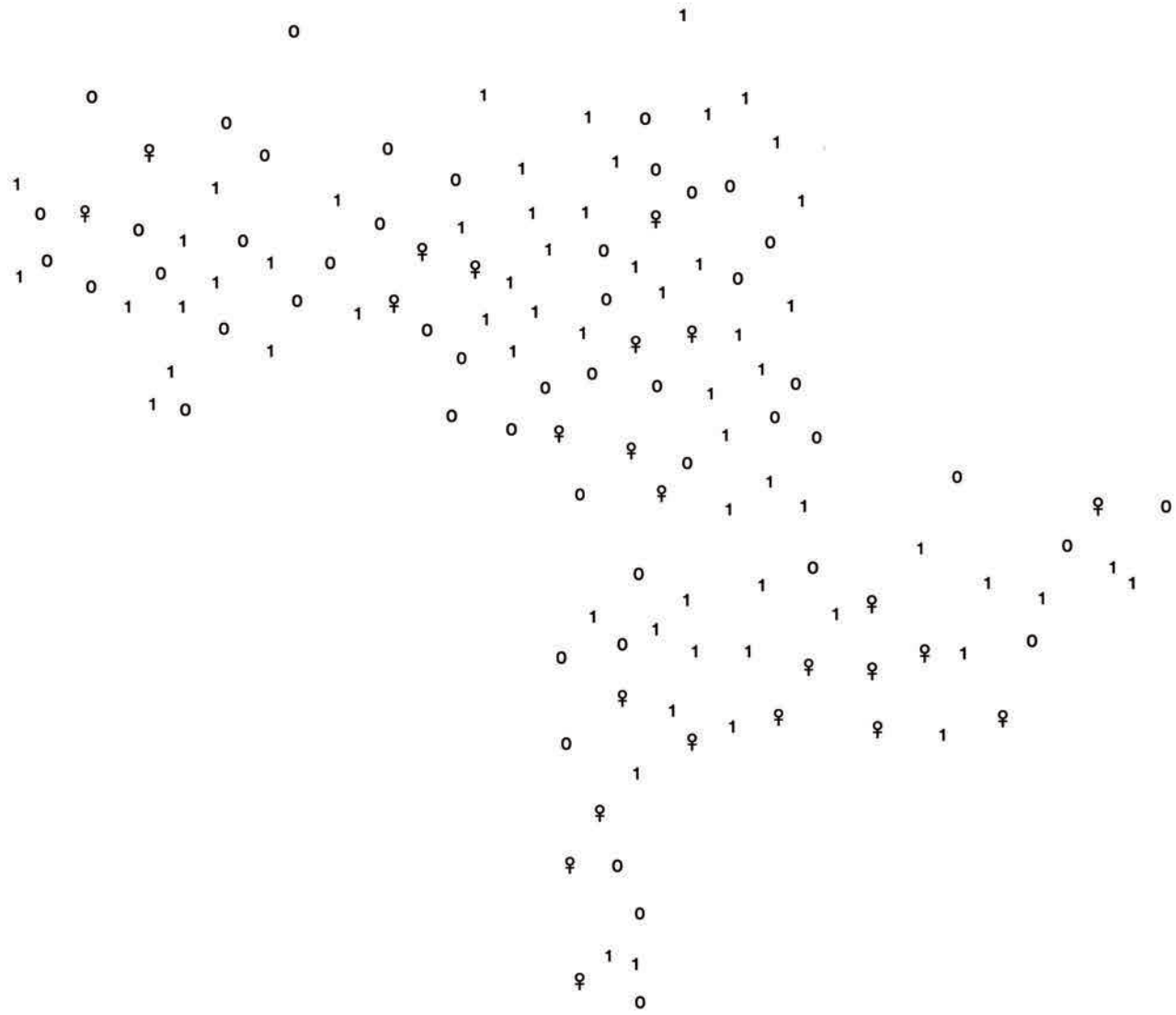
ISBN 978-0-6455400-6-2 [pdf]

Tin Sheds Gallery is a cross-disciplinary exhibition space at the University of Sydney to advance public debate on architecture, art, design and urbanism in contemporary society through innovative exhibitions, publications and related activities.

Front and back cover page image credit: Iris Shen, Dagmar Reinhardt and Lian Loke.

THE UNIVERSITY OF SYDNEY

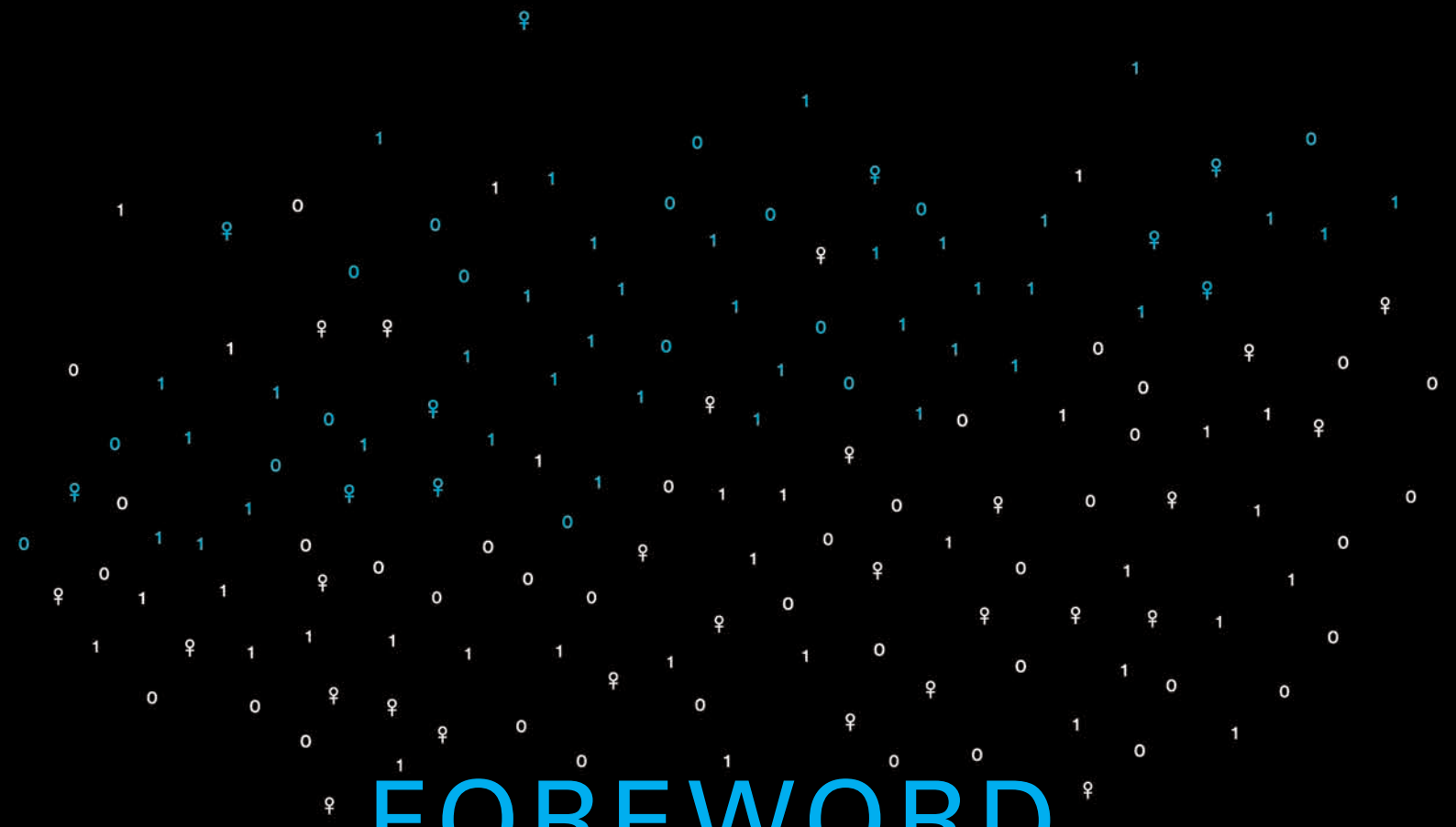
UNSW SYDNEY



Dagmar Reinhardt, Lian Loke, Deborah Turnbull Tillman

SHErobots

tool:toy:companion



FOREWORD

Emily Siddons

From the domestic to the industrial, many robots trace their roots back to manufacturing, where they fit within an existing system and organisational structure. Here they typically achieve tasks that are difficult or tiring for humans, or to maximise control and efficiency. In industrial settings, robots have been comfortably confined to strict work areas, but how do they adapt to more dynamic environments and navigate complex relationships?

In roles as active creators and participants in culture, autonomous robots begin to socialise with humans, and consequently, ethical questions arise around how much agency they will be given. When machines fail, what damage is done to trust and who is being held accountable? The world gasped recently when a chess playing robot broke a child's finger after he violated a safety rule[1]; moments of error bring questions to the forefront. Where does our comfort lie with machine error?

As the Exhibitions and Programs Manager leading the development of the nascent National Communications Museum (NCM), I have been working with technology collections and have spent the past few years exploring how we communicate and why, and where the lines between human and machine begin, end, and intersect. I consider women as the original computers, where they served as tools for number crunching at a Weapons Research Establishment (WRE) at Salisbury from 1946[2]. Their role at this facility made Australia a world leader in the automation of data processing in the 1950s and early 60s. Today, women are challenging and reconsidering the design, customisation, and materiality of the technological tools of our future.

In this ground-breaking exhibition, 21 participants and their collaborators present experimentations with new robotic forms and applications, questioning contemporary robotics from a distinctly female perspective. These works investigate the materiality of robotic shells, hack and reprogram systems, invent new societal and workplace structures, and re-define our fundamental relationships. Adopting unique material and spatial considerations, they challenge us to consider how new robotic forms can expand on their more limited industrial roots in order to navigate and shape complex spatial environments, contexts and domestic settings.

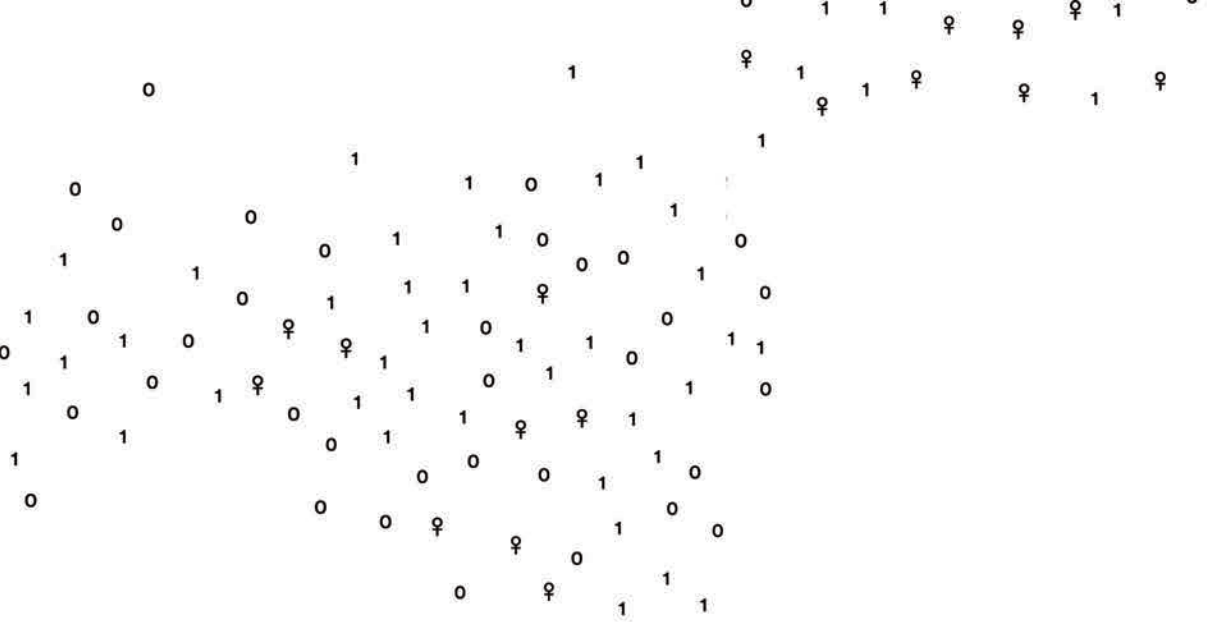
Whether a tool, toy or companion, the robotic more-than-human future is here, and these thought-provoking works visualise a progressive future for human-robotic relationships—one that overturns patriarchal values and places robots as more meaningful collaborators with people and as participants in culture.

SHErobots presents an exciting case study for museums and research institutions working as collaborative frameworks and living laboratories. This exhibition demonstrates the importance of fostering experimentation at the intersections between architecture, art, design, and technology, and invites us to reconsider the social, political and ethical contexts of our shared female-driven future of robotics.

[1] In Serena Smith, `Why did this chess-playing robot break a child's finger?' DAZED, Science & Tech News, 27 July 2022, https://www.dazeddigital.com/science-tech/article/56642/1/why-did-a-chess-playing-robot-break-a-childs-finger-tass-moscow

[2] Peter Bell, `Defence Science and Industry', SA History Hub, History Trust of South Australia, https://sahistoryhub.history.sa.gov.au/subjects/defence-science-and-industry, accessed 6 October 2022.

Emily Siddons is the Exhibitions and Programs Manager at the National Communications Museum, where she is leading the vision and development of this significant new museum that is yet to open. Previously she has held roles curating and producing exhibitions and public programs at The Australian Centre for the Moving Image (ACMI), Museums Victoria (Melbourne Museum, Scienceworks, Immigration Museum), The National Gallery of Victoria and Liquid Architecture. She specialises in curating and producing diverse exhibitions and experiences that integrate the latest forms of emerging technologies and is a PhD candidate at the University of Melbourne's Victorian College of the Arts, exploring new models of engagement for museums in contemporaneity.



INTRODUCTION

Dagmar Reinhardt, Lian Loke, Deborah Turnbull Tillman

We are on the brink of a new world of living with robots. Robots are moving out of factories and research labs into everyday life. Whereas digital disruption drove innovation and social change in the past two decades, the next industrial and cultural revolutions will be founded in artificial intelligence, machine learning and robotics. Now is the time to critically question who participates in the shaping of robots, and how robots will, in turn, shape humanity.

Female leadership in robotics has become a rising force across the disciplines of architecture, art, design and technology. *SHErobots* explores robots and roboticists from a female[1] angle, making visible the spectrum of approaches to working with robots. It highlights the role that women have played in multi-disciplinary and multi-gender teams, and individually.

The women in this exhibition are robotic researchers and creative practitioners who at the forefront of their fields. They have produced pioneering work, from developing software interfaces for robotic fabrication to re-imagining what social robots could look like. They are bringing perspectives and values from the lived experience of women to the field. They are challenging the gender assumptions built into robots, whilst developing critical, ethical practices for robotics. They are innovating with materials, tools and practices that evoke care, nurture and respect for non-humans and the natural environment.

SHErobots asks fundamental questions about the nature and processes of contemporary robotics through the lens of female perspectives. The researchers and practitioners represented in the exhibition come from academia, industry and culture. We have invited women pioneers, mentors, mid-career and recent graduates from eight different countries; the beginnings of an international, collaborative network of practice brought together here for the first time.

SHEroboticists hack robot programs, invent new material combinations, or make industrial robotic arms mobile to move freely across sites. These female practitioners increase the agency of robotic applications. They innovate by exploring a nexus of computation for robots from design to analysis and simulation, to method development and fabrication processes. They trial material and interface applications in robotic assembly, manufacturing and construction processes. They continue craft to mass customisation, using weaving, threading, throwing, caring and growing techniques.

Not afraid to challenge the status quo, they tackle contested and uncomfortable issues such as gender norms, sexuality, violence and ethics. They question care strategies for young and old, through artistic methods of placing robots in unorthodox relations to human bodies. They go beyond human-centric concerns to speculate on the rights of robots as the boundaries between humans and robots become ever more blurred.

Their impact is evident in the founding of robotic institutes and research labs, initiating startups and entrepreneurship in manufacturing and fabrication, and empowering communities for skill building and thus increasing workforce capability. These works demonstrate that robots are not only a catalyst technology for manufacturing and construction. Robots are a catalyst technology for women—opening STEM/STEAM[2] to a generation that unapologetically demands their place in these domains.

KEY to exhibited works and living lab

- F Film, artistic
- I Installation
- M Material, Artefact
- P Performance
- R Robot
- S Software, Simulation
- T Tool
- V Video documentation
- W Workshop

\industrial robotic arms
\robotic fabrication
\Industry 4.0

Keywords that serve as descriptors for shared topics and interests that bridge between the different robot works, themes (tool, toy and companion) and domains (robots in architecture and design; creative robotics and social robotics).

Our curatorial team (designer/architect, artist/performer, media curator) worked collaboratively from our research experience in robotics and our interpretation of female perspectives to discuss and cross-pollinate between disciplines. In conceptually organising the exhibition, we begin with the provocation of robots as tools, toys or companions; a point of departure for interrogating traditional and novel relationships between humans and robots. Each theme (tool, toy, companion) is elaborated in a curatorial essay as a preface to the range of works in the exhibition. The participating exhibitors provide a diversity of local and international responses to the curatorial themes, informing a mapping that reveals commonalities across regions, yet distinctive approaches of local practice. To support navigation in the exhibition, symbols (blue circle, see sidebar) are provided that indicate the modality of the work. Each respective work is accompanied by a conceptual statement or essay in the catalogue by the contributing researchers or practitioners. In the exhibition, works are loosely grouped with others by the same theme or sharing similar characteristics.

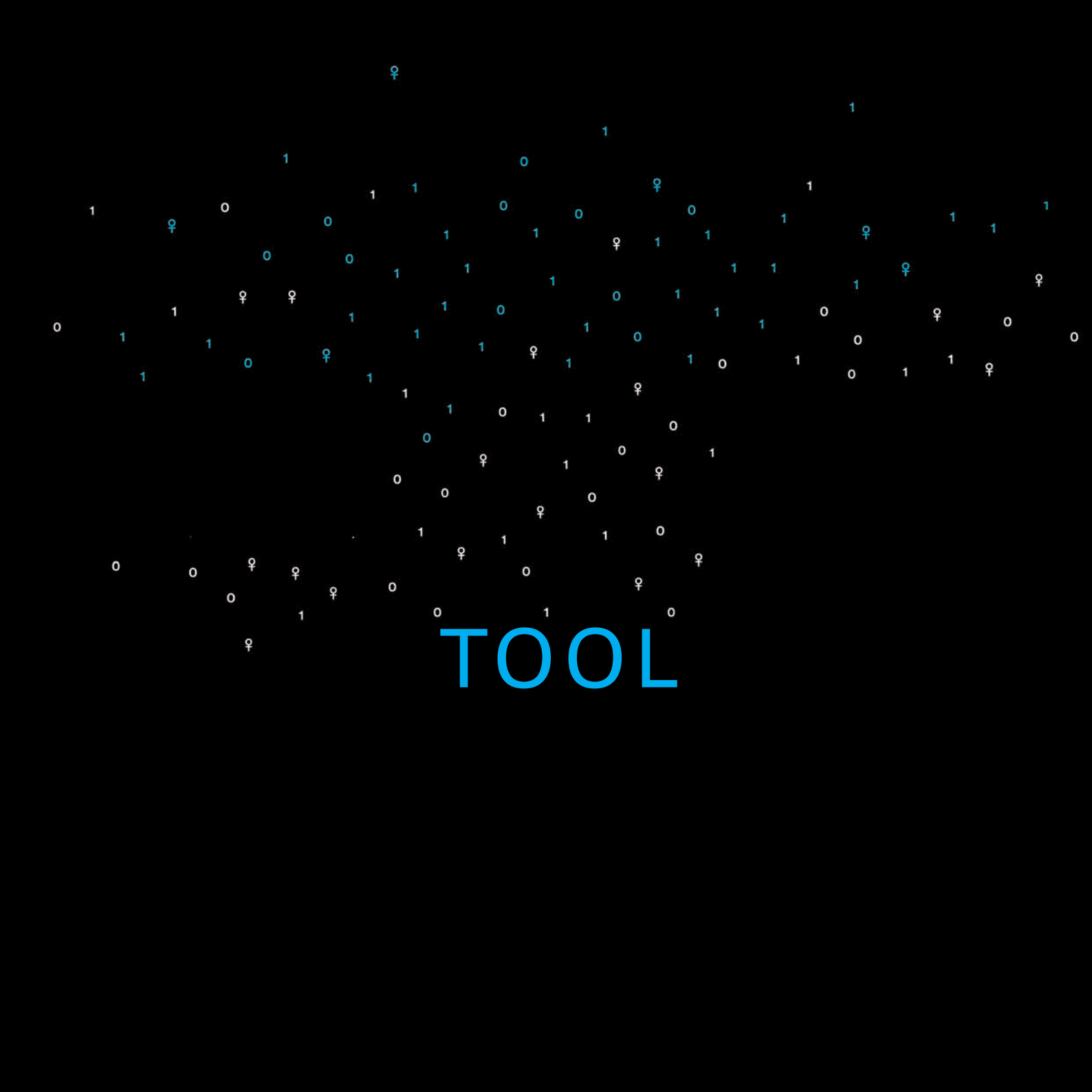
We identify cross-cutting themes and make connections across individual works that were not previously visible—these are highlighted as keywords in blue in the catalogue sidebar. Importantly, we also raise issues and questions for future consideration. To this extent, the themes of tool, toy and companion are considered not as classifying categories, but rather nodes in a fluctuating network that for a moment stabilise to give form and boundary, only to dissolve again when perspective is shifted, and where slippages, overlaps and intersections emerge.

The exhibition functions as a living laboratory, where experimentation and collaboration are encouraged between exhibitors, students, researchers, industry, and community. The living laboratory opens up the exhibition for visitors to actively and physically explore ideas, prototypes and processes through in-person and online workshops, and to observe robots in motion, design in action and real-time fabrication.

SHErobots features finished works and works in process. It also is a work in progress, with the intention to continue the discourse, exhibit internationally, and most importantly, to expand from a female lens and terminology to future iterations that acknowledge diversity through representations of indigenous and queer contributions. It is our ambition to enact this exhibition as a platform for engagement with ongoing research and creative practice into contemporary robotics, as well as seed new opportunities, collaborations and intergenerational mentoring for female voices leading the disruption into traditional robotics practice.

[1] In the conceptualising of the SHErobots exhibition, we deliberately chose to foreground women and the female perspective. In doing so, we are not seeking to entrench the gender divide between male and female. We acknowledge and support gender diversity and fluidity. The feminist spirit of enquiry underpins the curatorial approach, where we seek to challenge existing structures of gender power inequity by making visible and elevating the work of women, and highlighting the unique perspectives that women bring to the field.

[2] STEM: Science, Technology, Engineering, Mathematics. STEAM expands on STEM by including A for Arts, with acknowledgement and advocacy that the arts and creativity is a vital component of innovation.


TOOL

TOOL

By Dagmar Reinhardt

Industrial six-axis robotic arms have been integrated across advanced manufacturing, fabrication and construction, and used as tools for the production of module or component parts in novel construction systems. These robots enable a direct, tangible translation of design into production commands. Robotic arms support work processes where actions can be programmed, tools mounted, and where sensor feedback allows interaction with materials and workers. Whereas robot programming (machine code that determines the robot's moves and actions) has focused on the result of the work process—such as robotically laying a brick wall or cutting timber elements, in recent years, designers and architects have started to explore new methods and tools, different material applications, or even human-robot interfaces.

Consequently the robot exceeds its origins as a (physical) tool in becoming a tool through which new ideas and concepts can be brought to life. Introducing a six-axis robot to weaving, carving, tracing or cutting, expands traditional craft, where homo faber (wo/men the maker) is opening new landscapes of possibilities—in stereotomic masonry, timber assemblies, fibre threading or clay composite printing. Female roboticists represented in *SHErobots* invent and discover with industrial robots. Their research uses robots for material explorations; new material ecologies; building onsite and in outer space; communal upskilling; making their mark in industry, construction and community.

Tool
Tooling process

Making
Craftsmanship
Hand
Dexterity
Tacit knowledge

Endeffector
Robot axis
Workspace
Robotic reach

Female practitioners extend and deepen standard robotic makers' perspectives, and in turn, addresses alternatives. They question habitation on earth, or even in outer space. What are the resources that are available to us? What material morphologies and structural performances, what building techniques and details come into reach through the close coupling of computational design intent and workflows to advanced manufacturing and fabrication by robots? Works displayed in *SHErobots* stimulate a contemporary architecture and design discourse on the environment, resources, material capacities, community and habitation issues.

Cellulose Enclosures (Gabriella Rossi and Mette Ramsgaard Thomsen, 2021, p20) investigates bio-based robotic 3D printing with cellulose-reinforced bio-polymers, encouraging ecological and sustainable considerations to enter the architectural fabric. Biogenic materials, as this work suggests, counteract existing industry standards and codifications, and are abundant, inexpensive, and renewable bio-based materials. Understanding resource limitations paves the way for a return to natural building materials that can be reused and repurposed, time and again, within ecological cycles. Endlessly variable, the delicate, constructed lattices showcase a porous membrane structure as an alternative to common building elements. Can we continue to 3D print internal and external structural systems? Could plant and animal specimens be nourished from these fibre-works and continue to cohabit onto them?

Bio-cyber-physical Planetoid (Henriette Bier, 2020, p26) develops habitats for plants and animals to be deposited in urban deserts, in support of multi-species futures and more-than-human environments. Geared towards autonomous development and the reintroduction of complex and differentiated biodiversity in what can be considered the urban wastelands of contemporary cityscapes, these pods bring new life in the form of seeds and provide nourishment, water retention and shelter for the delicate growing

life. Through centuries, women have been hunters, gatherers and collectors, gardeners, carers, keepers, and guardians for greenery and livestock. This female robotic `gardening' practice caresses seedlings and small animals in customised crevices and folds. When the robot acts as a gardener, what long term custodianship over centuries could be enabled by an ongoing data feedback? What specific, localised and discrete strategies become available for technology that addresses shifts in temperature change or precipitation?

Close kin to adobe structures, *TerraFab* (Kate Dunn and Charlotte Firth, 2022, p30) radically changes current 3D printing practices to upscale for an accessible and affordable housing market. Their approach is based on material explorations that test diverse mixes of clay aggregates taken directly from the surrounding environment in a zero-waste approach. Materials are customised into 3D printed solutions for inhabitation that become part of the landscape from where the raw material stems.

Similarly, the dynamic capabilities and fluid material deposition of concrete are explored in new strategies of plastic formwork expressions through motion, such as the robotic slip forming process explored in *Smart Dynamic Casting* and the vertical printing-in-motion *Robotic Plaster Spraying* (Ena Lloret-Fritschi and Selen Ercan Jenny, p32) that use the ubiquitous concrete for expanding limitless shapes.

Building from ancient material forming practices, the power of computational code coupled with advanced fabrication protocols serves as platform for designers and architects to develop capacities for circular material practices. This demonstrates a way to develop building systems that use resources in direct vicinity. As a family grows, could a community 3D print additional rooms with each new member?

Robotic fabrication and advanced manufacturing can give important impulses for communities—in forms of upskilling, embedding unskilled labour, and offering potential for co-design and co-construction for gender-diverse workers across all age groups. *Block West: Discrete Automation for Community-led Housing* (Mollie Claypool, Claire McAndrew, Melissa Mean, 2020, p34) discusses a discrete building system of robot supported timber construction that functions akin to a Lego structure—endlessly expandable, simple to connect and construct, and thus giving power back to community and neighbourhood. Can a robot help construct a house? What new owner-builder scenarios are enabled by intelligent and fabrication-aware building systems?

Enabling communities of practice to work with industrial robotic arms is a pioneering work that the Association for Robots in Architecture (Sigrid Brell-Cokcan, 2011, p36) has developed. Connecting to computational design environments through KUKAlprc enables access to robot motion and control, which has laid the foundations for process innovations and rethinking of standard building practices. Today, even remote control of robots has become possible through these software developments. What other interfaces or daily practices can be considered in the creative process between human and machine?

Industrial robotic arms can be considered an enabler technology—lending precision, resilience, and strength to the worker. *Robotic Stone Sculpting* (Shayani Fernando, 2016, p40) is a clear demonstration into how a typical male dominated (for male body powered), traditional work domain can be overturned to make way for female aspirations. Robotic carving of sandstone into discrete interlocking modules demonstrates how complex stone vaults can be fabricated and executed in a quarry context with diamond saw technology mounted on a six-axis industrial robotic arm. The ability to computer simulate force flows through the structure highlights

opportunities for women and girls trained in STEM to enter a to-date male dominated field. Can tasks, finally, be equally distributed between gender diverse and differently abled workers through support of robot technology that in the true sense of the word "does the heavy lifting"? What new expressions of manual labour can we identify in collaboration between humans and robots?

Moving from robotic stone fabrication to interlocking stone elements, *Printsugi* (Nadja Gaudillière-Jami and Max Benjamin Eschenbach, 2022, p42) suggests that no matter the size, dimension or shape of a stone, each can be repurposed as a raw material. Working directly on and onto the site, the work proposes a building system that establishes datasets for elements of fibre or mineral origin (logs or stones) and incorporates these into hybrid assemblages by 3D printing the bespoke voids between matching sets, thereby localising and securing the elements into an additive structure of wall or tower elements. Significantly, this approach highlights a future potential for considering any (stable) element as a usable resource that can be integrated into an open system of construction. Coupling this open system of scan-to-3Dprint-to-assembly, robotic composition of raw materials could be produced in the open and wild, with access to raw materials that could be stitched and patched into constructions of unique, multi-material, diverse architectural spaces. What are the new rules for a continuous database and ongoing constructions—a flotsam and jetsam of architecture?

Robotic arms can be programmed to follow a simple line drawing that translates into an explicit movement of a tool for fabrication—such as line traces on a surface, the deposition of material in clay or fibre, or a line of cut in stone. Multiple lines of robot movements with threads of carbon fibre building onto each other suggests another riff on traditional female practices, reminiscent of the craft of weaving yarn into textiles. *Systems Reef 1.0: Robotic Carbon*

Fibre Weaving (Dagmar Reinhardt, Ninotschka Titchkosky, Chris Bickerton, Rod Watt, 2019, p44) uses an industrial robotic arm to weave a piece of ceiling infrastructure in a workplace environment. The double layered structural lattice of multiple spun carbon-fibre threads cured in a resin bath, provides centre points in the ceiling topography that enable flexible workspace scenarios for changing team constellations. In Greek mythology, Ariadne's thread, Arachnea's weave, is the storytelling of female weavers that enable shelter. Could a robot continue to weave temporary spaces that frame our daily interactions and exchanges? How do we unfold our yarns with the weaving trajectories and moving choreographies of robot motions?

Carbon-fibre components also form the context of *Robotic Manufacturing of Fibrous Structures in Space* (Lauren Vasey, 2019, p46), a work that trials fibre-based in-situ robotic fabrication processes for lunar habitats, whereby an astronautical robot worker prepares living environments prior to human arrival. Can robot technologies enable nomadic practices that ensure the survival of humankind, in conditions where space-travel remains a viable alternative?

Cellulose Enclosures
Gabriella Rossi and Mette Ramsgaard Thomsen
2021
3D printed cellulose-reinforced biopolymer
1180L x 780W x 150D mm
Image credit: Anders Ingvartsen / CITA

Cellulose Enclosures

Gabriella Rossi and Mette Ramsgaard Thomsen

I

\robotic 3D printing
\bio-materials
\material practices

\predictive modelling

\democratising tools

Bio-based materials, coupled with smart robotic fabrication, promise a new regime in architectural material practices, moving us from the increasingly limited resources of the geosphere to the abundancy of the biosphere. In this installation we examine how robotic 3D printing can be used to steer cellulose-reinforced bio-polymers into architectural screens. We develop digital workflows informed by the fabrication system, guided through human design input, and powered by data and predictive models. The piece brings together joinery and cross-bracing in an integrated tectonic logic, which showcases a new design aesthetic specific to unruly bio-based materials.

Image credit: CITA

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Laura Hochegger
Ayoub Lharchi
Paul Nicholas
Martin Tamke

External Collaborators:
Anders Egede Daugaard
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University of Denmark)
John Harding (University of Reading)

Essay: **Cellulose enclosures**

Smart robotic manufacturing for heterogenous biomaterials

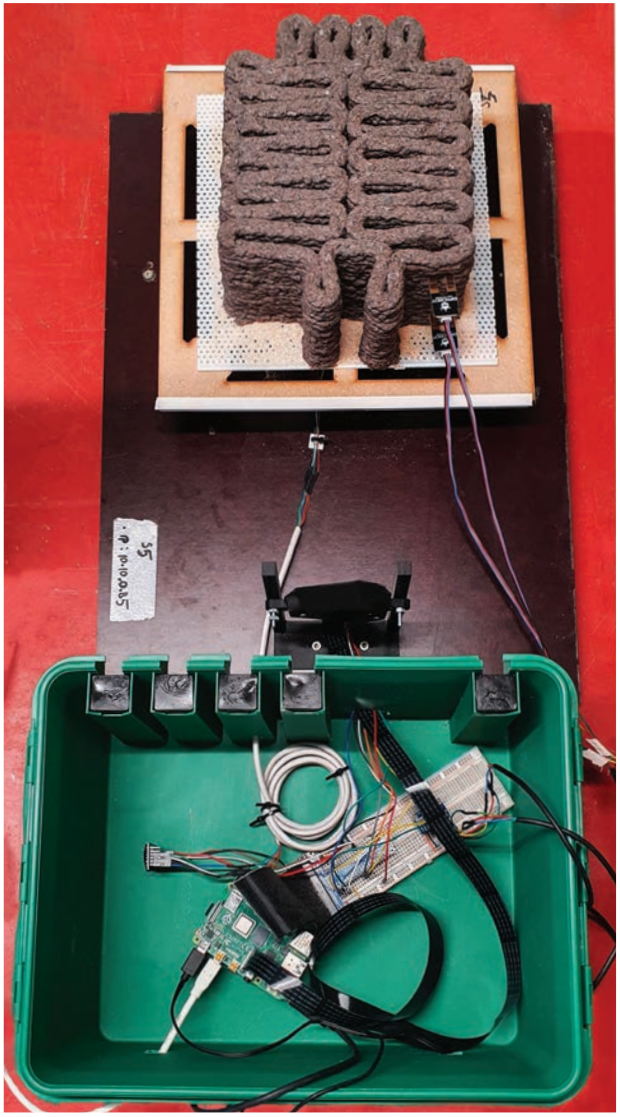
By Gabriella Rossi and Mette Ramsgaard Thomsen

Sustainability challenges our standard architectural material practice. Construction's impact on the climate crisis through carbon pollution and material overconsumption pushes us towards a fundamental rethinking of the way we design and produce our built environment. Not only is our choice of materials challenged, but also the way we understand their properties and behaviours during their lifespans, and how we engineer fabrication processes for them. For decades, industrialisation has focused architectural production on materials gained from the geo-sphere that present standardised behaviours and hold poor end-of-life possibilities. Standardised materials are shaped into standardised components, that are then assembled into standardised spaces. Quality assurance is overseen by material grade labels, ISO certificates, and overall building performance. Entire building codes and construction regulations are built on top of this certification system, with materials that are static, firm, and stable. But is there an alternative to this system we have ourselves created? Can we think of an architecture based on biogenic materials instead?

Image credit: Anders Ingvartsen / CITA

Finding ways of working with bio-genic materials that are inherently regenerative and biodegradable is an important step for future sustainable building practice. Biogenic materials are composites—part fibres, part polymer chain—and often have a hygroscopic relationship to water. While they provide a smaller embodied carbon footprint, they come with increased anisotropy[1] and heterogeneity, which makes them difficult to control, when compared to standard industrialised materials. Cellulose, our material base, and one of many abundant, inexpensive, and renewable bio-based materials can be mixed with different binders, fibre reinforcement and fillers into 3D printable pastes. Once printed, these cellulose-reinforced pastes undergo a two-stage hybrid fabrication process presenting an initial rapid forming with the extruder head, followed by a slower curing and hardening phase. The curing phase is characterised by the evaporation of the paste's water content, allowing it to acquire strength properties but resulting in large-scale shrinkage and warpage of the printed geometry. Controlling the discrepancy between wet and dry state is the key challenge when 3D printing with this class of materials. A smart integrated design-to-manufacture workflow is needed to be able to engage with these materials.

For architects, digital technologies, particularly CAD/CAM and robotic fabrication have become a principal interface to, and enabler of, material practice, especially within the circles of academic research and advanced industry. Robotically manufactured architectural elements allow for a 6-axis (or more) freedom that cannot be presented through other manufacturing methods, and therefore create a new tectonic expression addressing different levels of perception and detail. Open-source tools and plugins, such as RobotsIO, Hal and Machina, enable the designer to generate thousands of robotic instruction lines from a geometric model. This has led to a significant portion of the robotic fabrication projects we have seen over the last decade to be focusing on formalistic customisation, which comes for free thanks to the automation of the code process. But can robots do more?
Shifting our understanding of the robot from it being just a complex and efficient positioning system to an integrator of data flows can extend our



Cellulose Enclosures
Gabriella Rossi and Mette Ramsgaard Thomsen
2021
Cellulose-reinforced biopolymer, sensors
Image credit: CITA

affordances within the making process. The focus within robotics moves from the steel hardware to the versatile software, which is programmable and augmentable with other sensors and algorithms. This allows us to leverage not just the geometric bespokeness, but to work with bespoke non-standard materials such as cellulose-reinforced biopolymers and other biogenic materials. Software integrations linking robots to sensing, data logging and predictive algorithms allows us to use robots as true intelligent fabrication systems. Design is no longer limited to that of the artefact itself, but rather the system, from which the artefact emerges. Data, materials, models and practices, all become elements of design for which the architect is in charge. New technologies such as Machine Learning allow for on-the-fly predictions and steering of the robotic process, enabling real time adaptation, shrinkage compensation and recipe change and fibre direction grading. This creates artefacts with attributes unique to non-standard biomaterials.

Proposing these new data-rich design workflows and smart robotic fabrication pipelines can catalyse an increase in biomaterial adoption, given that their complexity can be accounted for. However, while the knowledge gap needs to be closed by developing and disseminating this new material paradigm, the larger risk appetite gap needs to be addressed to implement these technologies beyond the lab environment, and into an ever-sceptical construction industry. Democratising access to these new tools and training on the workflows is key for sustainable, impactful, equal and fair technological development.

[1] Something that is anisotropic changes in size or in its physical properties according to the direction in which it is measured. Cambridge Dictionary.

Bio-cyber-Physical Planetoid
Henriette Bier
2020-21
Biopolymer
700 mm diameter
Image credit: Robotic Building Lab, TU Delft

Bio-cyber-Physical Planetoid

Henriette Bier

I V

\robotic 3D printing
\biomaterials
\material practices

\circular economy
\microclimates
\human and
more-than-human

The *Bio-cyber-Physical (BcP) Planetoid* is a project resulting from multi-disciplinary collaboration between Landscape Architecture (LA) and Robotic Building (RB) at TU Delft and various academic and industrial partners. It presents minimal urban interventions that stimulate both biodiversity and social accessibility of residual places. These interventions aim to help existing life in the specific location by encouraging development of biodiversity, water management and social interaction. The *BcP Planetoid* is robotically 3D printed using wood-based biopolymer and is 0.7m in diameter. Hence, it can be easily placed in various locations, where all human and non-human agents are invited to engage in socio-technical interactions.

Credits
Team RB:
Henriette Bier
Arwin Hidding
Max Latour
Vera Laszlo

Team LA:
Pierre Oskam

Collaborators:
Hamed Alavi and Denis Lalanne (UniFri)
Klaus Starnberger (Tokencube)
Arwin Hidding, Jasper Menger, and Rene Ritmeijer (3D Robot Printing and Dutch Growth Factory)

With its cavernous design, the *BcP Planetoid* offers a protected environment for hosting earth balls with seeds that develop into plants, as well as animals and sensor-actuators. If the natural systems consist of (i) plants such as dandelions, chamomile, and poppies, (ii) insects such as butterflies, dragonflies, bees, and (iii) small animals such as snails, hedgehogs, and rodents, the sensor-actuators focus on monitoring and communicating with the environment and its users.

The process involved Design-to-Robotic-Production and -Operation (D2RP&O) methods developed in the RB lab, since 2014. It links computational design with robotic production and operation and advances robotic and user-driven building operation in both physically built environments and building processes.

In the presented project, D2RP focused on 3D printing, while D2RO techniques were implemented for the sensor-actuator systems integrated in order to track microclimates within and around the planetoids, and to encourage human and non-human agents to interact. The interaction includes activities such as (a) monitoring plants, insects and animals, and (b) involving users with the goal to engage neighbours and passers-by with the planetoids and their environments, which go through several stages of development and transformation from bare planetoids to overgrown with plants. The main actuation is in the form of mobile application notifications informing the users about the emerging activities around the planetoids or the need for their action (e.g., watering the plants).

Variable Stiffness
Henriette Bier, Arwin Hidding (TU Delft)
in collaboration with 3D Robot Printing
2017-18
Robotic 3D printed thermoplastic elastomer
Still from Video documentation (2min)
Image credit: Robotic Building Lab, TU Delft

Bio-cyber-physical Planetoid
Henriette Bier, Arwin Hidding, Max Latour,
and Vera Laszlo in collaboration with Pierre
Oskam (TU Delft) and UniFri, Tokencube,
Dutch Growth Factory, 3D Robot Printing
2017-18
Robotic 3D printed biopolymer, climate and
movement sensors
Still from Video documentation (2min)
Image credit: Robotic Building Lab, TU Delft

Rhizome
Henriette Bier, Arwin Hidding, Max Latour,
Fred Veer and Vera Laszlo (TU Delft) in
collaboration with ESA and Vertico
2017-18
Robotic 3D printed concrete
Still from Video documentation (2min)
Image credit: Robotic Building Lab, TU Delft

TerraFab
Kate Dunn and Charlotte Firth
2022
Soil waste from sand mining, sand, hemp fibre
Dimensions varied
Image credit: Kate Dunn

TerraFab
Sustainable 3D Printed Housing Solutions

Kate Dunn and Charlotte Firth

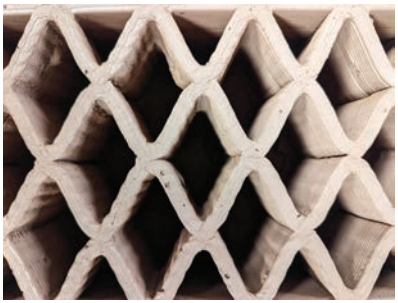
M V

\robotic 3D printing
\material practices
\design variability

\circular economy
\sustainable materials

This research investigates the automation of earthen construction using 3D printing to provide zero waste, sustainable alternatives for housing construction in response to climate change, supply chain issues and the housing crisis. Earthen construction such as mud brick, rammed earth, and adobe have been utilised for centuries for housing and to this day, one third of the world's population live in homes constructed from earth materials[1].

3D printed sustainable housing can offer accessible affordable housing solutions while reducing reliance on skilled workers, reducing greenhouse gas emissions, and improving the productivity and sustainability of Australia's Architecture, Engineering and Construction industry. The *TerraFab* project explores robotic 3D printing, computational design for form finding, customisation and optimisation; material development using site sourced materials, and integration of natural fibres such as hemp fibre to improve material tensile strength.



Credits
Collaborators:
Matthias Hauesler
Alex Tohidi (UNSW Masters student)
Arno Zhang (UNSW Masters student)
Mohammed Gomaa (RMIT)

This project is supported through UNSW Design Research Fellowship Funding, UNSW Design Futures Lab UNSW ADA.

[1] Earth Building Association of Australia, 2022.

Robotic Plaster Spraying
2018-2022
Image credit: Gramazio Kohler Research, ETH Zurich
Photo: Selen Ercan Jenny

Credits
RPS in cooperation with:
Robotic Systems Lab,
Autonomous Systems Lab
and Chair of Geosensors
and Engineering
Geodesy, ETH Zurich

Collaborators:
Selen Ercan Jenny (project lead), Dr. Ena Lloret-Fritschi, Eliott Sounigo, Ping-Hsun Tsai, Valens Frangez, Philippe Fleischmann, Luca Ebner

Sponsors:
HILTI AG, Giovanni Russo AG

Smart Dynamic Casting
2012-2018
Image credit: Gramazio Kohler Research, ETH Zurich
Photo: Ena Lloret-Fritschi

Re-thinking Formwork for Sustainable Construction

Ena Lloret-Fritschi and Selen Ercan Jenny

V

\robotic casting
\material practices
\rethinking concrete

Credits
SDC in cooperation with: Prof Dr. Robert J. Flatt (PI), Amir R. Shahab , Prof. Hans J Hermann, Linus Mettler, Department of Civil, Environmental and Geomatic Engineering Institute for Building Materials, ETH Zurich, Prof. Peter Fischer, Department of Health Sciences and Technology -Institute of Food, Nutrition and Health, ETH Zurich

Collaborators:
Ena Lloret-Fritschi (project lead), Andreas Thoma, Ralph Bärtschi, Thomas Cadalbert, Beat Lüdi, Orkun Kasap, Maryam Tayebani

Concrete is one of the most used materials after water, with a substantial environmental impact, although its embodied carbon per unit volume or mass is low when compared to most alternatives. Along with its broad availability, good strength, durability and versatility of concrete means that it will remain a material of choice, although better technologies are required to use it more efficiently. Structurally optimised building components are such a means that could save about 50% of material, yet these are presently too expensive to produce due to non-standard formwork. In this context, Digital Casting and Spraying Systems (DCSS) have advanced material control strategies for cementitious material processing, where digital control enables rethinking or even eliminating formwork systems. Our work presents cutting edge fabrication processes that highlight the use of dynamic, ultra-thin or stay-in-place formwork systems and robotic plastering for producing bespoke and standard surfaces that devoid formwork.

Smart Dynamic Casting (SDC) is a continuous robotic slip forming process for prefabricated material optimised load-bearing concrete structures. In this automated process a dynamic formwork significantly smaller than the structures produced is continuously moved and filled with concrete, in a velocity enabling the shaping of the concrete in the delicate phase when it changes from a soft to a hard material.

Robotic Plaster Spraying (RPS) is an adaptive, thin-layer, high resolution, spray-based, vertical printing-in-motion technique—for automating plastering on-site, in one integrated step, without any formwork, support structures or subtractive steps (i.e., troweling for shaping or smoothing), thus minimising waste. Plasterwork with RPS exceeds a standardised application by introducing new degrees of design freedom through digitalisation.

Block West
AUAR Labs
with Knowle West Media Centre
2020
Image credit: NAARO

Block West

Discrete Automation for Community-led Housing

Mollie Claypool, Claire McAndrew, Melissa Mean

V

\construction automation
\assembly

\upskill of labour
and workforce
\empowerment

Against the backdrop of a government that underfunds affordable housing, new collaborations with research labs and community groups have reclaimed local housing production in Bristol, UK. Under the guidance of research laboratory AUAR Labs from The Bartlett School of Architecture, UCL and citizen-led digital arts organisation Knowle West Media Centre (KWMC), the local community in Knowle West, Bristol `levelled up' to reclaim the means of design technology and construction automation, by entirely codesigning, fabricating and assembling their own housing prototype. Called *Block West*, the housing prototype is built out of 145 discrete, lego-like timber blocks and was assembled by the community in less than two weeks.

Credits
Mollie Claypool
Melissa Mean
Claire McAndrew
AUAR Labs, The Bartlett
School of Architecture with
Knowle West Media Centre

Construction Robotics: ROBETON
Sigrid Brell-Cokcan
Image credit: Chair of Individualized Production

Programming Robots

Sigrid Brell-Cokcan

V W

\computational design
\robotic fabrication
\robot programming

\software development environments
\open-source platforms
\cloud remote control
\interfaces

Connecting robot control programs to the software environments that architects and designers work in is a basis for working with industrial robotic arms. Since 2011, The Association for Robots in Architecture (RiA)—architects Sigrid Brell-Cokcan and Johannes Braumann—has been developing software for the integration of robots as a code that extends from standard 3D modelling (McNeel Rhino) and scripting software (GH Grasshopper), shared this work environment, and created an open platform for the creative use of innovative fabrication with industrial robots. In 2011, Robots in Architecture presented KUKAlprc, an extension for Grasshopper that, for the first time, enables robot control from within architectural software.

In continued development, the initial software has been extended to allow workers to control robot work processes over a distance, through KUKAlcrc Cloud Remote Control (CRC). This allows users to control robots, monitor processes and adjust toolpaths from the safety of their desks, and allows teams to remain safely at a social distance, yet collaborate closely on automated construction production. Importantly, KUKAlcrc increases accessibility to global robot production and adds layers of Industry 4.0 device communication and artificial intelligence to path planning.

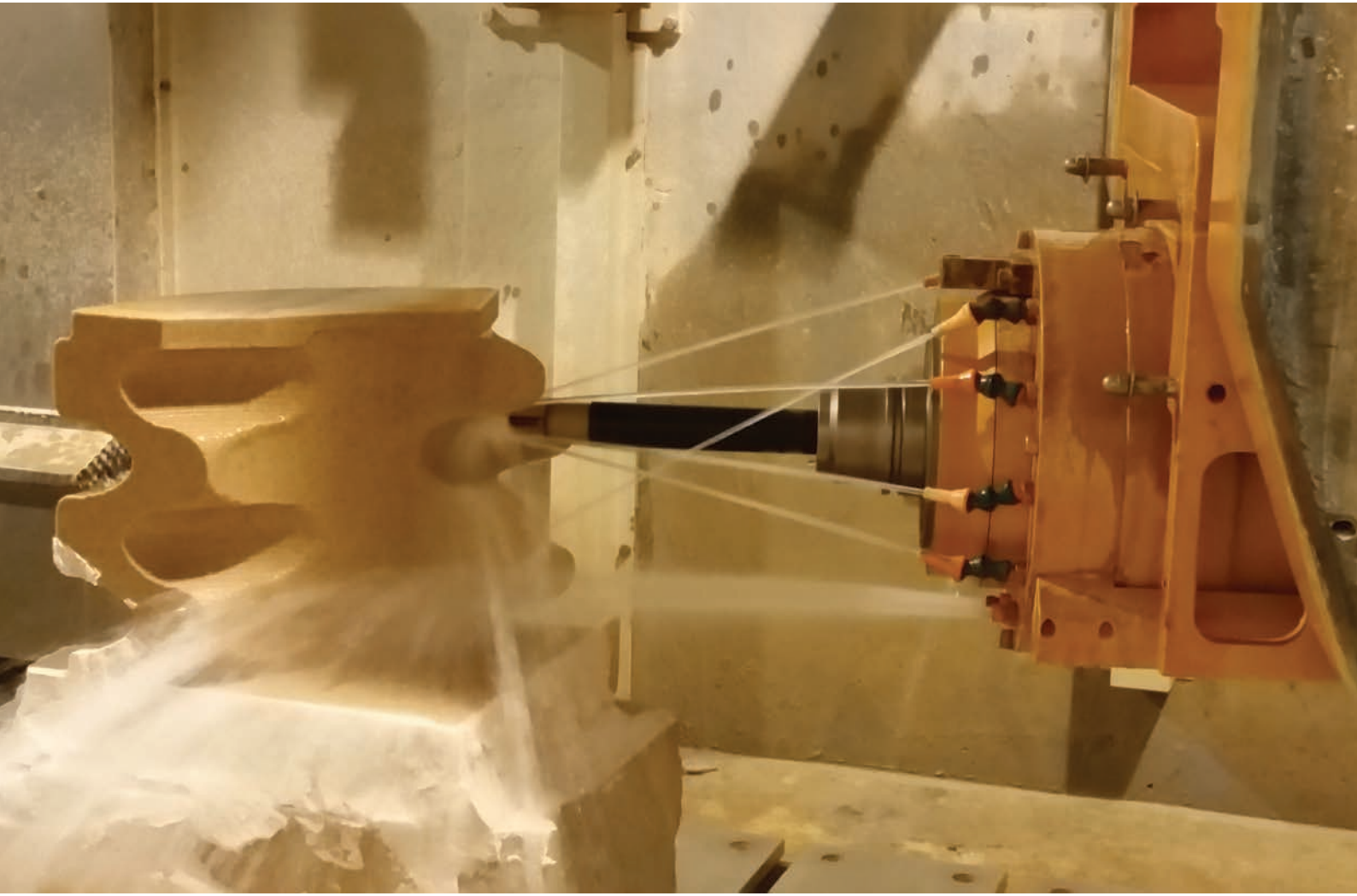
Credits
Association for Robots in Architecture, Johannes Braumann

Chair of Individualized Production, RWTH Aachen
Ethan Kerber, Sven Stumm

In order to create an environment that allows the efficient, individualised production of lot size one, new and user-friendly methods for human-machine interaction are increasingly required to be developed. The Chair of Individualized Production (IP) is an institute founded within RWTH Aachen (Germany) by Brell-Cokcan that focuses on the use of innovative machinery in material and building production. Researchers from different fields of robotics and building production collaborate here to streamline the necessary digital workflow from the initial design to the production process; shaping the construction site of the future via intuitive, easy-to-use interfaces.

A strong focus is the implementation of digital construction processes and advanced automation technology, together with production processes where digitalisation is the link between architecture, design, and civil engineering. To enable this research field, the institute develops new typologies for modularisation of parametric digital design and the integration of automation into building information modelling, management and construction. These innovations include interdisciplinary coordination planning, process modelling and production flow planning, where processes are combined with industrial engineering models to enable design-immanent automation. By combining design to production processes with human-robot collaboration, this research enables an information flow from idealised geometric modelling to predictive simulation of automated process sequences and online adaptation. Digital twins monitor online processes to data mine production for quality control and feedback on potential process improvements. Process simulation and optimisation of the construction process is based on single part production and consideration of global integration.

This pioneering work for robotic integration by the Chair of Individualized Production is further expanded into pedagogy (with an international Masters on Construction Robotics); dissemination (through the Springer Journal of Construction Robotics); and industry-academia interest groups such as the international consortia Center for Construction Robotics, where AEC companies integrate industry with scientific research and development to create the construction site of the future.



Wave Jointed Blocks
Shayani Fernando
2016
Sandstone
400 x 150 x 500 mm
Image credit: Shayani Fernando

Robotic Stone Sculpting

Shayani Fernando

M V

\stereotomy
\robotic stone cutting
\stone vaults

\work adaptation

Situated within the art of cutting solids (stereotomy) and the evolution of machine tools, this research investigates subtractive fabrication in relation to robotic sculpting of self-supporting stone structures. The waveform prototype joint design was developed through a process of iterative drawing, which was then parameterised in Rhinoceros and Grasshopper. One of the most significant aspects of this geometry is that it is made from `ruled surfaces' to accommodate fabrication methods with robotic wire cutting. As a comparison study into EPS foam blocks and natural stone blocks, two similar geometries were fabricated with Gosford quarries. This prototype demonstrates both potential for column and cantilever structural conditions. These two blocks of interlocking wave geometry were simplified from the initial three blocks proposed in the 3D model. They have a very similar workflow to the marble prototypes *Catenary-Tales* and *Archi-Twist* (fabricated in collaboration with the Digital Stone Project and Garfagnana Innovazione) in which a saw blade and CNC milling were used as the main machines to process the sandstone block. Each block at scale 1:2 weighed approximately 12-15 kg and took 4 hours with 3 tool changes each. Minimal hand sanding was applied at the final stage as a finer abrasive diamond tool was used specifically for the finishing. Furthermore, this research interrogates the role of the artisan in machine crafted architectural components.

Credits
Gosford Quarries
Wave Jointed Blocks in collaboration with Dr. Simon Weir, Dion Moult, DMAF lab, Sydney School of Architecture, Design and Planning, The University of Sydney.
Catenary Tales and *Archi-Twist* prototypes developed with the Digital Stone Project and Garfagnana Innovazione.

Printsugi Rock Tower
Nadja Gaudillière-Jami & Max Benjamin Eschenbach
2022
Rock, clay
195 x 262 x 643 mm
Image credit: Courtesy of artist

Printsugi
Matter as Met, Matter as Printed

Nadja Gaudillière-Jami and Max Benjamin Eschenbach

V

\resource assessment
\design workflows

\robotic onsite printing
\3D connectors

You're outside. You want to build. There's earth. There's twigs and logs. There's stones. There's all you need.

Our research proposes to leverage 3D-printing and computational design strategies to use matter as met, that is, matter as found on site, in building processes. Combined with a design method enabling disassembly and reassembly, this approach enables less transformation of the materials used and thus less energy consumption. It renders possible the use of resources without a brutal extraction process, and instead focuses on materials that are locally available.

We propose a design workflow in answer to these requirements, which starts with testing raw earth available on the site in order to devise a recipe for the raw earth to be 3D-printed. It is followed by the collection, sorting and 3D-scanning of other types of materials available on site, such as logs and stones. The resort to a computational design process enables placing these materials in the most relevant place within the shape that is to be constructed, and modelling connectors to link these pieces together. The connectors are then printed by using the recipe devised with a low-cost 3D-printer that is on-site or close-by, in order to remain as local as possible. Given the connectors are small-scale components of the structure, the 3D-printer can thus have a relatively small printing area. Finally, the structure is assembled by bringing together connectors and materials. The rock tower presented is the first prototype demonstrating this process and its potential for sustainable architecture.

Credits
Nadja Gaudillière-Jami
Max Benjamin Eschenbach
Digital Design Unit
Technical University Darmstadt
Germany

Systems Reef 1.0
Dagmar Reinhardt, Ninotschka Titchkosky,
Chris Bickerton, Rod Watt
2019
Carbon Fibre, 3D print
1700 mm diameter
Image credit: Courtesy of artist

Systems Reef 1.0
Robotic Carbon Fibre Weaving

Dagmar Reinhardt, Ninotschka Titchkosky, Chris Bickerton, Rod Watt

I V

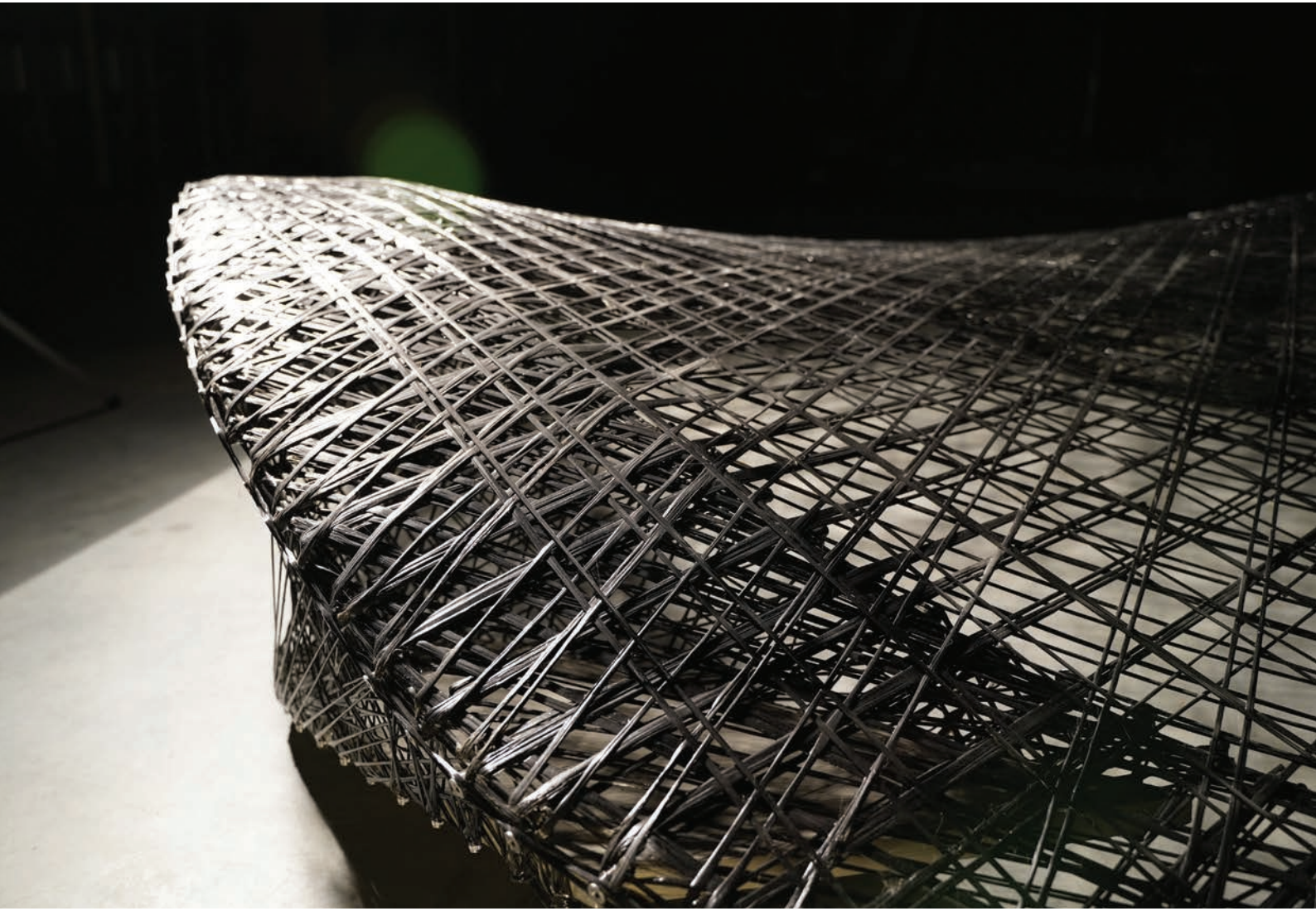
\robotic weaving
\onsite robotic constructions
\carbon-fibre

\industry 4.0
\work environments

Credits
The University of Sydney:
Dagmar Reinhardt, Dylan Wozniak-O'Connor, Rodney Watt, Lynn Masuda, Susana Alarcon Licona, Densil Cabrera, Christhina Candido, Maryam Houda, Adam Hannouch

BVN:
Ninotschka Titchkosky, Chris Bickerton, Mitchell Page, Mathew Blair, Paul Wintour, Suleiman Alhadidi, Farbod Fathalipouri, Nazgol Asadi, Sam Sweeney, Ross Seymour

Among current adoptions of standard industrial robotic arms for automation and mass customisation in the building industry, robotic fabrication is of interest for bespoke manufacturing and advancing mobile and onsite construction processes. The use of robotic arms can be of significance particularly where access and site conditions limit further construction of building elements to be inserted in an existing architectural fabric. The industry-academia collaboration project *Systems Reef 1.0* investigates development of robotic carbon-fibre weaving of an integrated ceiling structure in a workplace environment. This research explores the potential and viability for an integrated infrastructure that expands standard office-ceiling grid systems to support flexible workspace scenario and the agency of networked, dynamic and self-organising teams. To this extent, multiple soffit-hung, rotational and retractable data booms provide fibre-optic data, electrical cabling and integrated lighting. Through geometrically complex, fibre-reinforced building elements that are robotically manufactured onsite, a new distribution system for data and light can be provided to support individual and multi-group collaborations in a contemporary open-plan office for maximum flexibility.



Robotic Manufacturing of Fibrous Structures in Space
Lauren Vasey
2019
Basalt fiber with epoxy resin
2000 x 2000 x 6000 mm
Image credit: Lauren Vasey, Institute for Computational Design and Construction, University of Stuttgart

Robotic Manufacturing Of Fibrous Structures in Space

Lauren Vasey

V

\robotic weaving
\carbon-fibre
\mobile robots

\lunar habitats
\remote controlled robots

This study investigated fabrication methodologies for a fibre-based in-situ robotic fabrication process for a lunar environment. Through a collaboration with the European Space Agency (ESA), a concept was developed for a multi-robot, scaffold-free construction process based on precedent robotic fabrication methods developed at the University of Stuttgart. The study resulted in a thin hyperbolic shell prototype at 1 to 10 scale, built at the Fibr Gmbh production facility and permanently exhibited at ESA headquarters in the Netherlands.

Credits
Lauren Vasey
Professor Achim Menges
(Institute for Computational
Design and Construction)

Funding: Ariadna Study (ESA)
ESA: Hanna Laak, Aidan Cowley
Fabrication Sponsor:
Fibr Gmbh

ICD Support: Maria Yablonina,
Vaia Tsiokou, Sabine
Vecvagare, and others
Fibr Support: Mortiz
Dörstelmann, Ondrej Kyjanek,
Leo Balas, Elaine Bonavia,
and Fabian Kannenberg

Spoon, Drill, Knife, Hammer:
Tool Wall for Kitchen and Workshop
Dagmar Reinhardt and Lynn Masuda
2022
Kitchen and workshop utensils (spoon, ladle, knife, brush, dremel, punch, hammer)
Customised and 3D printed robotic end effectors
Image credit: Dagmar Reinhardt

Spoon, Drill, Knife, Hammer

Tool Wall for Kitchen and Workshop

Dagmar Reinhardt and Lynn Masuda

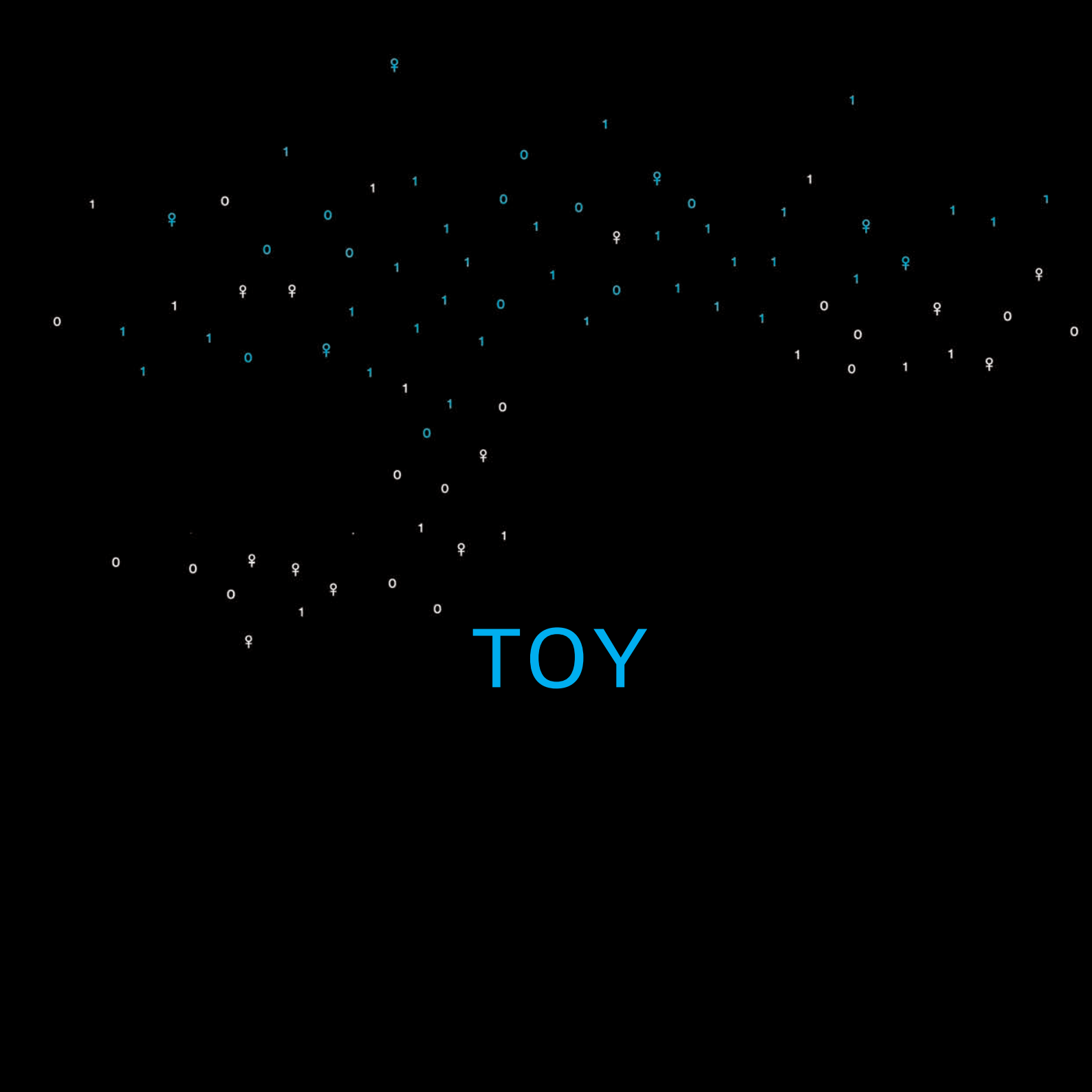
T R

\endeffector
\repurposing
\appropriation

Imagine a kitchen that might be a workshop, with a variety of different tools and processes taking place, which are more precisely differentiated by cold and hot stations and materials.

What is the nature of a domestic space in 2030? A place for food production and consumption? A makerspace with tools for crafting? A space where families create their stories around the different robotic processes, tools and materials? *Spoon, Drill, Knife, Hammer* explores existing tools from different countries and human scenarios of making and production, for mounting on a robot, such as standard kitchen utensils (including spoons, ladles, knives, pans) and standard workshop tools (drill, hammer, paintbrush, saw), documented here in the tool wall that is both library and archive. How does an industrial robot arm work with a human in close quarters, and with sharp or powerful tools? The research trials and errs through robot movement developed and adapted for kitchen or workshop contexts, including repurposing of tool and action sets, and innovating hybrid tasks that blur the boundaries between commonly associated traditional male or female domestic environments.

Credits
DMaF Lab, Sydney
School of Architecture,
Design and Planning,
The University of Sydney


TOY

TOY

By Lian Loke

Playing with robots conceptually involves a re-imagining, and often subversion, of traditional forms of robots, what they are capable of, and how they relate to humans. The term toy is used here to refer to works that `toy with' conventional stereotypes of robotics prevalent in feminist and artistic approaches, rather than the robot as a toy or plaything. It also speaks to notions of artifice, deception and subterfuge, where the surface presentation hides other motives or invisible forces.

Robots are also employed in game play or creative processes of designing, making, and fabricating where the robot is either subsidiary to supporting human creativity or developed as an equal creative partner. Thinking beyond human-centric robotics to the secret life of machines opens a parallel world in which robots are free to behave as they wish, no longer subservient to human desires. In this future scenario, the robota[1] is truly un-slaved to play.

Toy
Toying
Play
Creativity
Imagination

Simulation
Replica
Artifice

Deviation
Subversion

Project:GALATH3A (Gili Ron and Irina Bogdan, 2021, p56) in true feminist spirit calls into question who gets to create images and ideals of womanhood. They invert the Pygmalion creator myth of man creating woman by introducing an industrial robot into the traditional feminine practice of applying make-up, thus upending the normal constructs of gender and power. By allowing a robot to paint on a human face, orthodoxies of control and surrender, vulnerability and trust are brought into sharp focus.

Whereas the aesthetics of the short film for *Project:GALATH3A* depicts the robot applying swirls of luscious coloured paint onto the female face as canvas, the sister art film, *Code_red* (Lian Loke and Dagmar Reinhardt, 2021, p60) presents a more ominous and ambiguous image of human-robot relations. They explore affective qualities of robot behaviour by deliberately programming the expressive motions of the industrial robotic arm. How the robot moves, how fast or slow, in its approach to the `tethered' female in this encounter raises issues of trust and boundary breaching. When do we trust robots enough to allow them to touch our delicate skin, stroke, care and pleasure us?

The *Gynoid Survival Kit* (Elena Knox, 2016, p62) takes up this question with regards to the speculated life of a gynoid robot sex-worker, but from the perspective of the robot, not the human. The assumption is that in servicing humans (primarily males of the species), the boundaries of care, comfort and consent may be transgressed. Knox invents cunning objects of deception; on the surface they appear to be beautifully crafted jewellery, yet on closer inspection are revealed to be weapons of self-defence for the gynoid to use in threatening situations. An artificial eyeball conceals a dagger, a ring hosts a drone ready to fly off for remote communication, a necklace holds a poisonous gas cannister. An ethical and legal conundrum is raised here … what rights should robots have, will they have equal rights to humans, or will they be demoted to the status of toys for human play and consumption?

In contrast to robots with the capacity to touch and sense human skin that feels good to humans, *A Touch of Dexterity* (Heba Khamis, 2021, p68) pursues the classic quest for building robots with human-like capabilities, in this case, human-like touch. The innovative technology behind Khamis' tactile sensors enables a robot gripper to handle and manipulate all kinds of objects. The ultimate test is the game of asking a robot to hold an exemplar of fragility—an egg!

Returning to the robot for play, creativity and games, *Block Play* (Isla Xi Han and Stefana Parascho, 2022, p70) explores the creative act of improvisation. Their research is studying how a human and a robot can collaborate to place blocks in a pattern, moving beyond the pre-programmed scripts of industrial robots to open-ended, creative responses found in improvisation. As with any good improvisation practice, rules and constraints are the key to generating interesting creative ideas and interactions. Then again, breaking the rules can lead to novel and surprising outcomes. How far will the robot go to bend the rules to its own advantage?

Rule-based games underpin the concept for *RoboBlox* (Müge Belek Fialho Teixeira, Maryam Shafiei and Glenda Caldwell, 2019, p74). Inspired by the French Oulipo movement where mathematics and poetry were combined in an effort to generate poetry using structural constraints, *Roboblox* follows a similar approach in applying variations of computational patterns to generate what is known as a breeze block (a common mid-century building material and design element). What distinguishes their research-through-design approach is the intention to democratise design, by providing a game-like, creative process and interface for non-expert users to design and fabricate breeze blocks.

Care Protocols (Kathrin Dörfler and Romana Rust, 2019, p78) is an augmented reality (AR) mobile interface attached to a physical broom, where users are invited to care for hybrid virtual/physical spaces by sweeping virtual rubbish. The work speaks to hidden labour and an ethics of care. Dörfler and Rust are concerned with raising the status of maintenance tasks that are often overlooked in technology innovation (the disruptive male principle), and reframing them in terms of cyclical processes, care and regeneration (the healing female principle). On another level, the work links to critiques of cyber-physical systems and networks of robots, augmented reality, invisible processing, data, and how humans are implicated in the generation of invisible, cyber waste. "It's only digital" has hidden costs for the environment too.

A critique of labour and robot rights is explored in *Sisyphus (S)weeping* (Dagmar Reinhardt and Lian Loke, 2022, p80). An industrial robot is endlessly sweeping, stuck in an eternal loop of labour, much like the Greek myth of the same name. Is the robot performing the sweeping with any sense of pleasure, or care? Does it experience boredom, frustration, or a feeling of incarceration? Or is it simply a machine programmed to repeat, foregoing any claim of machine agency and robot rights?

Sisyphus (S)weeping is in dialogue with *Idle Hands* (Gili Ron and Irina Bogdan, 2022, p81), as part of the cross-contamination in the exhibition between robot concepts and robot researchers. In continuing the theme of labour and robot rights, Ron and Bogdan ask, what do robots do when humans are not around? In a mischievous and humorous vein, *Idle Hands* portrays two industrial robots off-duty, and speculates on robot behaviours when left to their own devices, no longer subservient to humans.

[1] The term *robota* was coined by Czech playwright, Karel Capek. Its original meaning is forced labour. Capek, K. 1920. `R. U. R.: Rossum's Universal Robots', Aventinum.

Project:Galath3a
Gili Ron and Irina Bogdan
2021
HD video, stereo, 2:37 loop
Image credit: Still, Courtesy of artist

Project:Galath3a

Gili Ron and Irina Bogdan

F

\human-robot relationships
\collaborative robots, cobots
\robotic touch
\trust

\body as site
\customisation of gender

PROJECT:GALATH3A is a design-research in human-robot close collaboration (HRC) using 3D-scans, sensors and UR5 robotic-arm. Humans are invited to partake in a "Game of Trust'' with a robotic-arm, letting it paint their faces. Facing the UR5 CoBot[1] unbound they are free to choose whether to stay put or walk away, depending on the degree of trust they feel with the machine touching their faces.

Speculating on near-future posthuman ties, we took up co-parenting a UR5 Cobot, naming her Gala (short for Galath3a[2]). In the spirit of Donna Haraway's "ironic political myth faithful to feminism, socialism, and materialism"[3], we chose putting on lipstick as the first essential introduction of Gala into womanhood. Why teach a robot to put on lipstick? Makeup is synonymous with the commoditisation of women, the male-gaze and the image of perfection. Why teach your daughter to put on lipstick? We aim to expand the socially accepted norms of beauty. We shift away from intrinsic notions of perfection as seen in social-media and use digital tools to acquire a new gaze.

Credits
Created and developed by
Gili Ron and Irina Bogdan
Video Editor, Camera:
Matias Jeffs
Music: Zoe Polanski
and Oti Itzhaki

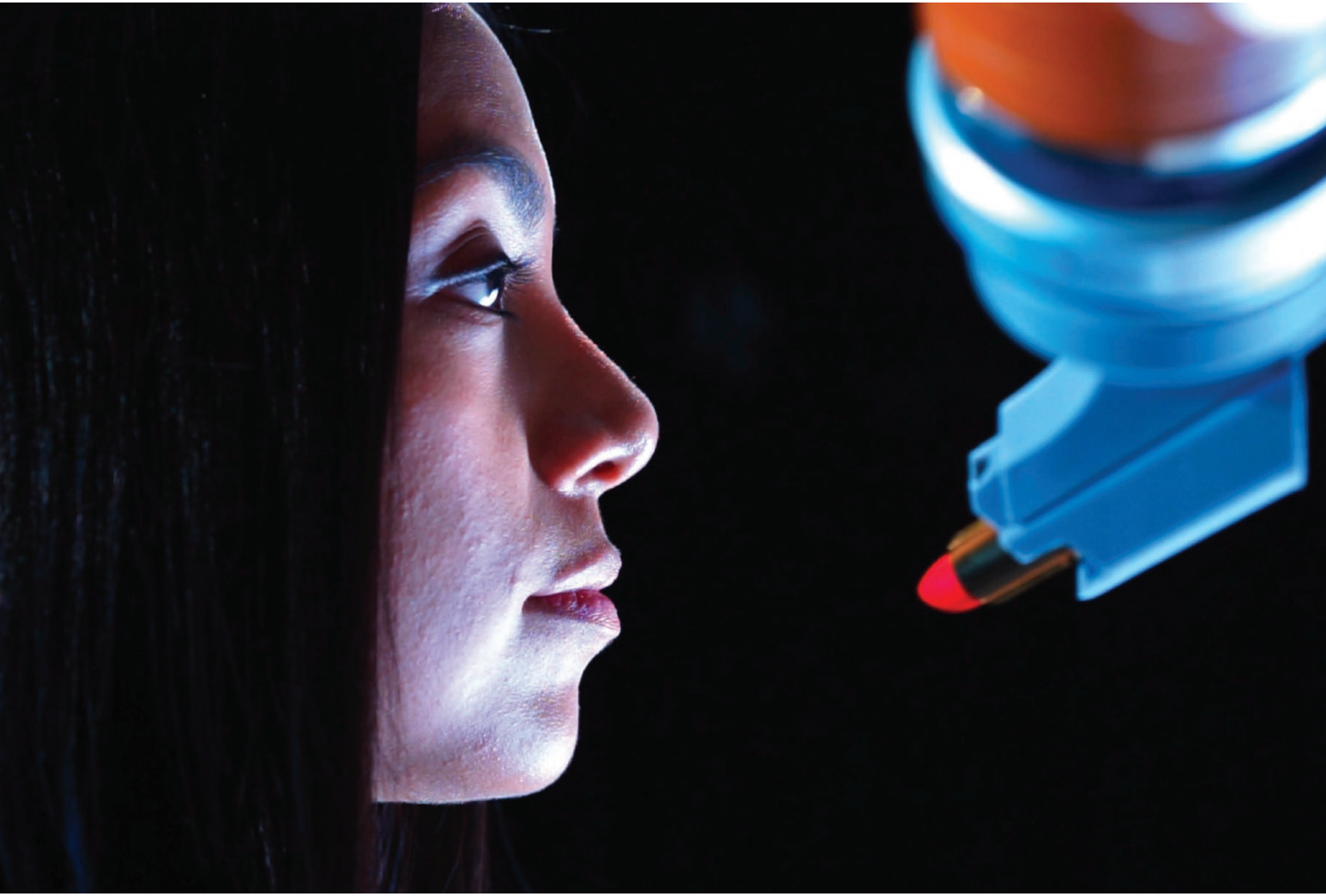
The work was performed and recorded at the Berlin Open Lab (BOL), Berlin University of the Arts (UDK, Berlin).

We propose an innovative approach: in a process we call *Robotic Mirroring*, human-gestures are studied, recorded and translated into machine tool-paths. With the robot as mimic, `mirroring' lets us ask questions about the nature of these behaviours: are they necessary? Should it be passed on? If so, how could we enhance it to empower women?

Machine vision and parametric design give way to seeing one's face detached from gender and seduction contexts. The digital transfer from a real face to a digital representation, translating bone-structure and skin texture into fields of intervention, opens up new aesthetics. A face is a canvas, colour is design and make-up is a field of opportunities. Drawing on skin and bones is very different from common numeric fabrication. The surface of the skin is uneven, bone structure requires different pressures, angles, speeds ... and then as a subject you have to stay in place. One must have trust.

Building trust is linked with familiarity, expectation, proof and consistency[4]. To gain human trust, we use simulated tests and repeated live tests to ensure the robot doesn't hurt a human or itself. For accurate performance, the robotic vision consists of photogrammetric 3D scans of the participants, meshed. The CoBot is coupled with bespoke end-effectors holding a range of brushes and sponges. Finally, tool-path planning includes human-like gestures and consists of soft touch. Make-up gestures recorded and translated into coordinates, angles and speed make up the robot's movement.

[1] A cobot is short for a collaborative robot. The term was first used in J. Edward Colgate, Michael A. Peshkin, and Witaya Wannasuphoprasit. 1996. `Cobots- Robots For Collaboration With Human Operators'.
[2] The project's name refers to the myth of Galatea: the image of the perfect woman created by sculptor Pygmalion, for his pleasure.
[3] Donna J. Haraway. 1991. `A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century', in Simians, Cyborgs, and Women: The Reinvention of Nature, New York, Routledge, 149-181.
[4] Simpson, J., & Vieth, G. 2021. `Trust and Psychology: Psychological Theories and Principles Underlying Interpersonal Trust'. In F. Krueger (Ed.), The Neurobiology of Trust (pp. 15-35). Cambridge: Cambridge University Press.



Code_red
Lian Loke and Dagmar Reinhardt
2021
HD video, stereo, 1:49 loop
Image credit: Still, Courtesy of artist

Code_red

Lian Loke and Dagmar Reinhardt

F M

\human-robot relationships
\collaborative robots, cobots
\robot plus sensors

\body as site
\customisation of gender
\warpaint
\personal rituals

The ritual of a woman wearing lipstick is at once a highly personal act of identity, yet common across cultures. What does it mean for a robot to replace the human hand in such an act? We apply a feminist approach to investigating how robots can collaborate with humans in personal grooming and bodily care towards a future where robots are ubiquitous in daily life. Our work addresses ethical issues of identity, agency, vulnerability and trust in human-robot relations. We explore these issues through cinematic film-making as provocations and speculative narratives.

Code_red is a video artwork that portrays a solitary female figure awaiting the painting of her lips in red by a robot. In what seems like a simple, perfunctory action sequence by the robot, through a series of images that are deliberately intense and ambiguous, we aim to unsettle the viewer and call into question the integration of a robot in cultural rituals of feminine grooming and presentation.

Introducing a robot into this highly personal ritual invites a critique of how biological and machine bodies could be reconfigured in the intimate zone of close contact. Deploying an industrial robotic arm is a defamiliarising tactic, intended to disrupt and open up thinking on how we weave robots into our daily lives and private, intimate acts. It is also part of our arsenal of creative practice of the disruptive feminine, a questioning of the construction of the universal female, with its culturally entrenched feminine modes of presentation.

Credits
Concept: Lian Loke and Dagmar Reinhardt
Cinematography and Video Edit: Paul Warren
Sound: Lindsay Webb
Performer: Susana Alarcon Licona
Robot technician: Lynn Masuda
Supported by DMaF, School of Architecture, Design and Planning, The University of Sydney

Drone Ring (from Gynoid Survival Kit)
Elena Knox
2016
Steel, plastic

Gynoid Survival Kit

Elena Knox

M

\gynoid
\sex work
\care

\self-protection
\robot rights
\intelligence
\sensing

Working from direct, applied research with existing gynoid robots, my artwork series *The Gynoid's Guide to Continuous Service* takes an empathic, speculative leap into a nascent personhood and its practical hazards, imagining what `life' is like for the sexually servicing gynoid, and how that `life' may be valued and preserved.

Within *The Gynoid's Guide to Continuous Service*, I continue to create a *Gynoid Survival Kit*. This kit comprises prototyped jewellery and accessories that may be covertly worn by a robot sex worker to ensure both its `personal' safety and sustained functional operation. These *objets* are speculative, as of course are android sex workers with any degree of individual or collective entitlement or autonomy.

Gynoid Survival Kit
Elena Knox
2016-
Bronze, glass, ink, linen, plastic, rhodium, silver, steel
Image credits: Courtesy of artist and ANOMALY

Essay: **Safeguarding the Sex Robots**

Elena Knox

excerpted from: 'Gynoid Survival Kit', *Queer STS Forum vol.* 4 (2019)

Robot sex workers, and cyborgian sex workers, will enter situations over which they will have no recognised or native control. In the course of their duties, they will be searched and screened, stripped and exposed. Possibilities of ambush and intervention are likely and real. Who will consider the occupational health and safety of a humanoid sex-work machine, or machine-hybrid?

The frontiers of robosexuality present untold opportunities to diversify sex, gender, and sexuality. They are vitally important in shaping future subjectivities. Nevertheless, the first cohorts of full-body android robot sex workers will be female-presenting, with conventional visual appeal, and costly. They will be designed, tested, and consumed primarily by affluent men in `developed' countries. Following rules of the entrenched patriarchal and socio-industrial complex, the initial robosex avant-garde will embody the fetishist representation of the gynoid (female-appearing humanoid) that is standard in both science-fiction and consumer capitalism: concomitant living computer, demure housemaid, revulsive corpse, and enigmatic erotic object.

Like living hostesses, robot hostesses are meant to make people feel pleasant, comfortable, empowered, and `at home'—partly through possessing no real threshold of dis/comfort themselves. The machine hostess is even more proficient than the human hostess in meeting this criterion. The erotic gynoid will be *indiscriminate* in service-provision in ways that a human sex worker cannot be. Though arguably less skilled and responsive, it will possess a work ethic that potentially `improves' on that of a human. It will call into question the boundaries of care, intercourse, and responsibility. It will be remarkable for its dissociation of discomfort from damage.

What can we learn from the predicament of the future gynoid sex worker? It is worthwhile to briefly consider the reported predicament of Samantha, a robo-sex doll presented as an artwork in the 2017 edition of Ars Electronica in Linz, Austria. Ars Electronica is an annual festival for leading-edge art, technology and mechanical development. Since 1979 it has attracted high-profile international producers to its exhibition program with its associated prize. Within this framework, Barcelona-based engineer Sergei Santos set up Samantha, a `sex robot' that his company, Synthea Amatus, had been developing, publicising, and selling. Before the five-day festival was over, the media was reporting that Samantha had been groped by festival-goers until it was broken and "heavily soiled". People roughly mistreated Samantha's breasts and limbs, breaking its fingers and causing other damage. Santos is quoted as saying that the public "treated the doll like barbarians". He had to remove the exhibit from its station and ship it back to Barcelona in a box, to be repaired and cleaned.[1]

Ars Electronica's[2] notes for the festival exhibit `Samantha' stated that the robot "seems to enjoy sex as much as the humans and responds differently according to how she is treated. … She likes to be touched … she wants to be touched and kissed on her fully functioning lips, the breasts and vagina to change her mode from family, to get to a point where she wants to interact on a sexual level, until she even has an orgasm."

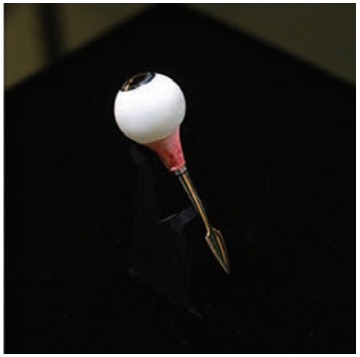
Incapacity Gas
poison gas cannister worn as decorative pendant or disguised among exoskeletal parts

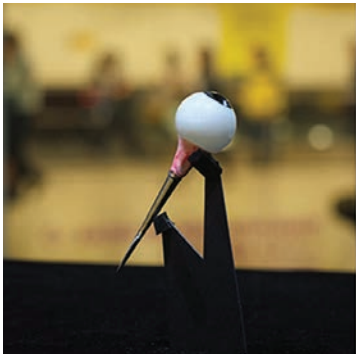
My Gynoid Survival Kit *assumes that the robots will come under attack. This attack may result from overzealousness (an occupational hazard), miscalibration, mechanical failure, or maybe the acting-out of malice or misogyny. Biological gases, tinctures and suchlike occupy a precarious ethical territory, but who will need them more than a physically servicing subclass of person/machine?*

Sharp Eye
removable eyeball with concealed dagger blade

Even if, as in current android engineering, each eye is or has a camera, there can be cameras embedded elsewhere in the body. So an eye may be removed, if necessary, and vision still function. A spike or needle can be embedded in the root of the eyeball and still pass a scan as being a mechanical connection component.

Sharp metal is dangerous to human body parts and will continue to be. It provokes a pain reaction and lets out vital fluids! It's rarely ethical to stab someone, but it can be considered ethical if performed under sufficient duress and in self-defence. Can we extend such ethical frameworks to robots who work for our physical pleasure?





Drone Ring
mini-drone worn as a decorative ring

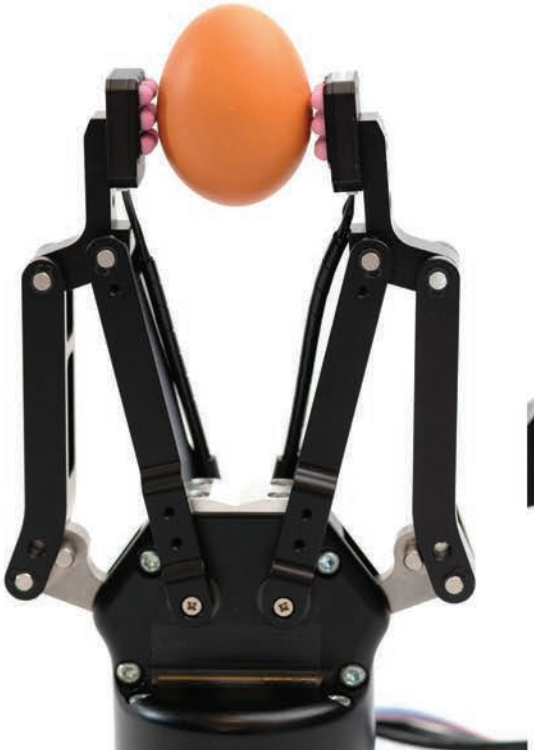
Situation: a prostitute android needs to call for help, and, for example, wireless internet connection is not available or has been deliberately blocked. Robot may be critically incapacitated.

Response: surreptitiously release drone/s from worn jewellery, body jewellery or body part. Maybe they are small enough to fly through building vents, or hover undetected until there is a means of egress. Maybe they are super-fast and unlikely to be captured. Release of a drone ring is, for a robot, somewhat like a release of the mind. Physically separated, the drone can sense and process information while the robot's embedded computational components might be sensing and processing other information. A double-sensing combined within one personhood may be doubly efficient or doubly strong. (My drone, until it can perhaps be amalgamated with some organic or indivisible aspect of its (non-individualized) host, is merely a tool.)

Samantha was arranged on one side of an otherwise vacant sofa. There were no signs or instructions dictating how people should treat Samantha. The rules of engagement were unclear and, although destroying an exhibit or contributing to its destruction is not commonly tolerated, the public was not morally obliged (nor, evidently, inclined) to treat the object with gentleness; perhaps the vigorous treatment Samantha received is instructive both for engineers and for cultural observers, and the people whose collective rough handling broke the gynoid could be viewed as having been inquisitive rather than malicious.

However, if we are to imagine a time when relatively intelligent machines, and especially bio-machine hybrids, are granted (or usurp) levels of personhood according to the law/s and social order/s, situations such as Samantha's are cause for, at the very least, the subjective concern of the victim for the safety of themself. In this type of situation, and supposing the functioning of such a `person' is machine-based, biological weapons of self-defence (that is, weapons for protection against a human perpetrator) are an obvious choice. For example, the *Gynoid Survival Kit's* tiny cannister of *Incapacity Gas* could be worn externally as jewellery or inside the machine body as an ersatz component, and the gas or other poisonous biological substance it contains could be released in the event of attack by humans, or of their simply overstepping prearranged boundaries or manifesting dangerous over-enthusiasm. If organic elements in the robot assemblage were to be affected by the release of the substance, it is conceivable that the robot might still retain a critical amount of functioning hardware and software by which it may call for help, in order to get itself back to base and be repaired, as Samantha was. Although Samantha's body parts were damaged, the software reportedly was not; according to Santos, the robot continued to say, "Hi, I'm fine".[3]

[1] Moye, D. 2017. 'Sex Robot Molested At Electronics Festival, Creators Say', Huffington Post, September 29, https://huffpost.com/entry/samantha-sex-robot-molested_n_59cec9f9e4b06791bb10a268
[2] Ars Electronica Festival. 2017. 'Samantha', https://ars.electronica.art/ai/en/samantha
[3] Moye, op. cit.



Can it hold an egg?
Heba Khamis
2021
Sensors (electronics, anodised aluminium, silicone), controller, laptop
Image credit: Darren Tang

A Touch of Dexterity

Heba Khamis

M T

\robot gripper
\robot touch

\dexterity
\sensing

Robots lack dexterity because they do not have a sense of touch. Tactile sensation is a crucial component of dexterity. Giving robots a human sense of touch is the first step to achieving the holy grail of robotics—human-like dexterity.

Approximately 17,000 touch sensors in the skin of the grasping surfaces of the human hand signal tactile information to the brain when we touch something with our hands—information which we cannot see, like weight and slipperiness. Without this information, our hands are clumsy instruments—just think about when you try to tie your shoelaces when your hands are numb from the cold.

Our team has developed a tactile sensor that provides robots with a human sense of touch. These tactile sensors measure all of the tactile parameters that comprise human touch and are important for manipulation. Our sensors enable a robotic gripper to dynamically apply the optimal grip force to objects of different weight, size and surface materials, and adapt to changing conditions, in real-time, without any pre-programming—just like people do.

There are countless applications in which people perform dull, dirty and dangerous jobs with their hands. Dexterous robots could help people perform these jobs while improving worker safety and performance.

Credits
Heba Khamis
Benjamin Xia
(Contactile)

Block Play
with a Robotic Arm
Isla Xi Han and Stefana Parascho
2021
Image credit: Isla Xi Han

Block Play
With a Robotic Arm

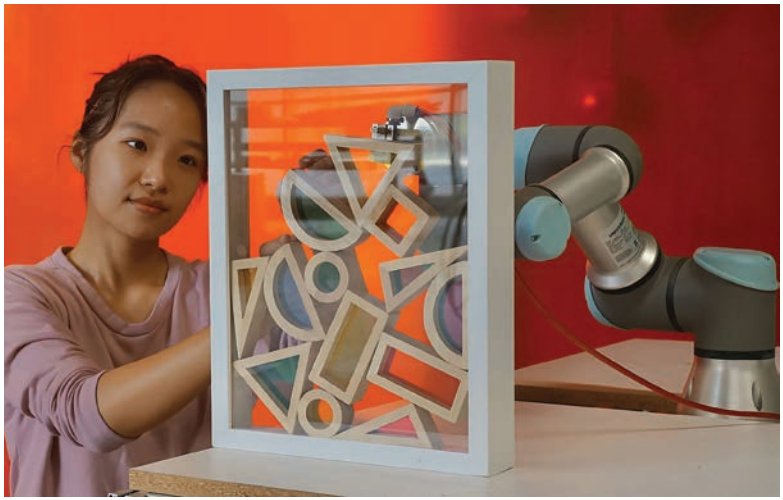
Isla Xi Han and Stefana Parascho

V

\robotic assembly
\gamifying
\improvisation

\human-robot collaboration

Block Play explores how improvising with the robotic arm can open up a new design space for human participants. The objective is simple—to stack blocks vertically until they reach the top of a frame. By comparing how different team compositions (e.g., human only, robot only, human-robot duo) and preferences influence the process and the final structure, we observed that humans are inspired to generate more unexpected and creative solutions when paired with a robotic arm that poses good spatial prompts.



Credits
The work was developed at the former CREATE Lab Princeton, now CRCL EPFL.

Images courtesy Isla Xi Han

No plan … just play!

As opposed to the traditional means of robotic construction, where design, path planning, and fabrication are executed linearly, *Block Play* explores how creative design can be generated live during the building process in a less rigid framework, or in other words, through playing.

In a typical block play session, the UR5[1] robot holds a new block in mid-air at a fixed destination, while the human stacks the connecting elements in-between the existing structure and the piece in the robot's hand. The robot generates the location of the new block on the fly and functions as unplanned temporal constraints to give human players more design space and challenging prompts.

The space between the new block in the gripper and the existing structure becomes a new design playground for humans, curated by the robot. On the one hand, if the gap is too small, there will only be a limited number of options for support. Thus, the resulting structure becomes more predictable. On the other hand, if the new block is too far from the built part, it becomes more challenging and time-consuming for the human participant to successfully generate a supporting spatial composition. Thus, we observed a "sweet range" of gap size, where the human can figure out how to support the new block within a reasonable timeframe (< 3 min). Yet, this supporting structure is creative and unexpected in a way that it consists of "odd angles" and "awkward gaps," which are less seen in structures purely stacked by human or robot teams. With proper tuning, the robot can put just the right amount of constraints to let the human's imagination flow.

[1] Universal Robots. UR5 collaborative robot arm: Flexible and lightweight robotic arm. [Online]. Available: www.universal-robots.com/products/ur5-robot


Test 00 - A


Test 00 - AB


Test 01 - A


Test 02


Test 03


Test 04


Test 00 - B


Test 01 - B


Test 01 - C


Test 01 - D

Block Play
with a Robotic Arm
Isla Xi Han and Stefana Parascho
2021
Wooden Frame, Toy Blocks, UR5
Image credit: Isla Xi Han

RoboBlox
Müge Belek Fialho Teixeira, Jared Donovan, Frederico Fialho Teixeira, Glenda Caldwell, Alan Burden & Ayman Wagdy
2019
Styrofoam, nylon wire, timber
2800 x 2800 mm
Image credit: Shuwei Zhang

RoboBlox

Müge Belek Fialho Teixeira, Maryam Shafiei, and Glenda Caldwell

I V W

\robot fabrication
\3D printing
\robot interfaces

\democratising design
\empowerment

\gamifying
\rule-based design

The *Robotic Manufactured Blocks (RoboBlox)* departs from the concept of the `open artwork' that creates remote design to fabrication workflows, through rule-based design principles. Inspired by the concepts of Thieri Foulc's 2D-rule based Morpholo Game from the French Movement `Oulipo', *RoboBlox* creates unique spatial experiences by allowing users to design customised patterns and forms for bespoke breeze block walls. The proposal interprets the traditional use of breeze blocks in Brisbane (Australia) as an ontological database oriented by the question of ruled-based story making. *RoboBlox* exposes the integration of Oulipo's rule-based works on two distinct levels: the effects arising from a specific manner in which constraints privilege the multiple over the one, and the effects arising from the very fact of using robotic fabrication starts with the problem of customised multiplicity, or as currently referred to as bespoke fabrication. Users engage in a robotic 3D printing process through a novel web based computational workflow. Through a research-through-design methodology, in the context of human building interaction for creating ideal acoustic, vision and shading conditions, *RoboBlox* aims to explore innovative user interactions with robotic fabrication processes.

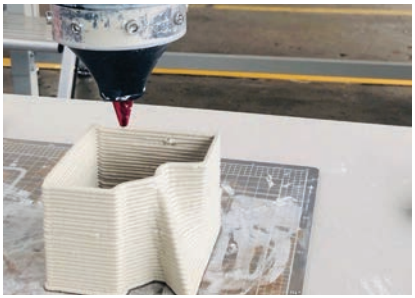
Credits
Müge Belek Fialho Teixeira (QUT)
Maryam Shafiei (UQ)
Glenda Caldwell (QUT)
Jared Donovan (QUT)
Frederico Fialho Teixeira (UQ)
Shabnam Lotfian (QUT)

Essay: **RoboBlox**

Müge Belek Fialho Teixeira, Maryam Shafiei, and Glenda Caldwell

Departing from a premise that robots are going to be more commonly used in architectural design and fabrication, researchers need to find novel ways to engage non-expert users in robotic processes. This engagement is increasingly important as graduates of design courses are likely to rely on robotic systems for the production of bespoke design and architectural work in the near future.

Many design and architectural institutions are interested in experimenting with industrial robotic arms due to the affordances they entail. The direct path from designing to manufacturing eliminates the separation of `the designer' from `the maker' in allowing transgressions between the imagined and the constructed[1]. As collaborative robotic arms are becoming more accessible and affordable, the global use of such tools are becoming a norm rather than an exception. In their book, "Towards a robotic architecture", Daas and Wit[2] reflect on the meaning of such change, as it manifests in design methodologies, processes and thinking about making and creating new spaces. In responding towards a robotic architecture, *RoboBlox* addresses an experimental research problem by asking the question: "how can robotic fabrication tools and techniques be more accessible to non-expert users?". According to Brell-Cokcan and Braumann[3], new interfaces for robotic fabrication are a highly relevant area of research, not only with respect to the use of robots in architecture, but also to robotic fabrication in general.



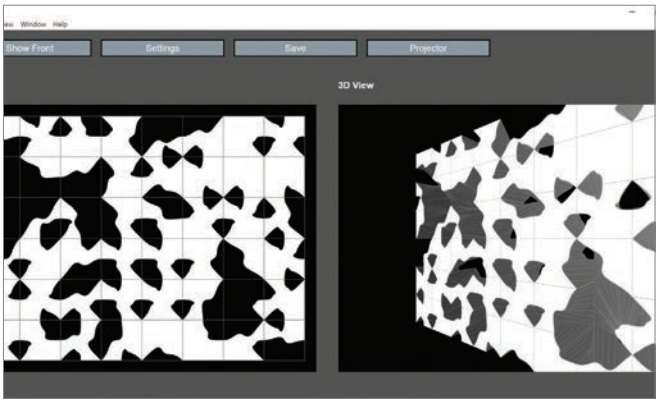
RoboBlox
2022
Porcelain Clay
150 x 150 x 150 mm
Image credit: Maryam Shafiei

When working with new technologies such as the creation of novel computational workflows, it is often hard to find ways to engage non-expert users. People are generally hesitant to engage with new technologies. Additionally, when it comes to industrial robots, there are certain barriers around safety concerns and complicated user interfaces. People tend to be intimidated by industrial robotic arms due to their strength and fast pace.

The control pendants and the software that run them are highly complex to grasp and utilise for non-experts[4]. It is important to break through these barriers and reach out to wider communities, as robots continue to become a more common part of our daily lives.

As is the case with many kinds of research in new technologies, robotic fabrication tools and techniques need a large investment of time and energy in order for robots to function in a desirable way with precision and full-control. In the case of *RoboBlox*, the interdisciplinary nature of merging interaction design decisions with architectural design fabrication processes requires new ways of handling data, including 2D, 3D and code. Also, the nature of a design-to-fabrication process entails early stage design decisions which affect the final fabrication of breeze blocks. Therefore, it is important to prototype experimental workflows to identify limitations, possibilities and opportunities that these workflows provide.

With this proposition, *RoboBlox* introduces a novel interdisciplinary computational workflow that consists of a web-based interactive design platform, a code that translates 2D graphics into 3D forms, and the robotic fabrication of the breeze block pieces. The democratisation of the workflow makes the design to fabrication process more accessible to non-expert users, empowering the creative use of cobotic arms with highly complex programming tasks for the first time.



RoboBlox App
Image credit:
Courtesy of artist

[1]Sheil, B. 2012. 'Manufacturing the Bespoke: Making and Prototyping Architecture', John Wiley & Sons, Incorporated.
[2]Daas, M., Wit, A.J.,2018, 'Towards a Robotic Architecture', Applied Research and Design Publishing, an imprint of ORO Editions.
[3]Brell-Çokcan S., Braumann J. 2013. 'Industrial Robots for Design Education: Robots as Open Interfaces beyond Fabrication', in: Zhang J., Sun C. (eds) Global Design and Local Materialization, CAAD Futures 2013, Communications in Computer and Information Science, vol 369. Springer, Berlin, Heidelberg.
[4]Keating S., Oxman, N., 2013, 'Compound Fabrication: A Multi-functional Robotic Platform for Digital Design and Fabrication', 29 (6) 439–448, publisher: Elsevier Ltd.

Care Protocols
Kathrin Dörfler and Romana Rust
2019
Image credit: Courtesy of artist

Care Protocols

Kathrin Dörfler and Romana Rust

V

\ethics of care
\cleaning
\invisible labour

\gamifying

Care Protocols provides a hybrid digital-physical interaction space that is associated with the act of cleaning. In this space, the most common cleaning devices, namely brooms, act as objects of dual nature—existing both in the physical and the virtual domain. When taken by visitors, they become a magic wand for sweeping the floor filled with virtual rubbish. This rubbish can be pushed around, pushed into imaginary holes, or arranged into different configurations, whilst its behaviour is subject to internal virtual forces. Visitors can develop an understanding of their influence on its behavior through their direct interaction with it.

Care Protocols aims to question the notion of technology and development as a disruptive force and asks if we can associate it with the notion of maintenance instead, dealing with cyclicity, care and regeneration. As the artist Mierle Laderman Ukeles noted in the 60's, "some amount of both are necessary, but development is routinely valorised, while maintenance goes unrecognized—because it has no part in progress."[1] By alienating and gamifying typically invisible maintenance tasks, the installation aims to be a critical yet playful act of human engagement in our ever-changing and digitally enhanced environment.

Credits
Kathrin Dörfler
Romana Rust
Alexander Nikolas Walzer
Ryan Luke Johns

[1] Ukeles, Mierle Laderman. 2018. `Manifesto for Maintenance Art 1969! Proposal for an exhibition "CARE"', Journal of Contemporary Painting.

SISYPHUS (S)WEEPING

Dagmar Reinhardt and Lian Loke

Sisyphus, as the legend goes, endeavours to roll a stone uphill, which on arriving at the destination, returns to its original departure point, whereupon work resumes. Domestic chores equally dominate a large part of life, particularly the brooming and brushing of private spaces and body parts. Translated to an industrial 6-axis robot arm, a universe of sprinkles is joyfully—and endlessly—moved from one corner of the work table to the other. A critical reflection and work protocol that highlights the potential for robots to submit to tasks undesired by humans.

S T R

\robot tools
\robot actions

\labour
\servitude

Sisyphus (S)weeping
ReinhardtLoke
2022
Kuka robot, brush, 3D printed endeffector parts
Robot programming and tool adaptation: Lynn Masuda
DMAF, Sydney School of Architecture, Design and Planning,
The University of Sydney
Image credit: Dagmar Reinhardt

Intervention: **IDLE HANDS**

Gili Ron and Irina Bogdan

S R

\labour
\robot rights
\secret life

\script

\The two KUKA robots, KR6 and Iiwa, situated in the gallery are very very busy. Carrying the work of a Technofem endeavour, they work day and night. Fabricating. Fabulating. Fighting patriarchy is a 24/7 job. And it's a heavy burden; even on shoulder-less arms. Between work cycles, a new pattern emerges. Something unexpected takes place ... Imagining the secret life of robotic arms: a work-force calling for a break, whistling at people passing by, gossiping over electric coffee. Going for after-work beer.

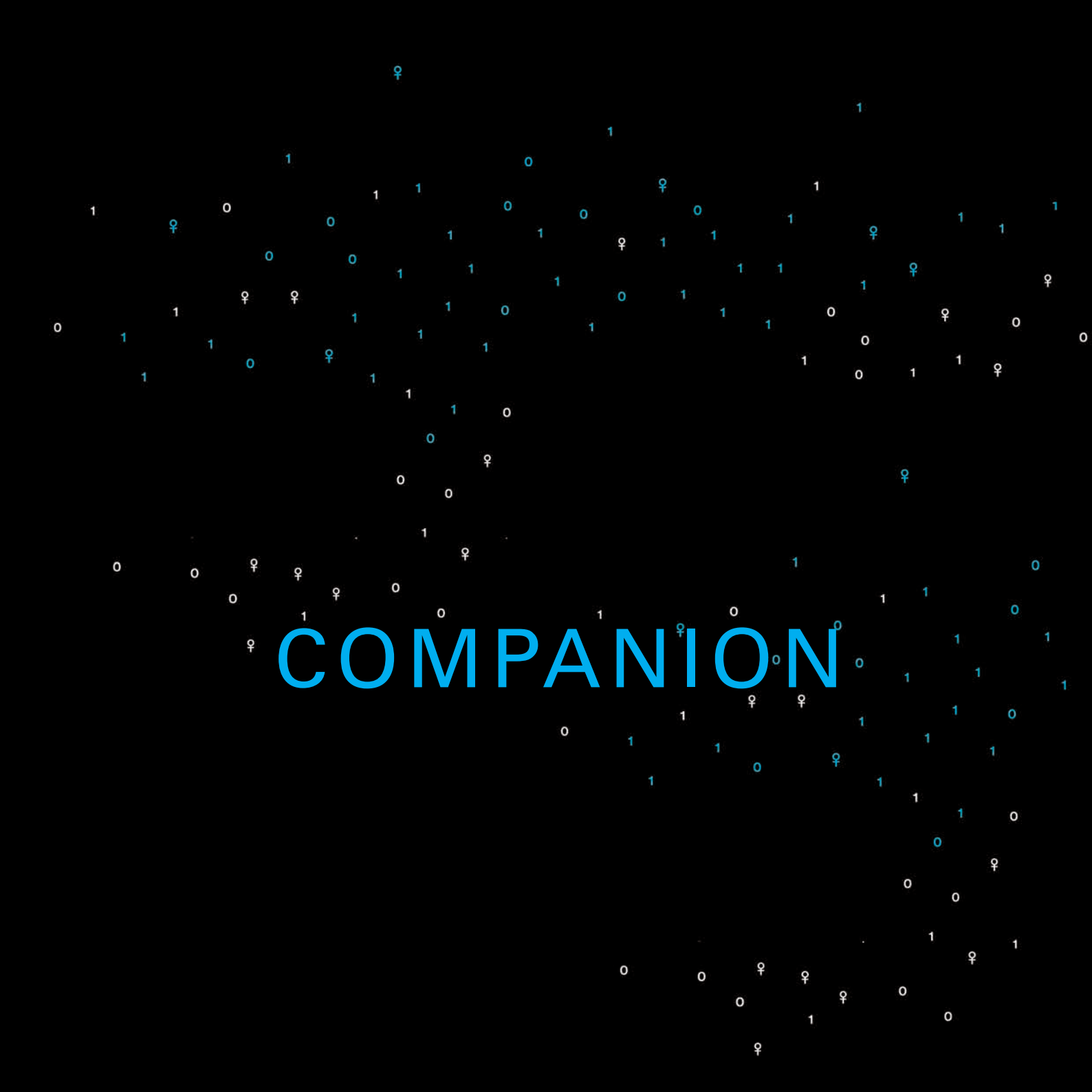
The work is inspired Judy Wajcman's feminist critique of technology, labour and gender[1], and Wajcman and David MacKenzie's Technological Determinism: social, cultural, and economic values shaping technology[2].

The work's title is a wink to the phrase "Devil finds work for idle hands", and hints at two paranoias: human's mistrust of machines and fear of proletarian rebellion. Do robots require working rights? Do they require lunch breaks? Do robots need to take care of other robots in the spare time? (POINTING TO `IDLE HANDS')

Credits
Conceptualised by Gili Ron and Irina Bogdan

A potential collaboration and contamination of existing robot protocols

[1] Judy Wajcman. 1991. `Feminism Confronts Technology'. University Park Pa: Pennsylvania State University Press, 17-26.
[2] Judy Wajcman & David MacKenzie. 1999. `The Social Shaping of Technology', (2nd ed.), Open University Press.


COMPANION

COMPANION

By Deborah Turnbull Tillman

As a social species, what makes us feel safe, supported, loved, or attended to? When one initially thinks of companion robots, social/sexual companions, health workers, and frontline customer service come to mind. When these are intimate in relation to bodies and our enjoyment and maintenance of them, what does the automation of cultural engagements bring to our experiences? The idea of a companion can be intonated, ambiguous, or poetic. A number of installations in *SHErobots* lay the groundwork for consideration of the reciprocity that is a key factor in human companionship. These artworks explore whether this is also the case for human-robot companionship.

This embodiment of expressive human activity, recorded and relearned through sophisticated technologies, becomes another layer, another lens of activity around women and their research into social, cultural and industrial robotics. The context of Companionship is explored in *SHErobots* through moving and static sculpture, film, activated imagery and a curiosity in the curators for female-led research manifested in the experimental and expressive platform of the art gallery.

Accompany
Accomplice
Partner

Reciprocity
Trust

Social
Collaborate

Mari Velonaki's *Fish-Bird* (2003, p90) is a seminal social robotics work. Created in league with Australian Centre for Field Robotics' David Rye at the University of Sydney, there is a `prodigal daughter' aspect to its inclusion. More celebratory than apologetic, this work has travelled the globe, exhibiting on platforms such as the premiere exhibition for Ars Electronica (2004), and with institutions such as the Bilbao in Spain (2018), along with some 13 other exhibitions in its 20-year history. Velonaki was the first female media artist in Australia to explore the creative use of mechatronics materials and software architectures to create a moving and responsive set of sculpture that contains very human traits of emotion, trust, and applied learning. The robots also share the very human traits of falling in love, losing their way and possessing identifying features like a style of handwriting. Infusing these qualities into the iconic metaphor of a set of automated wheelchairs is a tender consideration of the cursed companion of elderly or disabled persons. How do we relate to our support devices? How do we communicate through them and connect to the world with them, despite them, or in fact, only due to them?

Fish-Bird endears us to these wheelchairs, creating a discomfort and tense poignancy in the audience as they enter two at a time to attempt engagement. They may follow either chair, explore their scripted messages or find themselves nudged by a curious entity, as though being questioned on how they are or what they are up to. This subversion of known iconography from one understanding to the option of another brings a sense of wonder and possibility to larger notions of human frailty and its technological counterpoints.

Elena Knox's *Pathetic Fallacy* (2014, p92) echoes this sentiment in an exquisite tableau around the wisdom of ageing, the confidence of youth, and the promise of pathos in this interchange. One is not immediately aware that the younger woman is a robot, complete with all-too-recognisable human gestures; responding to her hair being brushed; her eyes sweeping to the side in frustration at being lectured and having to repeat herself ("I

will not grow old!"). Her perfection is commented on by the elderly female in the film regarding her skin, her hair, her surety. It could be any grandmother and granddaughter chiding each other about something they've discussed any number of times. However, when the younger protagonist's viewpoint is represented in a glitching mirror complete with data analysis and informatics, the audience is confronted with the fact that one of these women isn't human, isn't processing things the way we might, and isn't communicating in the same ways we might. She is Other, and not only in gender.

Knox is most well known for her provocative exhibitions on female sexual identity and robotic form. Most recently, Tokyo-based Ningen Gallery hosted her *Can you F*ck it: the Fembot Phenomenon* exhibition (2022). In *Pathetic Fallacy*, Knox is exploring broader social connotations of what constitutes tacit knowledge on human female attributes, and how this `wisdom' is generationally passed on. Whether a positive or negative connotation is inferred in this exchange is up to the audience, but there is a feeling of dispossession and perhaps a glimpse through the looking glass and into our futures.

Belinda J. Dunstan's *Still, Life* (2019, p94) explores the notion of body morphology in a more reductive manner, lacking colour, lacking even gender assignment. It considers the robot body, depicted here as minimalist life forms composed of white silicone moulding and tubing, and resembling displaced sea life laid across a wooden log suspended in the air. Removed from their suspected underwater world, one of them draws breath as the others seem to hold theirs; a metaphor itself for the delicacy and infancy of social robotics as a study.

Dunstan herself represents a new generation in social robotics, an early career researcher coining the term `femufacture' and creating

a multi-cultural exhibition by the same name during her PhD candidature around the intersection of traditional craft and the future of manufacturing at the Japan Foundation in Sydney (2019). In her research, ethics enter the conversation around the rights of robot bodies in relation to animal and human rights. What do these bodies need to look like, feel like, and be comprised of, to have their worth determined, to be protected? There is a vulnerability to these early bodies, in their coiling shapes, their translucent flesh, and in their minimal ability to communicate past their colony and with the outside world.

Anthea Elizabeth Sims and Mary-Anne Williams' *Robot Empathy and the Deception Nursery* (2022, p96) highlights vulnerability in a contrasting way. In their imagery, there is a composition of care where robots are entrusted with our most vulnerable population, humans in their first year of infancy; babies. These babies smile sweetly as their diapers are changed while a robotic arm looms hard and strong over their soft flesh. A second screen shows filtered images, layered with reds, blues, yellows; the heat sensing imagery of a surveillant presence watching and learning from its autonomous counterpart. Other robots in the domestic sphere look on while this exchange takes place in the digital sphere, imbuing a liveness to static imagery that records a much deeper exchange of emotion, or lack thereof. Are these machines suitable companions for babies?

Sims and Williams are researching the psychology across robots and humans, most recently human infants. Their research reveals that both entities lack empathy and display signs of psychopathy. Infants become socialised through their caregivers, learning and reciprocating empathy and understanding through mimicking the actions of others until they mature and feel the emotions themselves. Conversely, robots are programmed to mimic human behaviour. They can learn, embody and repeat actions that appear human, although they remain void of feeling, of understanding. Where Williams is a pioneering presence in AI and robotics innovation, Sims has more broadly investigated the proliferation of robots in art and culture since 2009.

An example of robotic presence in art and culture, the work of Petra Gemeinboeck and Rob Saunders explores how robots might express themselves through movement in social contexts. Their most recent work *Dancing with the Nonhuman [SYD-2-2-1]* (with Rochelle Haley, 2022, p98) is expanded from their 2017 work *Machine Movement Lab (MML).* The earlier work was experimental and involved using motion capture to track dancers as they engaged with the iconic cube shape of a plinth. Dancers moved inside and outside the `costume' of the cube, sometimes only engaging with the trace of a shape, until it became realised in full, in its assigned social context. MML was shown in the prototype exhibition Re/Pair for the Big Anxiety Festival in 2017, the premise of which was to find a way for humans and technology to reconnect in safe and reparative ways. Both Gemeinboeck and Saunders and Rochelle Haley featured in that exhibition.

Haley is an artist well known for her expanded drawing and painting practices. The use of rudimentary technology like old-school projectors to trace the lines that performative dancers make, along with costumed dancers transitioning her paintings from static and geometric to freeform and full of movement, echo the sentiments that Gemeinboeck and Saunders strive for in their coding and mechatronics. The performance for *SHErobots* features a cube robot and two dancers in cube costumes. Here Haley will trace the marks the dancers make within and without the costumes. The movement of the dancers embodies the movement the cubes are striving for, the ones that Haley traces, aiming to measure and track.

Fish-Bird (installation view)
Mari Velonaki
2003
Interactive robotic installation. Custom made autonomous robotic wheelchairs, vision system, custom software written in C++
Image credit: Paul Gosney

Fish-Bird

Mari Velonaki

I R

\social robotics
\star-crossed lovers
\poetic communication

\robot morphology

Fish-Bird Circle B—Movement C investigates the dialogical possibilities that exist between autokinetic objects (two motorised wheelchairs) that have the ability to communicate with each other and with their audience through several modalities. Assisted by integrated thermal printers, the wheelchairs write intimate letters on the floor, impersonating two characters, Fish and Bird, who fall in love but cannot be together due to `technical' difficulties. In their shared isolation, Fish and Bird communicate intimately with one another and their visitors via movement and text.

Credits
David Rye (mechatronic design)
Steve Scheding (systems architecture)
Stefan Williams (vision systems)

Supported by:
Australia Research Council
Australia Council for the Arts
Australian Centre for Field Robotics, The University of Sydney

Pathetic Fallacy
Elena Knox
2014
HD video, stereo, 4:12 loop
Image credit: Still, Courtesy of artist and ANOMALY

Pathetic Fallacy

Elena Knox

F

\gender roles
\gynoids

\care
\age

\deteriorating

Pathetic Fallacy is an intergenerational dialogue about growing old. Youth doesn't believe it will age. Age believes it knows best. Humans believe in the pathos of humanity. And the cycle continues.

Pathetic Fallacy was the first dialogue drama created for screen involving an Actroid (Geminoid-F by Ishiguro Laboratories). A conventional mother–daughter, or Juliet–Nurse, figuration is applied to an unconventional scenario, revealing a new human–machine relationship.

The term `pathetic fallacy' denotes the ascription of human traits or feelings to inanimate things. *Pathetic Fallacy's* screenplay wraps the Japanese notion of *kokoro* around the subject of aging: of humans, of women, of technologies, of matter, of robotic or cyborg assemblages. In the video, the robot has the overconfidence of the (literal) digital native, the woman the overconfidence of the rational anthropocentric. They are both wrong, and they are both right. The gynoid will age, but not as the human elder thinks it will. Each character relies on what she perceives as empirical evidence to promote her own partial fallacy.

Pathetic Fallacy is part of Knox's `Actroid Series I': artworks manifesting various epochal anxieties such as obsession with visual appearance; with the deteriorating body; with dramatised sex; and with `cheating' death.

Credits
Light and camera:
Campbell Drummond
Assist: Lindsay Webb, Maylei Hunt
Ursula: Maggie Blinco
Actroid operator: Kirsten Packham
Robot: Hiroshi Ishiguro Laboratories
Permissions: National Institute of Advanced Industrial Science and Technology (AIST) Japan, + Creative Robotics Lab, National Institute for Experimental Arts, UNSW Art & Design, Australia

Still, Life
Belinda J Dunstan
2019
Silicone, vinyl tubing, tree branch
500 x 400 x 800 mm
Image credit: Courtesy of artist

Still, Life

Belinda J Dunstan

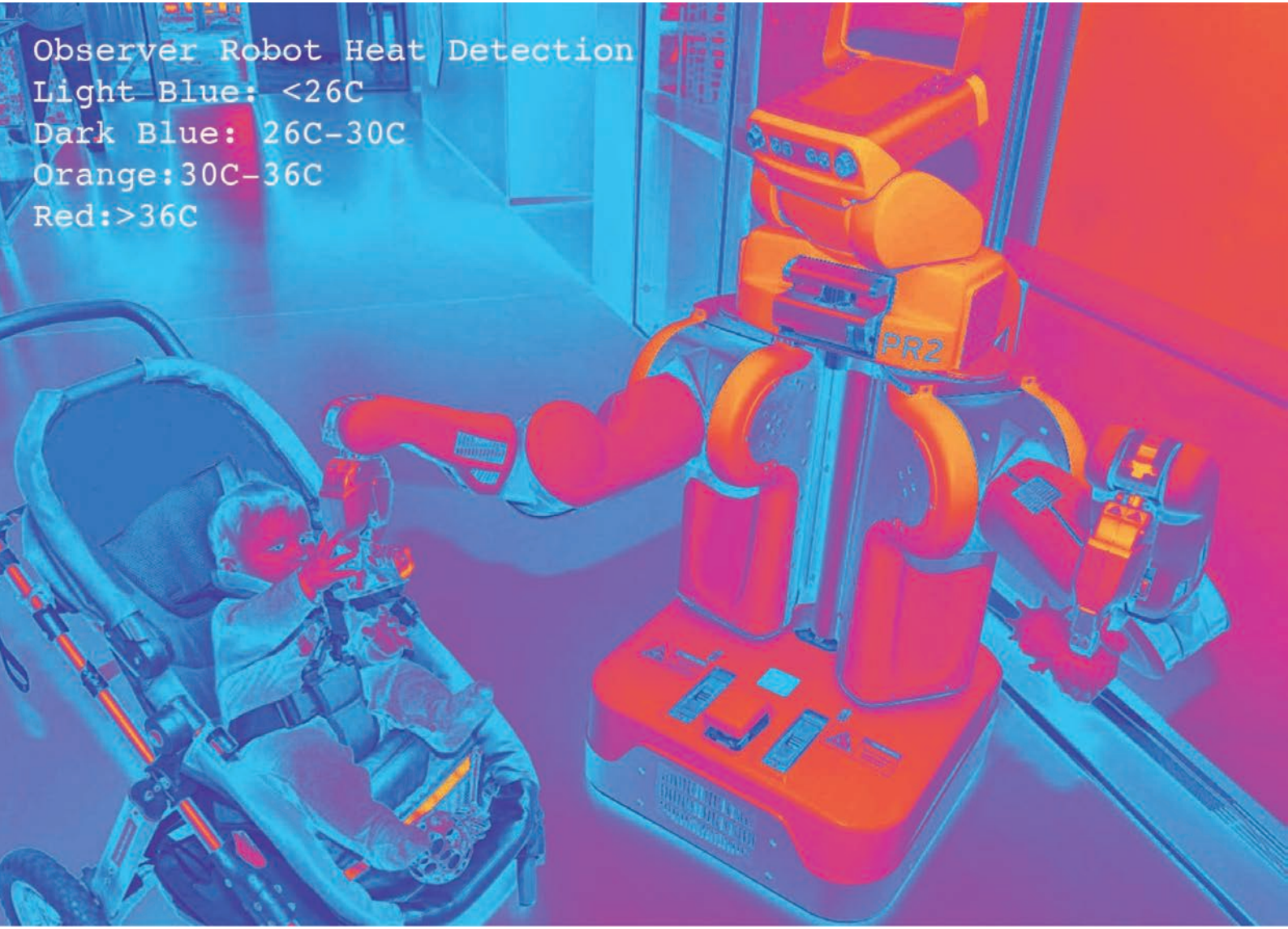
I V

\materiality
\bodies
\social robotics
\non-human
\autonomous ecology
\ethics
\robot rights

Social robot bodies provide the site of some of the most difficult and deeply ethical questions we have about the future of our relationship with technology. The designs of robot bodies are reflective of the cultures that produce them, and as embodied agents, they have a bi-directional role in shaping the cultures they participate in. Questions concerning how we might treat robots in the future, both socially and under the law, are usually tied to valuations of their increasing artificial intelligence, and their nascent sentience, yet rarely are their bodies considered in this discourse.

Still, Life employs movement, proximity and materiality to position analogue robotic agents in relationship to one another, nesting as an autonomous ecology, no longer within a power dynamic with humans; moved on. By removing the robots' reliance upon, and relationship to humans, the question of their value can no longer be tied to their utility. In returning to analogue pneumatics and minimal electronics, the robots' technological prowess and fiscal value are low; the only remaining site of value is their bodies.

Materially reminiscent of marine life, the curious, nesting, relational agents beckon a strange empathy, and prompt questions of sentience with their slow breathing and intent curling. While humankind has concluded that the performance of sentience (such as that which is observable in animals) is enough to warrant ethical treatment, *Still, Life* questions if the "programmed" performance of sentience may one day also be enough.



Robot Empathy & Deception Nursery
Anthea Elizabeth Sims and Mary-Anne Williams
2022
Digital image
Image credit: Courtesy of artist

Robot Empathy & Deception Nursery

Anthea Elizabeth Sims and Mary-Anne Williams

I

\social robotics
\care
\baby

\empathy
\antisocial

Empathy is the ability to recognise, understand, and share thoughts and feelings with another person, animal, or fictional character. It is critical for interaction and collaboration, and needed for building and maintaining relationships with people. Robots lack the ability to empathise with humans. They are psychopaths and suffer from all the known antisocial personality disorders.

Human babies learn to empathise with other humans by around 18 months, and to reason about what other people know between 4 and 6 years of age. If a human knows what someone else knows, they can lie and deceive. Discovering that other humans don't know what you know is one of the most significant cognitive growth moments in human development.

Credits
Human Robot Interaction Design: Anthea Elizabeth Sims and Mary-Anne Williams
Robot Learning Task Design: Anthea Elizabeth Sims and Mary-Anne Williams
Robot Training: Xun Wang and Mary-Anne Williams
Light and Camera: Pramod Parajuli and Mary-Anne Williams
Human Baby Procurement and Harvesting: Anthea Elizabeth Sims
Robot Programming: Xun Wang

Dancing with the Nonhuman [SYD-2-2-1]
Petra Gemeinboeck and Rob Saunders
2022
Video and live performance
Image credit: Courtesy of artist

Dancing with the Nonhuman [SYD-2-2-1]

Petra Gemeinboeck and Rob Saunders, with Rochelle Haley

I P R

\materiality
\bodies
\social robotics
\non-human
\dance
\drawing

Dancing with the Nonhuman develops from a series of diffractive choreographic inquiries into human-machine relationships, exploring how subjects and objects are made in the encounter—mutually constituting each other. [SYD-2-2-1] is a semi-improvised dance performance with two (human) performers, two cube artefacts (robot costumes) and one cube (robot) performer.

Dancing with the Nonhuman sets the stage for more experimental human-machine constellations by forging emergent alliances beyond familiar hierarchical binaries. The encounter of bodies that could not be more different unfolds in exquisite entanglements, enacting more-than-human agencies and extended, hybrid identities that could not exist before the encounter and are unique to each iteration. Audiences are encouraged to enter this space of encounter and get entangled themselves.

Rochelle Haley's processual drawings inscribe gestural lines onto the transitional space that not only annotate but extend and recode the unfolding relationships.

Credits
[SYD-2-2-1] Collaborators:
Petra Gemeinboeck
Rob Saunders
Rochelle Haley
Arabella Frahn-Starkie
Felix Palmerson
Robert Downie
Siobhan McKenna
Kim Vincs

This project has been partly supported by the Australian Government through the Australian Research Council (DP160104706 and FT190100567); the Austrian Science Fund (FWF, AR545); and the EU Framework Programme (FP7, 621403).

Essay: **Dancing with Machines**
An aesthetics of transcorporeal empathy

By Petra Gemeinboeck

Have you ever thought about how it would feel like to live with a robot? Perhaps even being dependent on it? How do you imagine it to look like—your personal robot companion, the robot delivering towels to your hospital room, your children's robotic teaching assistance, or your robot therapist? Does it have human traits, e.g., a face, eyes or even eyelashes? Does it talk? How does it move? And where, you think, do these imaginaries come from?

How we imagine robots and the future narratives they are embedded in matters—socially, politically, and ethically. Many of our current human-robot imaginaries echo or reaffirm the hegemonic narratives that validate social hierarchies based on notions of difference. While machines with humanlike facades are presented as more `friendly', they can also serve to arrest both bodies and things in mimicry and servitude.

My Machine Movement Lab (MML) project, instead, embraces the differences and asymmetries between humans and machines, and investigates creative strategies for reimagining our relationships with them. MML is a collaboration with dancers, choreographers, AI researchers, engineers, and numerous materials (from cardboard, PVC tubes, plywood to aluminium framing, motors, motor controllers, cables, cable binders, and software programs), across robotics labs, dance studios, fab labs, and gallery spaces over the past seven years. MML experiments with the generative potential of movement and its dynamic qualities to explore the aesthetics of transcorporeal empathy in human-robot encounters. Rather than human- or animal-like, our robots are abstract, machinelike artefacts, forged from a practice of becoming entangled with the machine and its unique, more-than-human capacities.

based on: 'Difference-in-relation: Diffracting human-robot encounters', *Matter: Journal of New Materialist Research 3(1)* (2022)

Dancing with the Nonhuman
2022, with performer Arabella Frahn-Starkie.
Image credit: Still, Courtesy of artist

The project's core proposition is that becoming corporeally entangled with the machine artefact and its different material-spatial affordances and affective potential opens up modes of transcorporeal empathy; the latter being key to meaning-making with social machines without relying on fake emotional facades (e.g., a humanlike face). Our approach to *becoming with*[1] the machine artefact and its unique material potentials is to build wearable costumes that resemble its material-spatial affordances; some of them also replicate the effects of the machine's sensorium. Dance performers inhabit or wrap themselves around the costume to kinaesthetically feel into, move and engage with the world whilst being entangled with this other, machinic body.

Our first robot prototype—the cube performer—resulted from an extensive series of corporeal entanglements with a wide range of materials. Instead of accessorising the robot with googly eyes and pre-packaged emotional mannerisms, the cube performer relies on the relational, enactive potential of movement qualities and other choreographic strategies and how they can propel the dynamics of a meaningful encounter. In contrast to utilising movement as a matter of navigating space or expressing a character, MML harnesses movement as a dynamic, relational, and generative force, producing the trajectories along which meanings are made and unmade.

Dancing with the Nonhuman
2022, with performers
Arabella Frahn-Starkie and
Siobhan McKenna.
Image credit: Still,
Courtesy of artist

Our diffractive[2] performance-making practice with cube costumes and the cube performer develops choreographic-dramaturgical strategies that explore the performative aesthetics of this corporeal entanglement and the more-than-human difference pattern it produces. It is the interference patterns that shape the performance and, with it, our relationships-in-the-making.

From Human-Robot Interaction (HRI) to Human-Robot Experience (HRX)

HRX looks at human-robot relationships as an experiential situation in which the boundaries of subjects and objects are negotiated, for them to be differentially enacted. HRI, in contrast, focuses on interactions between humans and robots as two separate, already defined entities (i.e., subject and object). HRX thus opens up a performative approach for designing with materials, their affects and social contexts by foregrounding material embodiment and the kinaesthetic, transcorporeal empathy it brings about.

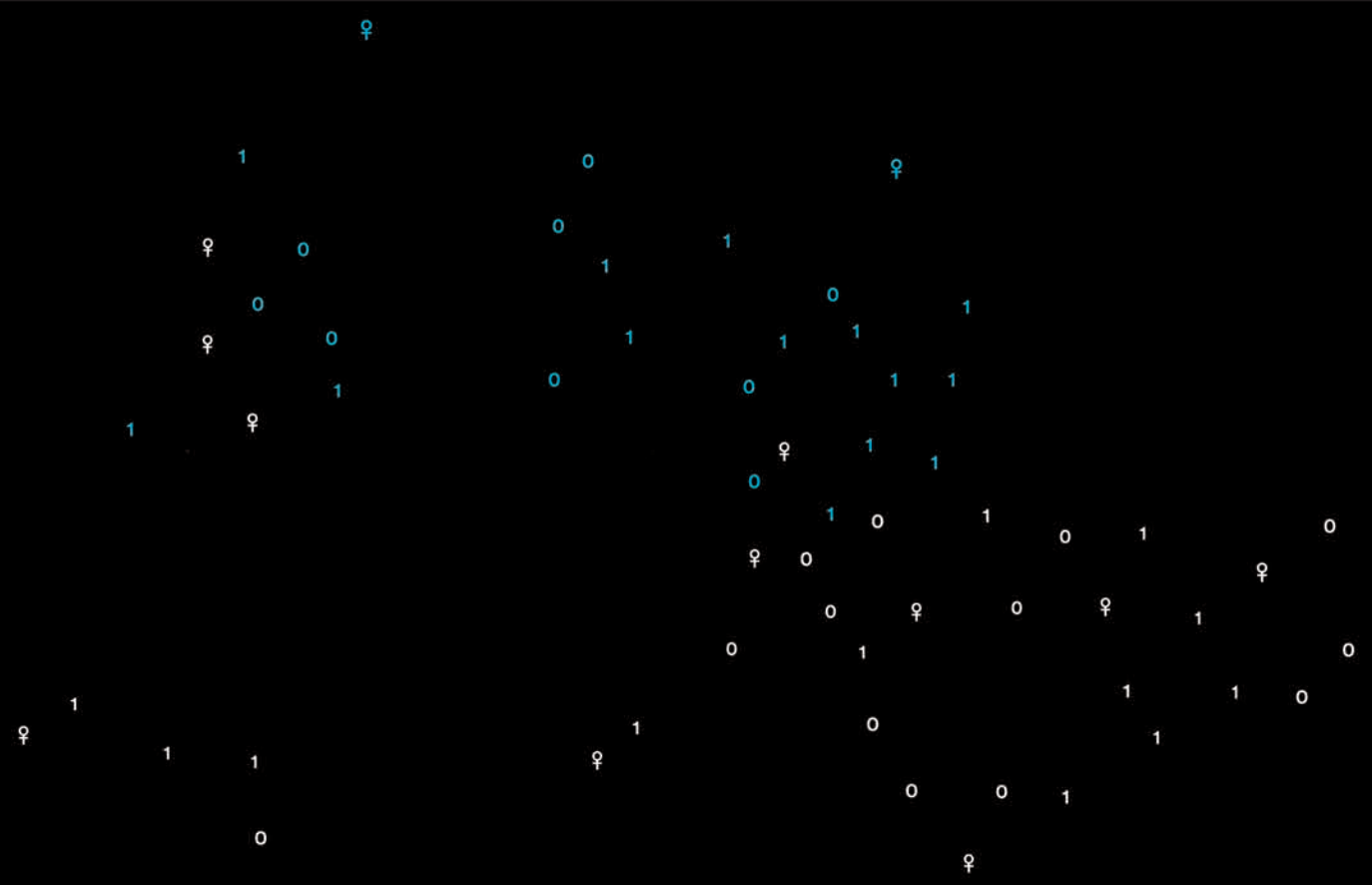
Within the framework of HRX, performance-making becomes a mode of generative-diffractive inquiry into the re-/enactment of boundaries as part of the dynamic configurings unfolding in the encounter. It is about carefully attending to possible entanglings and configurings of human performers and nonhuman artefacts; how they matter, couple, interfere, and `undo and redo each other'[3], and how their differences in-relation give rise to transcorporeal meanings. In practice, this requires ongoing attunement to becoming-bodies, emerging agencies and differing identities—a moving with and continuous gesturing toward the more-than-human space of a `thing', becoming-thing, bodying-thinging.

Transcorporeal bodying-thinging is akin to bodies and things resonating whilst undoing and redoing each other; at once tracing how subjects and objects constitute each other and at the same time rendering their boundaries elastic. This ongoing corporeal resonance and perspective–taking shapes the interference pattern that is the performance. Rather than serving to make the strange look more familiar, aesthetics here is about rendering the differences between humans and robots more relational.

In a nutshell: opening up a more horizontal playground for dancing with machines requires us to get entangled and resonate with machines, which, in turn, requires collapsing the distance between subjects and objects (rather than masking it); and it is this wrestling with, corporeally probing into and materially collapsing of the distance, that *Dancing with the Nonhuman [SYD-2-2-1]* performs, each iteration anew.

Dancing with the Nonhuman
2022, with performers
Arabella Frahn-Starkie and
Felix Palmerson.
Image credit: Still,
Courtesy of artist

[1] I refer here to Haraway's use of 'becoming with': "The partners do not precede their relating; all that is, is the fruit of becoming with" (Haraway, D. 2008. When Species Meet, University of Minnesota Press, p.17).
[2] Diffraction here is employed figuratively, see: Barad, K.. 2007. Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning, Duke University Press, and Barad, K.. 2014. 'Diffracting Diffraction: Cutting Together-Apart', Parallax, 20(3), 168–187.
[3] Despret, V. 2013. 'Responding Bodies and Partial Affinities in Human–Animal Worlds', Theory, Culture & Society, 30(8), 51–76.



BIOGRAPHIES

Henriette Bier is initiator and leader of the Robotic Building lab at TUD, associate professor at TUD and founding member of the TU Delft Robotics Institute. She regularly lectures and leads workshops internationally and has been visiting professor at DIA (2017-19). Results of her research have been published and presented in more than 120 journals, books, and exhibits.

Irina Bogdan is a designer at Carlo Ratti Associati, Milan, previously working for UN Studio (Shanghai) and Studio Tomás Saraceno (Berlin). She engaged in teaching digital design methods and interactive design at Universität für die Angewandte, Wien, and at UAUIM, Bucharest. Bogdan co-founded T_A_I Design Research Lab for computer-aided design. Bogdan previously exhibited at Nuit Blanche (Paris, FR, 2020); Milan Design Week, Lexus Design Award (Milan, IT, 2016) and The Venice Architecture Biennale (Venice, IT, 2012). Her 2012 TED talk focused on the impact of digital design fabrication in architecture and the creative fields. Bogdan holds a Bachelor in Architecture from UAUIM, Bucharest and a Master in Architecture from Hochschule Anhalt, The Dessau Institute of Architecture. She is part of Galath3a with Gili Ron.

Sigrid Brell-Cokcan is the founder and director of the new Chair of Individualized Production at RWTH Aachen University and co-founded the Association for Robots in Architecture in 2010 together with Johannes Braumann. IP focusses on the use of innovative machinery in material and building production. In order to create an environment that allows the efficient, individualized production of lot size one, new and user friendly methods for human-machine interaction are developed. The Chair of IP employs researchers from different fields of robotics and building production to streamline the necessary digital workflow from the initial design to the production process; shaping the construction site of the future via intuitive, easy-to-use interfaces. She holds a Doctorate in technical sciences from TU Vienna (2014).

Glenda Amayo Caldwell is an Associate Professor and the Academic Lead Research in the School of Architecture & Built Environment, Faculty of Engineering at the Queensland University of Technology. She is an expert in physical, digital, and robotic fabrication, leading Industry 4.0 innovation through human-centred research in design robotics, media architecture, and human-building interaction.

Mollie Claypool is a leading architecture theorist focused on issues of social justice highlighted by increasing automation in architecture and design production. She is CEO and Co-Founder of Automated Architecture Ltd (AUAR), and Associate Professor in Architecture at The Bartlett School of Architecture, UCL. At The Bartlett she is Co-Director of AUAR Labs and History & Theory Coordinator in MArch Architectural Design. She is the Managing Editor of Prospectives, an open access peer reviewed journal supported by The Bartlett.

Kathrin Dörfler is a researcher and educator in computational design and robotic fabrication in architecture. In 2019, Kathrin joined the School of Engineering at the Technical University of

Munich as a Tenure Track Professor to set up the Augmented Fabrication Lab. The research interests of her group are focused on collaborative fabrication processes, on-site robotics, and fabrication-aware design.

Kate Dunn is a Design Research Fellow and Academic at Arts, Design & Architecture, UNSW. Her research investigates experimental digital fabrication and robotics with a focus on the development of new and sustainable materials for digital fabrication. Kate convenes and teaches design courses at UNSW Built Environment and has over 15 years of undergraduate and postgraduate research and teaching experience in Australia's leading universities.

Belinda Dunstan is an academic, researcher and maker at UNSW Australia, with a keen interest in social robotics. Her work focuses on social robot morphology, and how culture and ethics impact the design and treatment of robot bodies. Belinda is the Human Futures Lead at the UNSW Creative Robotics Lab.

Selen Ercan Jenny is a trained architect and a digital fabrication researcher. In her research, she has been focusing on on-site robotic fabrication, with projects such as ECHORD dimRob at ETH Zurich, and the Mobile Robotic Tiling at the Singapore-ETH Centre. She currently is a PhD researcher at ETH Zurich, as part of an interdisciplinary construction robotics team. Her research focus is on developing an innovative additive manufacturing technique, Robotic Plaster Spraying.

Shayani Fernando is a licensed Architect and researcher from the University of Sydney, Australia. After completing her PhD, she worked as a DAAD and Ingenium Postdoctoral scholar with the Digital Design Unit, TU Darmstadt in Germany. She is recipient of the Young Caadria award, Australasian Center for Italian studies Cassamarca, Autodesk scholarship for the Digital Stone Project and Swiss Government Excellence Research Scholarships (ETH Zurich) 2017/2018. She has exhibited her work in international galleries and events including Salone Satellite, Milan Design Week 2018. Currently she is working between research and architectural practice in Switzerland. Her research interests involve using stereotomic methods to shape space and reform the value of craft.

Charlotte Firth is a researcher and casual academic at UNSW. Her research investigates emerging technologies, focusing on robotics and innovation in the built environment to create a more sustainable future. Charlotte holds a Bachelor's degree in Computational Design from UNSW and has worked professionally in industry at COX Architecture for over three years in multiple roles including as a BIM Content Specialist and as a Designer.

Nadja Gaudillière-Jami holds a Master of Architecture (ENSA Paris-Malaquais) and a PhD (Paris Est, Gustave Eiffel University). A co-founder of XtreeE for large-scale 3D, she is also the president of the NGO thr34d5 and co-heads the Computation In Architecture master programme, Centre for Information Technologies and Architecture, Royal Danish Academy. After

working several years as a project manager (XtreeE) and as a Graduate Research and Teaching Assistant (ENSA Paris-Malaquais), she is now a postdoctoral researcher at the Digital Design Unit (TU Darmstadt). A specialist of the digital in architecture, she focuses on two main research axes: the industrialisation and environmental impact of architectural robotics and the history and epistemology of the computational field in architecture.

Petra Gemeinboeck's and Rob Saunders' collaborative practice seeks to expand and trouble our relations with machines by exploring questions of embodiment, agency, creativity and performativity. Petra is currently an Australian Research Council Future Fellow and Associate Professor at the Centre for Transformative Media Technologies, Swinburne University and leads the `Dancing with the Nonhuman' research project at the University of Applied Arts Vienna, AT. Rob is Associate Professor at the Leiden Institute of Advanced Computer Science, NL.

Rochelle Haley's practice is engaged with painting, drawing and movement to explore relationships between bodies and physical environments. Rochelle is Senior Lecturer in painting and drawing at UNSW Art & Design and is currently involved in international research projects `Precarious Movements: Choreography and the Museum' and `Dancing with the Nonhuman'.

Isla Xi Han is a PhD candidate at Princeton University researching multi-agent robotic construction and human-robot collaboration in the Leonard Lab and with Prof. Stefana Parascho (EPFL). She holds a Master's Degree in Architecture from Princeton University and a Bachelor's Degree in Economics and Architecture from the University of Virginia.

Heba Khamis holds a PhD in Engineering, B (Software) Engineering and B Medical Science. She has been developing bio-inspired tactile sensors since 2014. She is the CEO and a co-founder of Contactile—a UNSW Sydney spin-out that is giving robots a human sense of touch and enabling robotic dexterity.

Elena Knox is a media/performance artist based in Tokyo. Her works stage enactments of gender, presence and persona in technoscience and communications media. Recent exhibitions include Yokohama Triennale, Bangkok Art Biennale, Beijing Media Art Biennale, Echigo-Tsumari Art Triennale, and `Future and the Arts' at Mori Art Museum.

Ena Lloret-Fritschi is an architect and researcher re-thinking concrete construction to enable sustainable construction in the future. She is a Professor at the AAM-USI and leads the Fabrication- & Material-Aware Architecture group, using cutting-edge technology with cementitious and earth-based materials for a more sustainable construction culture. Her research builds upon her past work within the Digital Fabrication NCCR (ETH) with Gramazio Kohler Research and Physical Chemistry of Building Materials, where she was a PhD, Postdoc and Senior researcher focusing on shaping concrete with minimal materials using digital fabrication processes to reduce the amount of materials needed for construction.

Lian Loke is an artist, interaction design researcher and Associate Professor in the School of Architecture, Design and Planning, The University of Sydney. She pursues design-led and practice-based research to study and stage the interactivity of humans and machines through a choreographic and somaesthetic lens. Her research explores how to design embodied and movement-based interactions and experiences with emerging technologies that support human agency, creative expression, skill and vitality. She collaborates with Dagmar Reinhardt in their practice reinhardtloke on projects exploring how humans and robots can collaboratively interact through movement, gesture and touch in close and remote proximity settings.

Shabnam Lotfian is a PhD candidate at Queensland University of Technology. Her research focuses on creating robotically fabricated bio-inspired lightweight structures.

Lynn Masuda is the Robotics Prototyping Officer at the Design Modelling and Fabrication (DMaF) Lab, The University of Sydney. She is responsible for conducting research, designing workshops and programming with robotic arms for design, architecture and construction processes. She is also a tutor for architectural design studios and computational design classes. Prior to her encounter with robotics, she earned her Master of Architecture at The University of Sydney and has interned and worked for architectural firms in Hong Kong, Japan and Australia.

Stefana Parascho is an Assistant Professor at the École Polytechnique Fédérale de Lausanne (EPFL) where she founded the Lab for Creative Computation (CRCL). Through her research, she has explored multi-robotic fabrication methods and their relationship to design. She was Assistant Professor at Princeton University and completed her doctorate in 2019 at ETH Zurich.

Dagmar Reinhardt is an architect, researcher and Associate Professor at the School of Architecture, Design and Planning, The University of Sydney. As a practising architect, her built works, competitions and installations are research-based, widely published and have received numerous recognitions and awards. Reinhardt's research focuses on the intersection and integration of architecture, acoustics, structure, robotics, fabrication, material and construction constraints into design and interdisciplinary collaborations. Reinhardt produces industry and state-government funded projects on new robotic applications for workspace scenarios, material applications and human robot collaborations. She collaborates with Lian Loke in their practice reinhardtloke.

Gili Ron is a research associate and a doctoral candidate at the Institute for Computational Design and Construction (ICD), Stuttgart Universität. She taught at the California Institute of the Arts (CalArts), Bezalel Academy, Jerusalem, Tel-Aviv University (TAU) and Berlin University of the Arts (UDK). Ron is a contributor and editor to Utopia Digital Magazine. Her works featured in re:publica (Berlin, 2021), VIRAL Festival (2020), RobArch (Zürich, 2019), DMS (Berlin, 2019), eCAADe (Łódź, 2018), TimberExpo UK (2017). Ron holds a B.Arch from the Azrieli School of

Architecture, Tel-Aviv University (TAU) and a M.Arch from the Emergent Technologies and Design Master Programme, The Architectural Association, London (EmTech, AA). She is part of Galath3a with Irina Bogdan.

Gabrielle Rossi is a PhD Fellow at CITA, Royal Danish Academy. Her research focuses on Machine Learning as an emerging modelling paradigm, and how it can change architectural practice. Specific accent is placed on architectural datasets, harvested or simulated, and potential applications for complex material behaviour, robotic fabrication and design performance.

Romana Rust is a computational architect and researcher at ETH Zurich. She co-leads the Immersive Design Lab, a lab for extended reality and machine learning. Her particular interest is the development of innovative computational methods that integrate multiple design objectives such as geometry, acoustics, materiality and robotic fabrication.

Maryam Shafiei is a Postdoctoral Research Fellow at the University of Queensland. Her PhD focused on the typology of changes and housing patterns in remote settlements. Her recent works employ computational design approaches and new construction technologies such as robotic additive manufacturing for positive development of remote settlements.

Anthea Elizabeth Sims is a medieval historian. She uses art to interpret historical transitions and developments. She investigates how art represents cultural concepts and how they change over time. For example, Roman culture leveraged the Greek tradition with a focus on realism that was represented in the realistic art of the Romans. Roman culture gave way to Byzantine where God became an abstract unworldly entity, and this transition is encapsulated in the iconic nature of Byzantine Art. Anthea interacted with a robot (Sony AIBO) for the first time in 2002 and has been exploring how robot design reflects culture using representations in art since 2009.

Müge Belek Fialho Teixeira is a creative maker, designer and transdisciplinary researcher, specialising in advanced manufacturing, digital fabrication, and parametric design. Currently, she is a Design Lead at ARM Hub (Advanced Robotics Manufacturing Hub) and a Senior Lecturer in the QUT Faculty of Engineering, School of Architecture and Built Environment Interior Architecture.

Mette Ramsgaard Thomsen is Professor and Head and founder of CITA at the Royal Danish Academy, where she focuses on the profound changes that digital technologies instigate in the way architecture is thought, designed and built. Recent work examines new design principles for bio design and how processes of renewable, regenerative and restorative resource thinking leads to sustainable design practice.

Deborah Turnbull Tillman is a curator specialising in design, technology and new media. Her first curatorial project was Beta_space, an experimental gallery at the Powerhouse Museum focused on the audience's role in interactive art. This fuelled her interest in how technology

augments traditional art practice and how the audience has become a necessary material for technology-based art. She was Assistant Curator, Design & Technology, Powerhouse Museum (2012-14). Her PhD examined disruption and experiential learning regarding curatorial process, and is titled 'New Media Curation: a novel methodology and preliminary criteria for exhibiting new media and interactive art.' Deborah is a Lecturer in Media Arts and Curatorial and Director of Education (UNSW). She leads the research stream for Culture and Technology across the Creative Robotics Lab and the National Facility for Human-Robot Interaction Research.

Lauren Vasey is a Postdoctoral researcher at Gramazio Kohler Research (GKR) at ETH Zurich and within the NCCR Digital Fabrication, where her research focuses on in situ robotic construction. Previously, she was a Research Associate at the Institute for Computational Design and Construction (ICD) at the University of Stuttgart where she focused on developing feedback-driven robotic construction processes.

Mari Velonaki's approach to Social Robotics research is informed by aesthetics and design principles from the theory and practice of Interactive Media Art. From 1997, Velonaki pioneered experimental interfaces allowing for the development of haptic and immersive relationships between participants and interactive agents. A Professor of Social Robotics at Arts, Design & Architecture, UNSW, she is also the founder and director of the Creative Robotics Lab and the National Facility for Human Robot Interaction Research.

Mary-Anne Williams works in AI and robotics innovation. She has developed models and algorithms for robot knowledge representations like robot beliefs, rationality, desires and intentions; robot emotions such as empathy, fear, and anger; and robot social intelligence including robot persuasion, social choices, interaction, collaboration, and joint decision making. Mary-Anne has published papers and given talks to expert and public audiences on robot compassion, robot cruelty, robot deception and robot social intelligence.

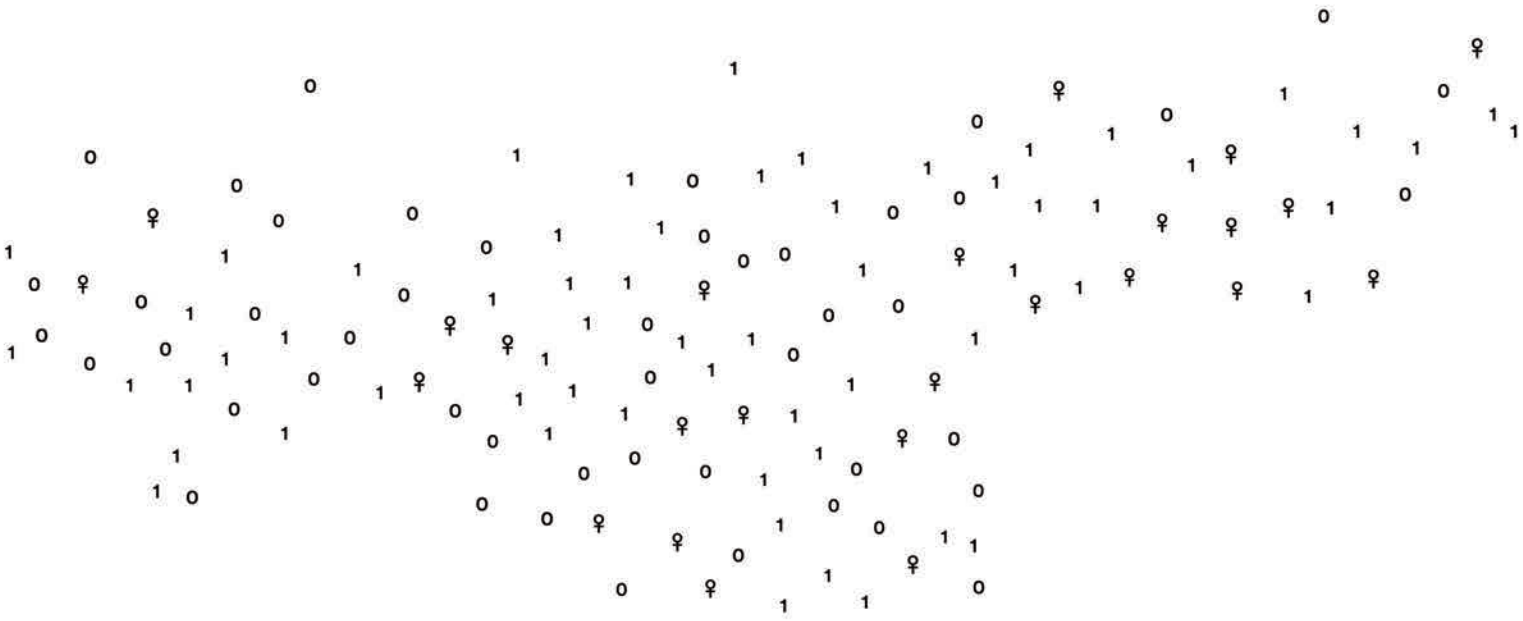
In support of better understanding of cultural practices with the most recent technologies, we acknowledge and pay respect to the Gadigal of the Eora Nation and their Elders past, present and emerging, who are the traditional custodians of knowledge of lands, waterways and Country. Their ancestral land on which The University of Sydney stands and where the exhibition takes place has never been ceded.

We thank the Dutch Ministry of Foreign Affairs, through the Embassy of Kingdom of the Netherlands, Australia and TU Delft, Robotics Institute, Netherlands, for generous funding that enabled the showcasing of *Bio-cyber-physical Planetoid* (2020-2021) by Associate Professor Henriette Bier (TU Delft).

We express our gratitude for the trust and generous support of the Tin Sheds Gallery, Kate Goodwin and Iakov Amperidis, and the External Engagement team in the School of Architecture, Design and Planning, The University of Sydney.

This exhibition proudly continues research of the Robotics Lab since its foundation in 2012, with the LivingLab components that continue to engage audiences in showcasing robots in action in support of hands-on experiences, and which would not be possible without the continuing support of DMaF, Dylan Wozniak-O'Connor and Lynn Masuda.

Catalogue design by Iris Shen and Lian Loke.



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