DISHITA TURAKHIA

PH.D. CANDIDATE | MIT

PART A

HUMAN-COMPUTER INTERACTION

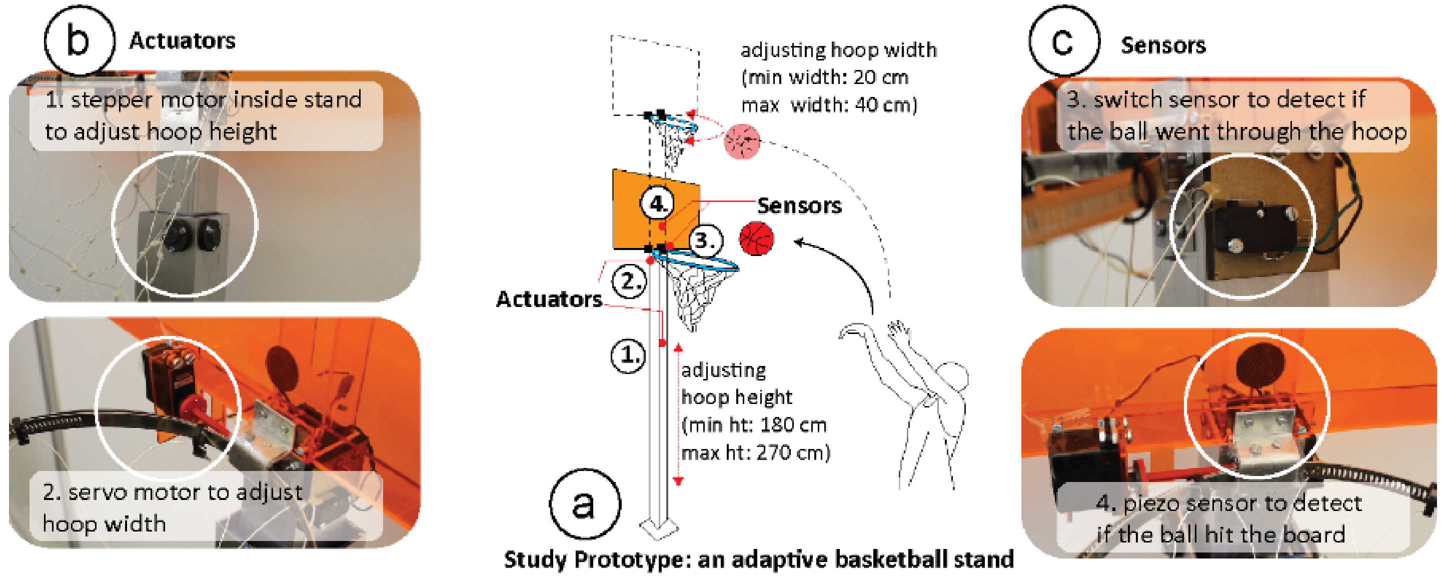
CLICK HERE FOR
PART B

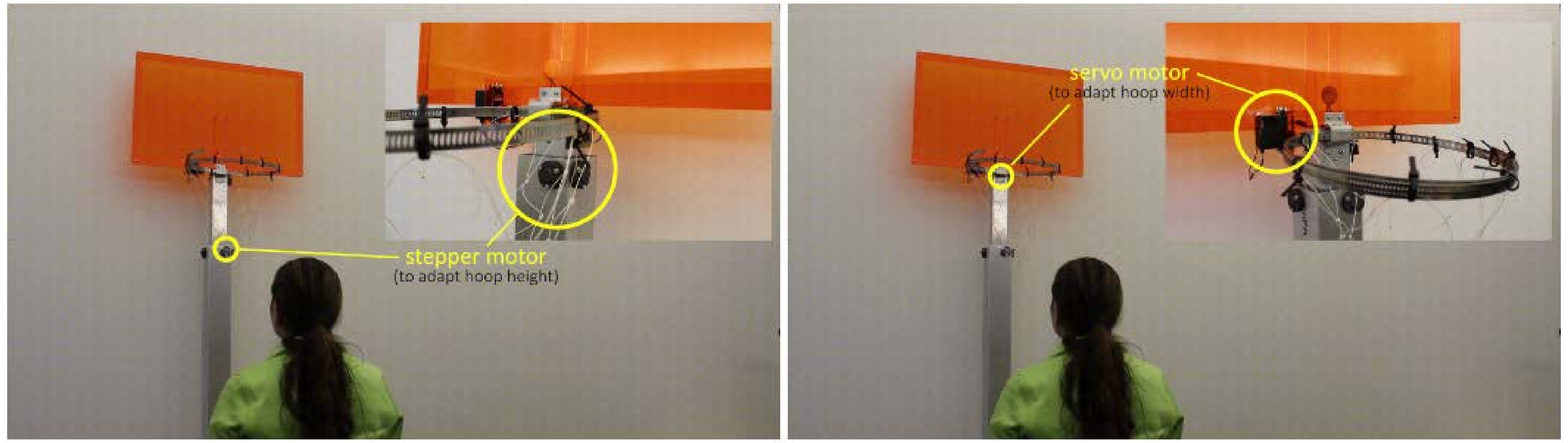
CONTENTS
(PART A - HCI)

ADAPTIVE LEARNING - STUDY

VISION

Adaptive tools that can change their shape to support users with motor tasks have been used in a variety of applications, such as to improve ergonomics and support muscle memory. In this paper, we investigate whether shape-adapting tools can also help in motor skill training. In contrast to static training tools that maintain task difficulty at a fixed level during training, shape-adapting tools can vary task difficulty and thus keep learners' training at the optimal challenge point, where the task is neither too easy, nor too difficult.



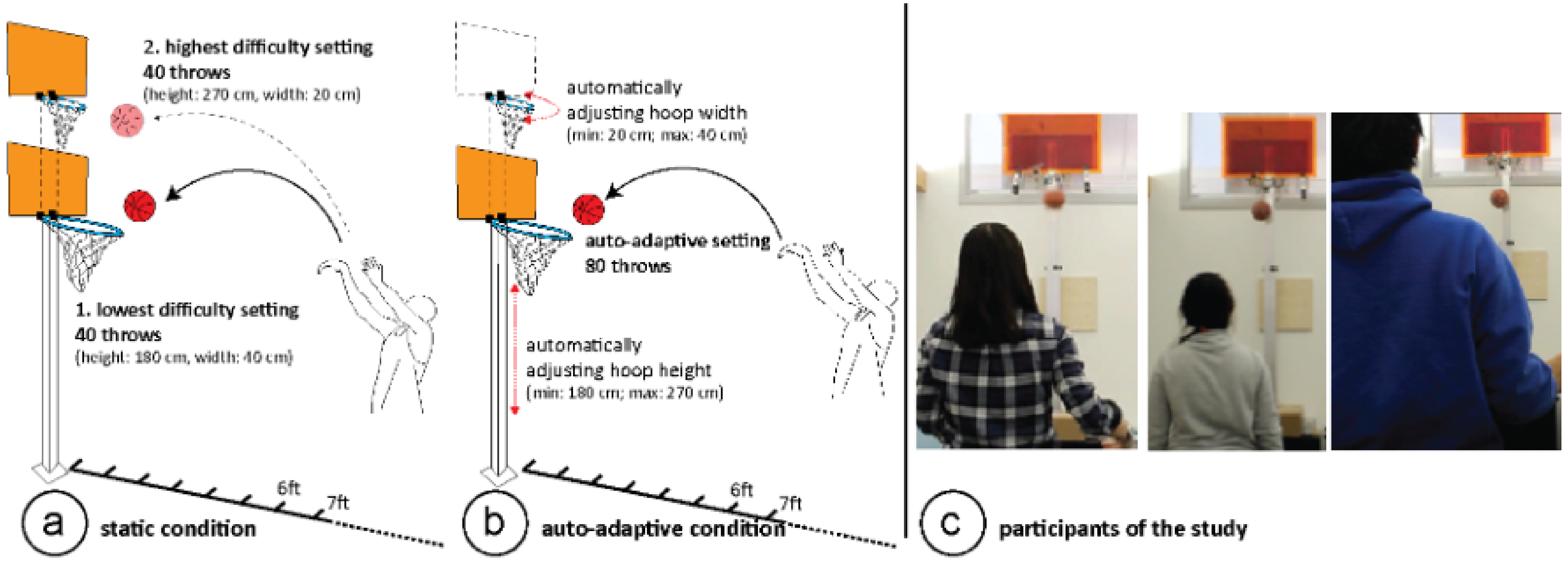


Does adapting the task difficulty during training lead to higher learning gains?

LEARNING STUDY

APPLICATION

To investigate whether shape adaptation helps in motor skill training, we built a study prototype in the form of an adaptive basketball stand that works in three conditions: (1) static, (2) manually adaptive, and (3) auto-adaptive. For the auto-adaptive condition, the tool adapts to train learners at the optimal challenge point where the task is neither too easy nor too difficult. Results from our two user studies show that training in the auto-adaptive condition leads to statistically significant learning gains when compared to the static ($F_{(1,11)} = 1.856$, $p<0.05$) and manually adaptive conditions ($F_{(1,11)} = 2.386$, $p < 0.05$).



CONTRIBUTIONS

Using our study prototype and the adaptation approach of the optimal challenge point, we demonstrated that training in an auto-adaptive condition leads to higher learning gains when compared to training in a static or manually adaptive condition. We showed that the experience of training in the auto-adaptive condition is also more enjoyable for learners since it removes the decision making process around which difficulty level to train on and provides feedback to the learner in the form of the shape-adaptation of the tool.

ADAPT2LEARN

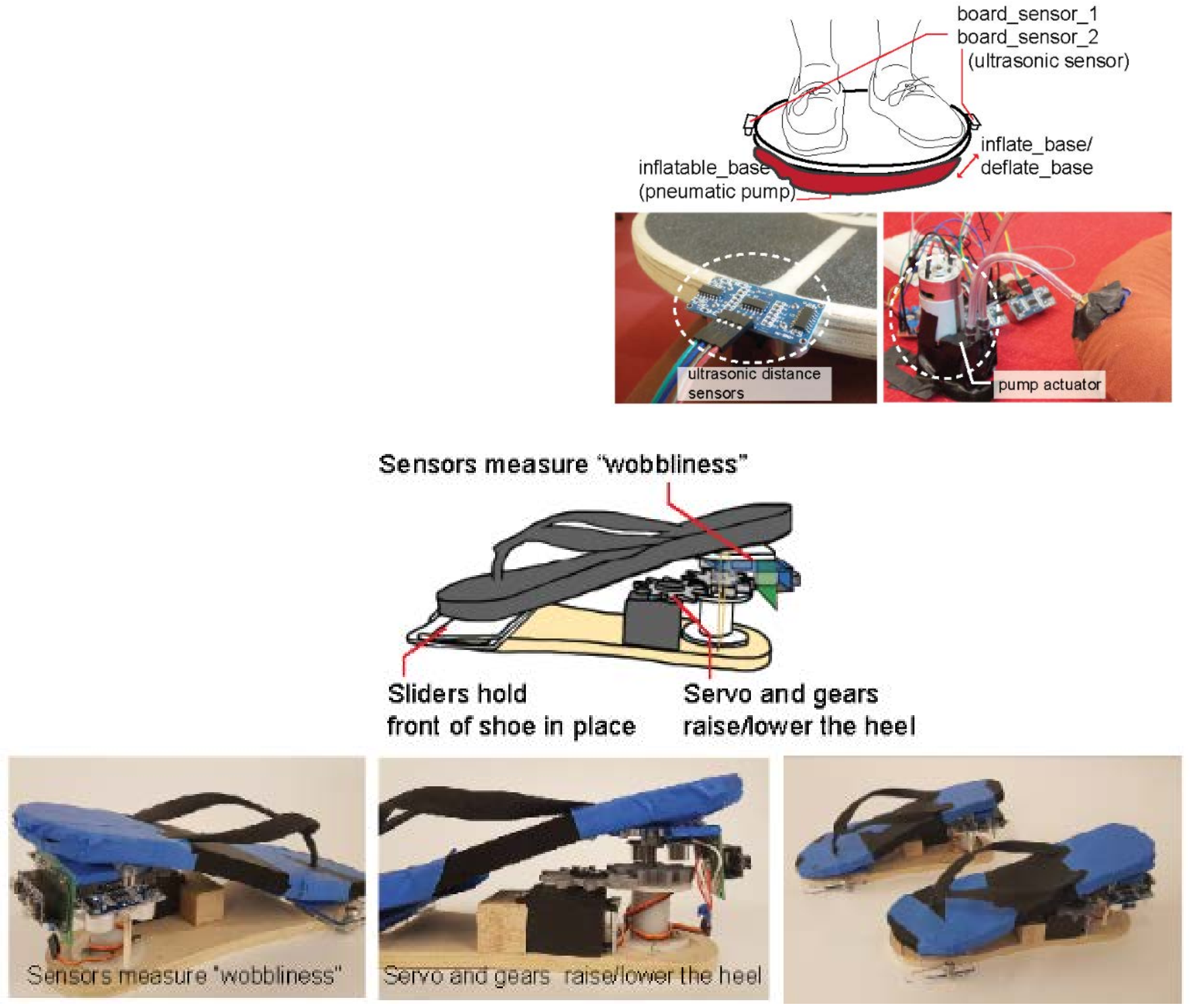
VISION

Recent study on motor-skill training suggests that adaptive training tools that use shape-change to adapt the training difficulty based on learners' performance can lead to higher learning gains. However, to date, no support tools exist to help designers create adaptive learning tools. Our formative study shows that developing the adaptive learning algorithm poses a particular challenge.

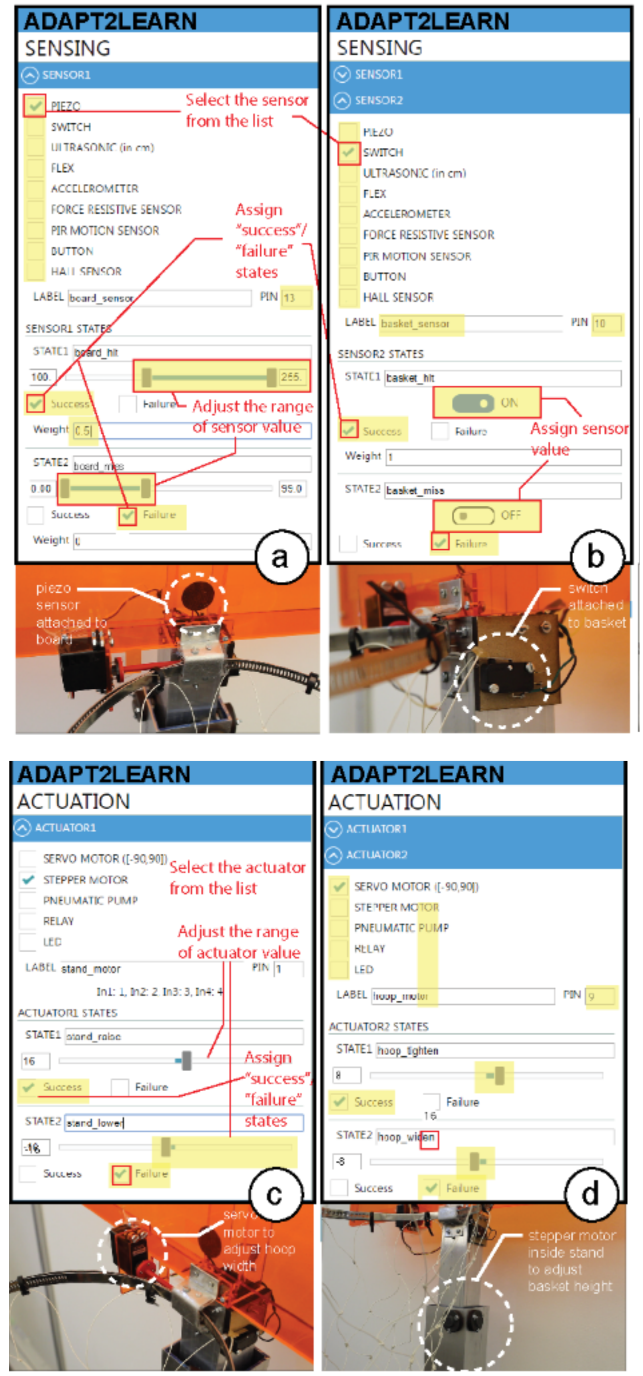
How can we assist designers to build adaptive training tools for skill-learning?

TOOLKIT DESIGN

To address this, we built Adapt2Learn, a toolkit that auto-generates the learning algorithm for adaptive tools. Designers choose their tool's sensors and actuators, Adapt2Learn then configures the learning algorithm and generates a microcontroller script that designers can deploy on the tool. Once uploaded, the script assesses the learner's performance via the sensors, computes the training difficulty, and actuates the tool to adapt the difficulty. Adapt2Learn's visualization tool then lets designers visualize their tool's adaptation and evaluate the learning algorithm. To validate that Adapt2Learn can generate adaptation algorithms for different tools, we build several application examples that demonstrate successful deployment.



APPLICATION



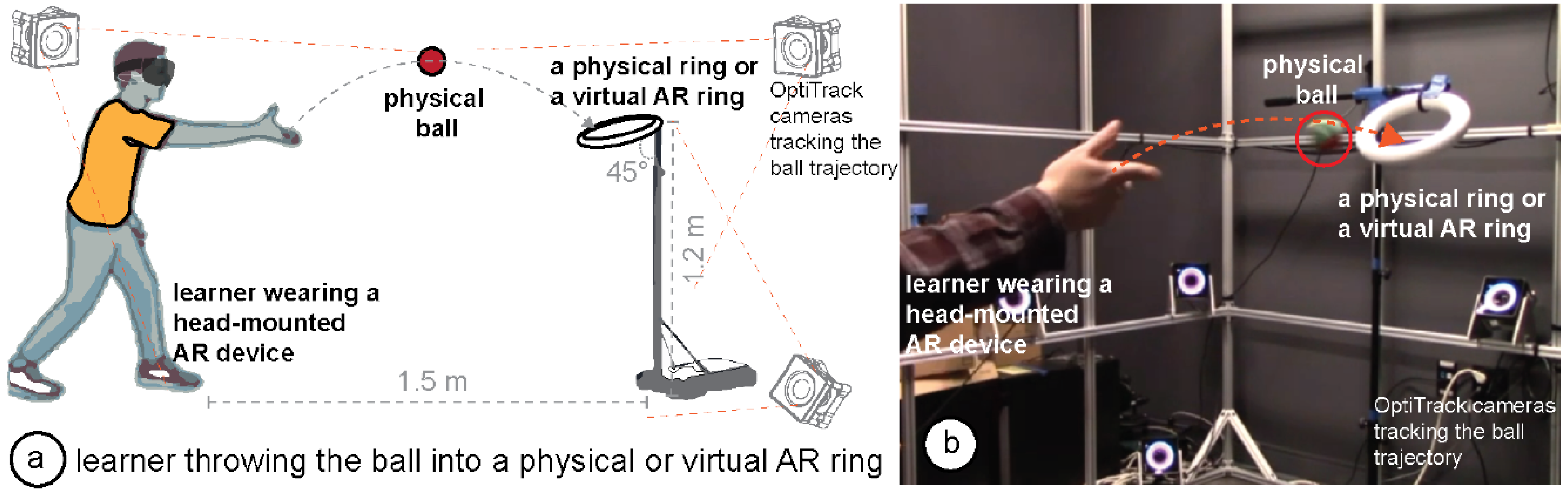
CONTRIBUTIONS

We illustrated how Adapt2Learn supports designers in configuring the learning algorithm for their custom adaptive training tools. Adapt2Learn's built-in visualization tool then supports designers in assessing the learner's performance and the tool's adaptation. The interface also allows designers to update the learning algorithm without re-programming the microcontroller code.

ADAPTIVE LEARNING IN AR

VISION

The acquisition of motor skills typically involves personalized training, with trainers adjusting the difficulty level according to a learner’s abilities. However, not everyone has access to a personal trainer, which limits the availability of tailored learning experiences. Recent research in motor skill learning has demonstrated that using physically-adaptive training tools that dynamically adjust the training task difficulty based on individual performance, can enhance learning outcomes compared to non-adaptive methods for selftraining of motor skills. Our research seeks to capitalize on this finding by examining how augmented reality (AR) can be leveraged to virtually adapt training tools and adjust the training task difficulty during self-training.

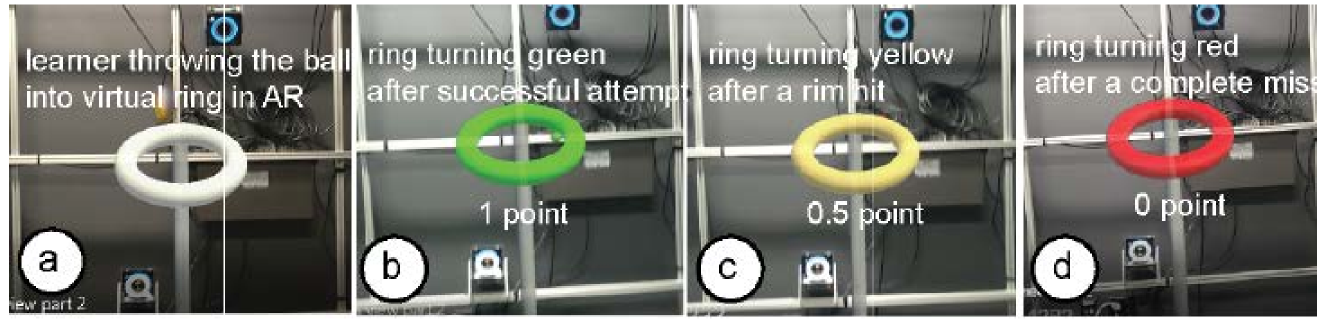


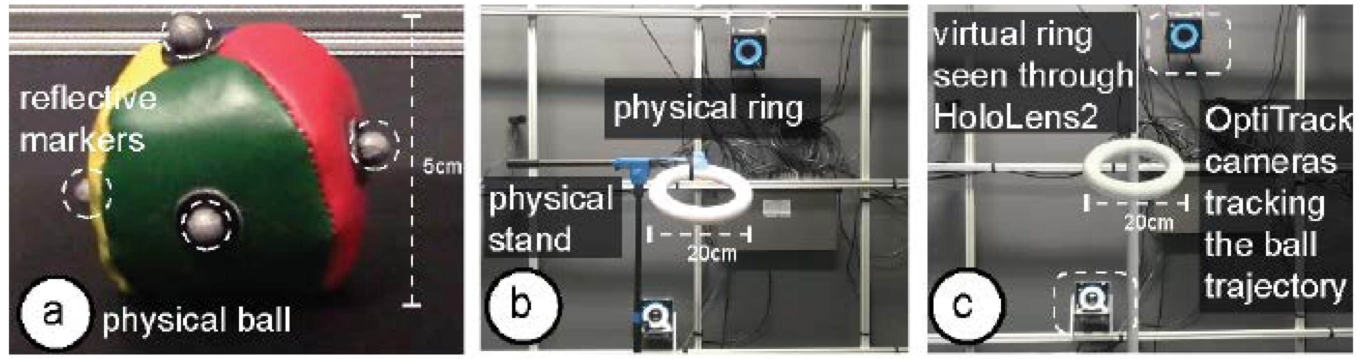
Can adapting the training using Augmented Reality tools support in skill-learning?

LEARNING STUDY

APPLICATION

This paper investigates the use of AR to design virtual adaptive tools that adjust functional task difficulty during motor skill training. Inspired by previous work on adaptive physical tools, we developed an adaptive virtual hoop in AR for ball-throwing training. Our system tracked the physical ball's trajectory, monitored the learner's performance, and adapted the diameter of a virtual hoop, displayed in AR via a Head Mounted Display\footnote{HoloLens 2, to match the user's skill level. We conducted a between-subjects user study with 16 participants, comparing performance improvements in the physical environment when training using a static virtual AR hoop versus an adaptive virtual AR hoop that changed diameter. We collected quantitative performance data and qualitative feedback to investigate challenges and opportunities in adaptive AR tool design.





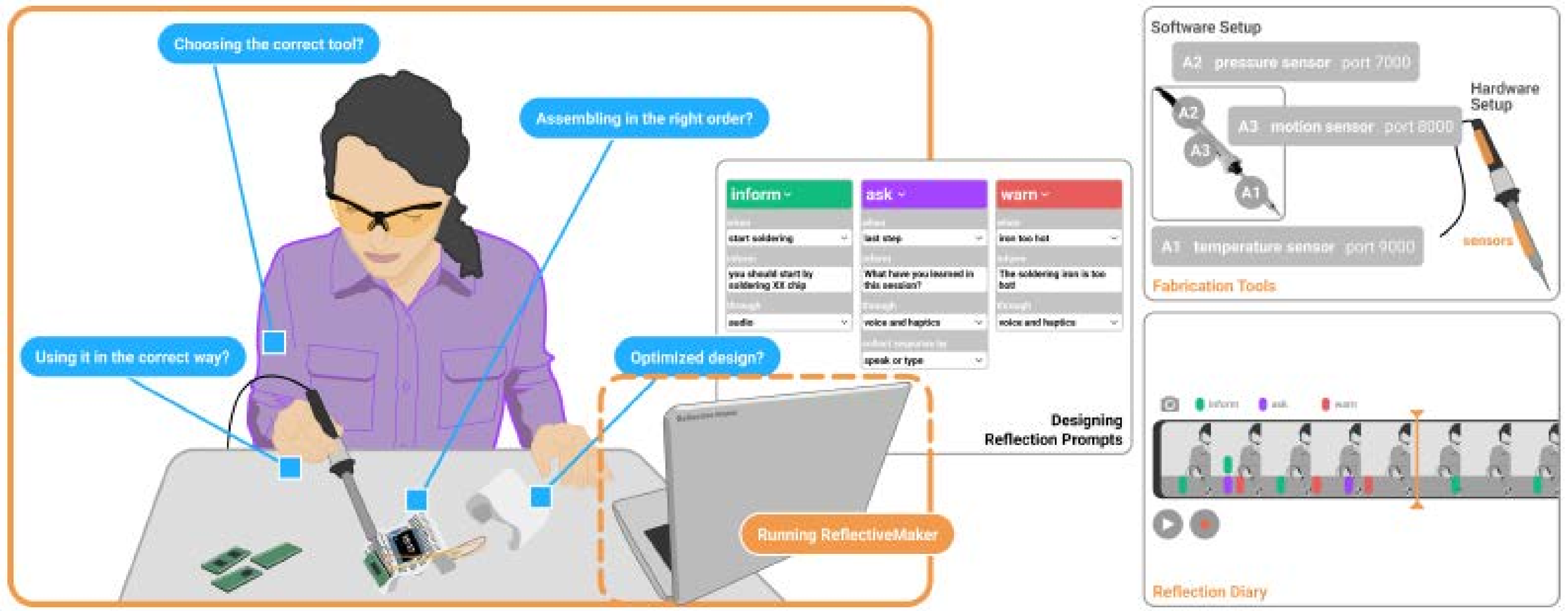
CONTRIBUTIONS

The learning gains results suggest that there may be a trend towards improved performance with adaptive AR, but further investigation is needed to establish statistical significance. Even though, the preference for the adaptive condition was slightly higher than that for the non-adaptive condition, the significantly higher preference for the baseline condition compared to both the AR training conditions highlights the need to further understand the impact of AR training tools on the learning experience.

REFLECTIVE LEARNING

VISION

Reflection is a powerful learning tool that allows learners to analyze successful and unsuccessful attempts at a task, leading to a deeper understanding and improved learning outcomes. The role of reflective exercises in supporting learning is widely studied in HCI. This has led to the development of several theories to understand reflective processes, frameworks to leverage reflection for improving learning, and systems to nudge reflective exercises during different tasks, such as musical skill development, and professional development. However, these ideas have not been explored in the context of maker skills learning. We bridge this gap through ReflectiveMaker - a toolkit to create reflection exercises for novices to complete during their maker projects.

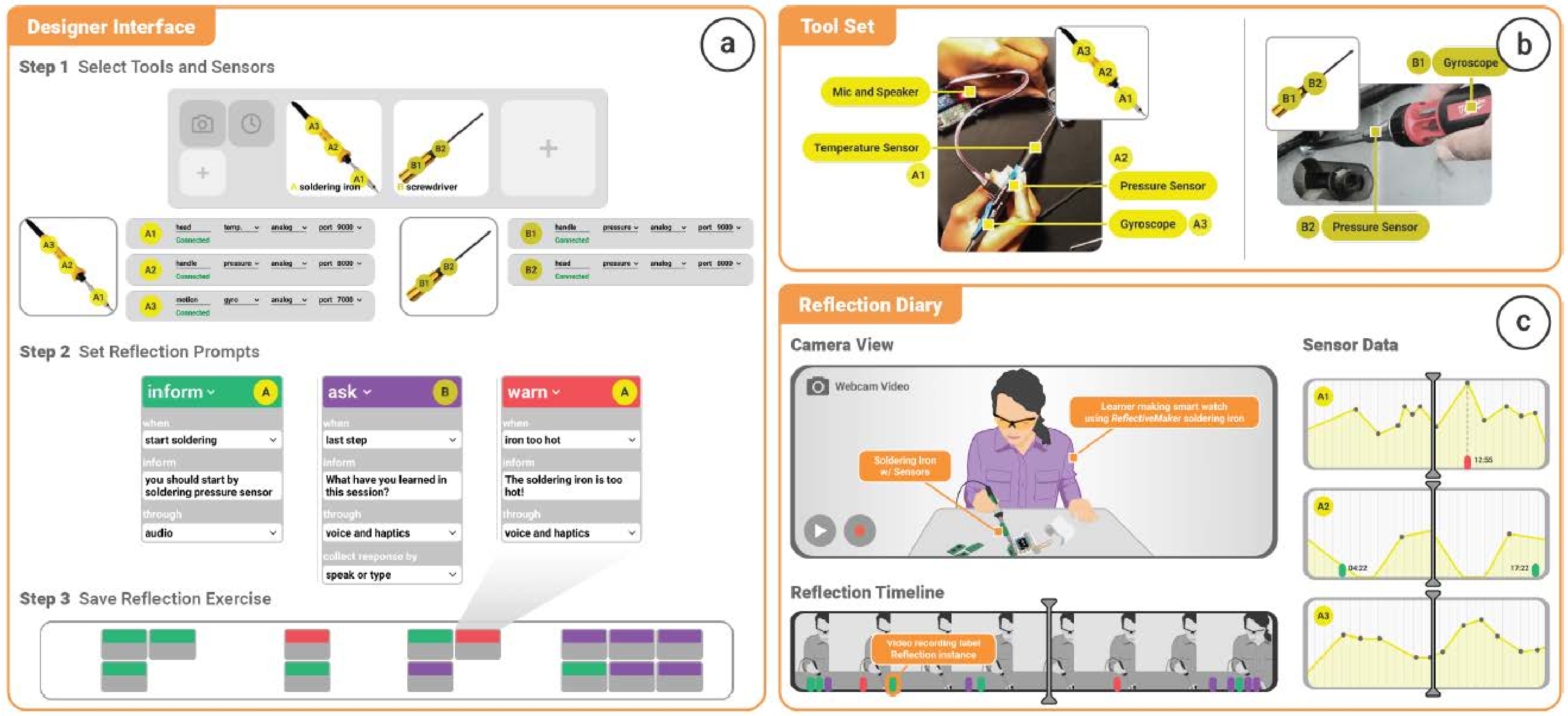


How can we prompt learners to engage in self-reflection during maker activities?

TOOLKIT DESIGN

RESEARCH

This toolkit monitors the learners' performances in real-time and prompts them to reflect both in-action and on-action i.e., during and after their maker activities. In this paper, we build on this prior work and use an augmented reality system to monitor, prompt, and record in-action reflections, i.e., while the maker activity is in progress. In particular, we propose a framework to design multi-modal reflective prompts for self-learning exercises using augmented reality with three specific goals - (1) adding real-world contextualization, (2) overlaying personalized multimodal contextual information for supporting in-action reflections, and (3) maintaining an immersive experience during the reflection exercises.



CONTRIBUTIONS

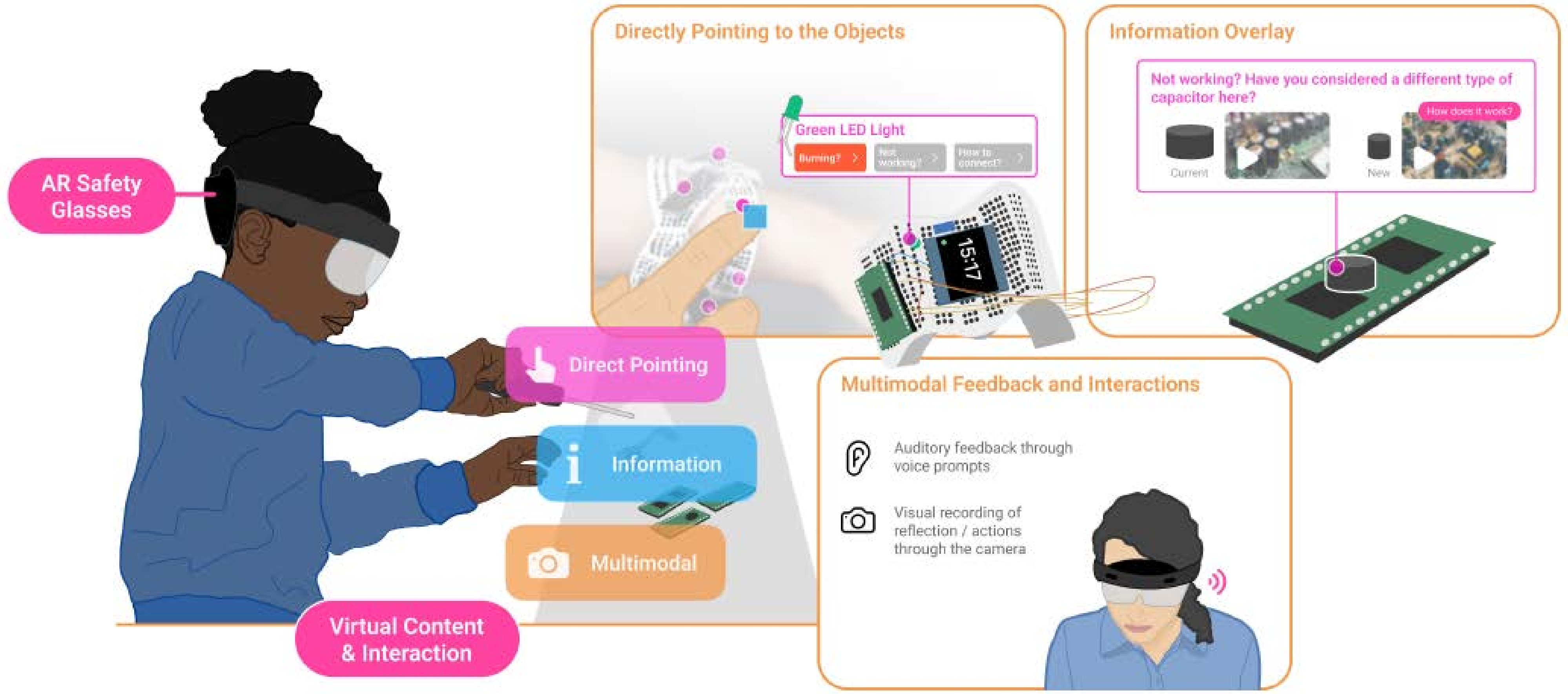
We presented ReflectiveMaker, a toolkit support reflection-based learning for novices in makerspaces. Experts and educators can use ReflectiveMaker to design the reflection prompts during fabrication activities, sense the user's activities and identify suitable events for prompting reflection, and record the user's reflections and analyze data on the learner's progress over time.

REFLECTIVE LEARNING IN AR

VISION

Reflection is described as ``a conscious, purposeful thought directed at a problem" with the goal to gain a deeper understanding of the problem. A reflective exercise typically consists of sequential thoughts aimed at problem inquiry and is often elicited through self-dialogue, social discourse (for example, with an instructor), or human-computer interaction (for example, with a system). The impact of the reflective exercises is generally an increase in knowledge, improvement in performance, or reduction of errors.

Augmented reality (AR) can enhance learning makerskills by allowing them to reflect on their work in a more contextual, immersive, and multimodal interactive way. AR can provide learners with real-world context for reflection as they work on fabrication projects by overlaying digital information onto the physical world.

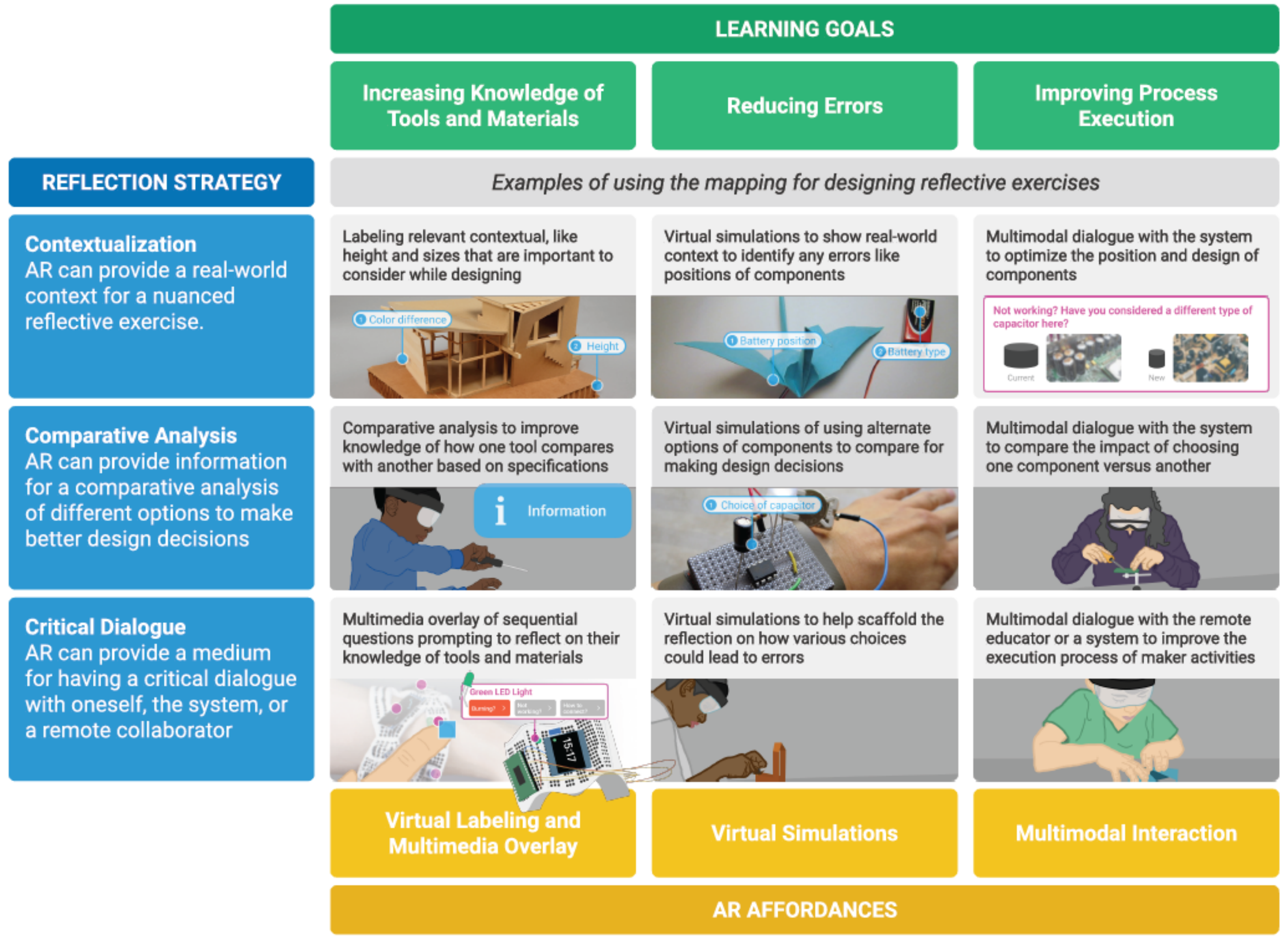


How can we design multimodal reflection prompts using Augmented Reality affordances?

FRAMEWORK

RESEARCH

In this work, we propose a framework to design multi-modal reflective prompts for self-learning exercises using augmented reality with three specific goals - (1) adding real-world contextualization, (2) overlaying personalized multimodal contextual information for supporting reflection, and (3) maintaining an immersive experience during reflection exercises. We present an end-to-end pipeline to design the reflection prompts using Optitrack to sense the performance and an AR app built using Unity3D and deployed on the HoloLens head-mounted AR device.



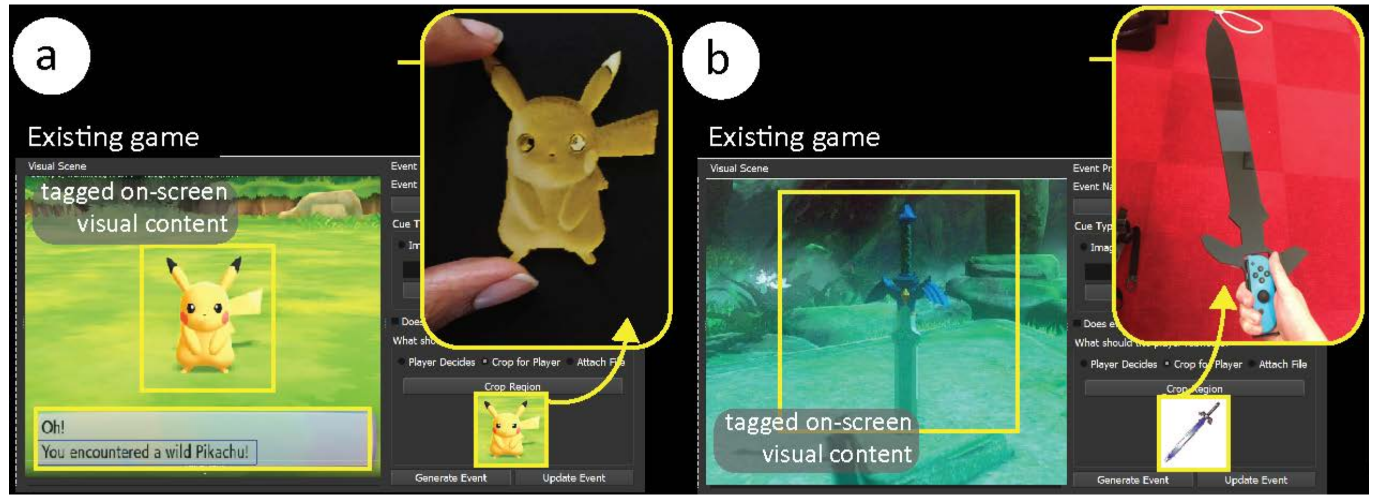
CONTRIBUTIONS

We demonstrate three cases of reflective exercises in art and design, engineering, and remote learning applications. We then detail our plans for future work on evaluating the impact of our AR-based reflection approach on learning makerskills through three user studies.

FABO

VISION

Fabricating objects from a player's gameplay, for example, collectibles of valuable game items, or custom game controllers shaped from game objects, expands ways to engage with digital games. Researchers currently create such integrated fabrication games from scratch, which is time-consuming and misses the potential of integrating fabrication with the myriad existing games. Integrating fabrication with the real-time gameplay of existing games, however, is challenging without access to the source files.



How can we use existing video games to teach fabrication to novice learners?

TOOLKIT DESIGN

APPLICATION

To address this challenge, we present a framework that uses on-screen visual content to integrate fabrication with existing digital games. To implement this framework, we built the FabO toolkit, in which (1) designers use the FabO designer interface to choose the gameplay moments for fabrication and tag the associated on-screen visual cues; (2) players then use the FabO player interface which monitors their gameplay, identifies these cues and auto-generates the fabrication files for the game objects. Results from our two user studies show that FabO supported in integrating fabrication with diverse games while augmenting players' experience.

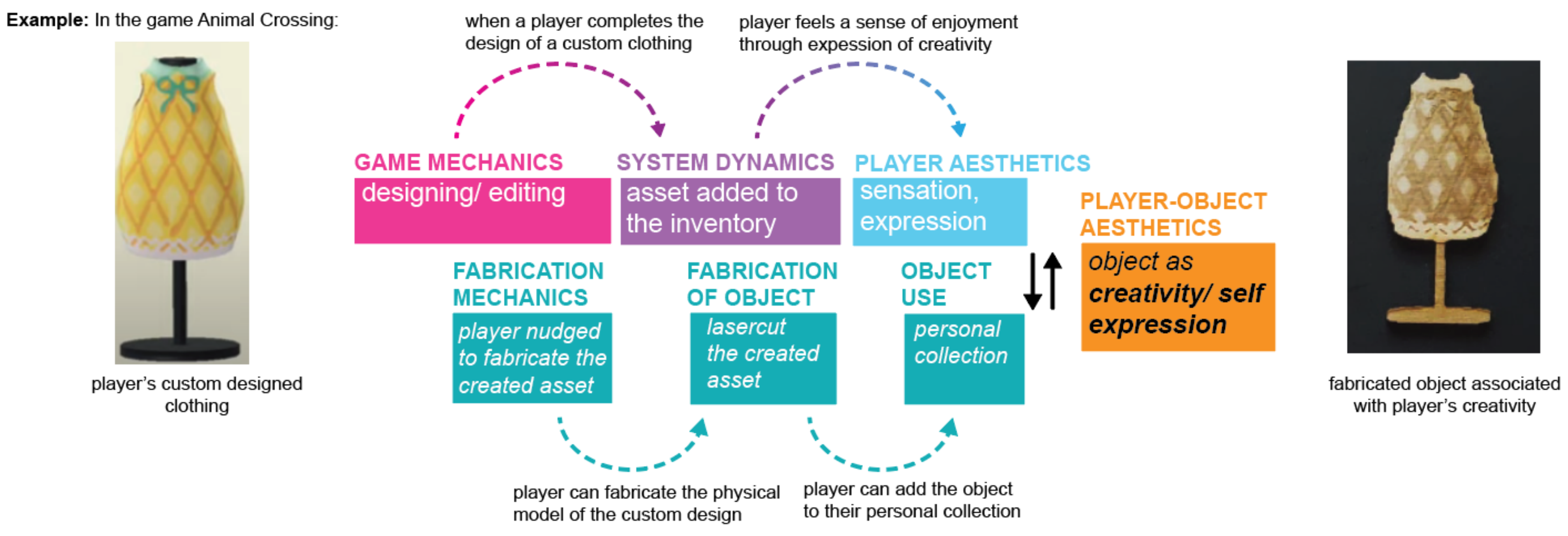
CONTRIBUTIONS

We showed that fabricating objects from player's gameplay, such as collectibles, can be accomplished using our FabO framework, which allows designers to use on-screen content instead of source files for integration and auto-generation of fabrication files. We implemented our framework in the FabO toolkit and demonstrated FabO's workflow that uses computer vision for tagging on-screen visual cues for embedding events and extracting on-screen objects for fabrication.

F-MDA FRAMEWORK

VISION

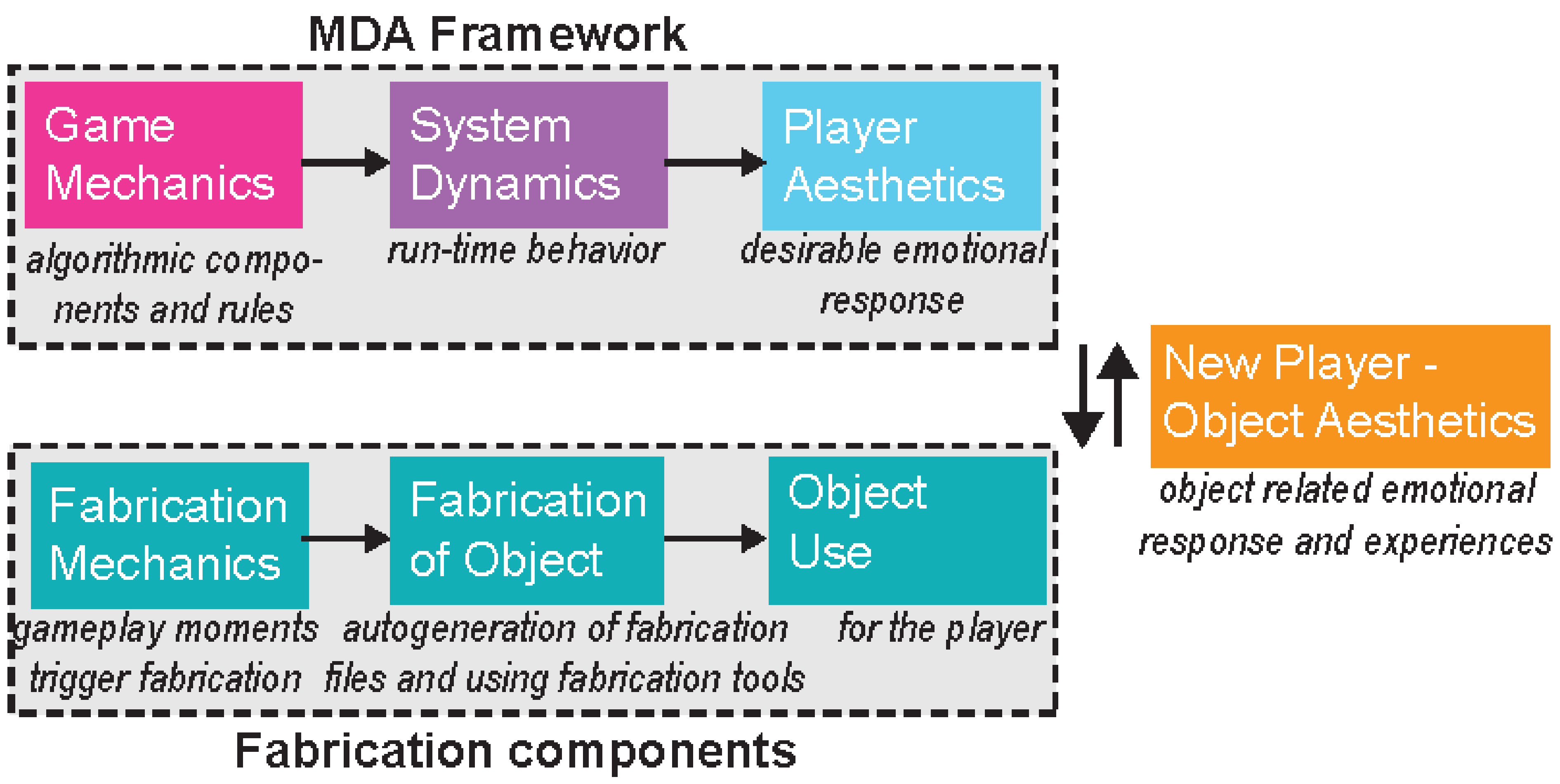
Integrating fabrication activities into existing video games provides opportunities for players to construct objects from their gameplay and bring the digital content into the physical world. In our prior work, we outlined a framework and developed a toolkit for integrating fabrication activities within existing digital games. Insights from our prior study highlighted the challenge of aligning fabrication mechanics with the existing game mechanics in order to strengthen the player aesthetics.



How can we support designers to integrate fabrication within existing gameplay moments?

RESEARCH

In this paper, we address this challenge and build on our prior work by adding fabrication components to the Mechanics-Dynamics-Aesthetics (MDA) framework. We use this f-MDA framework to analyze the 47 fabrication events from the prior study. We list the new player-object aesthetics that emerge from integrating the existing game mechanics with fabrication mechanics. We identify connections between these emergent player-object aesthetics and the existing game mechanics. We discuss how designers can use this mapping to identify potential game mechanics for integrating with fabrication activities.



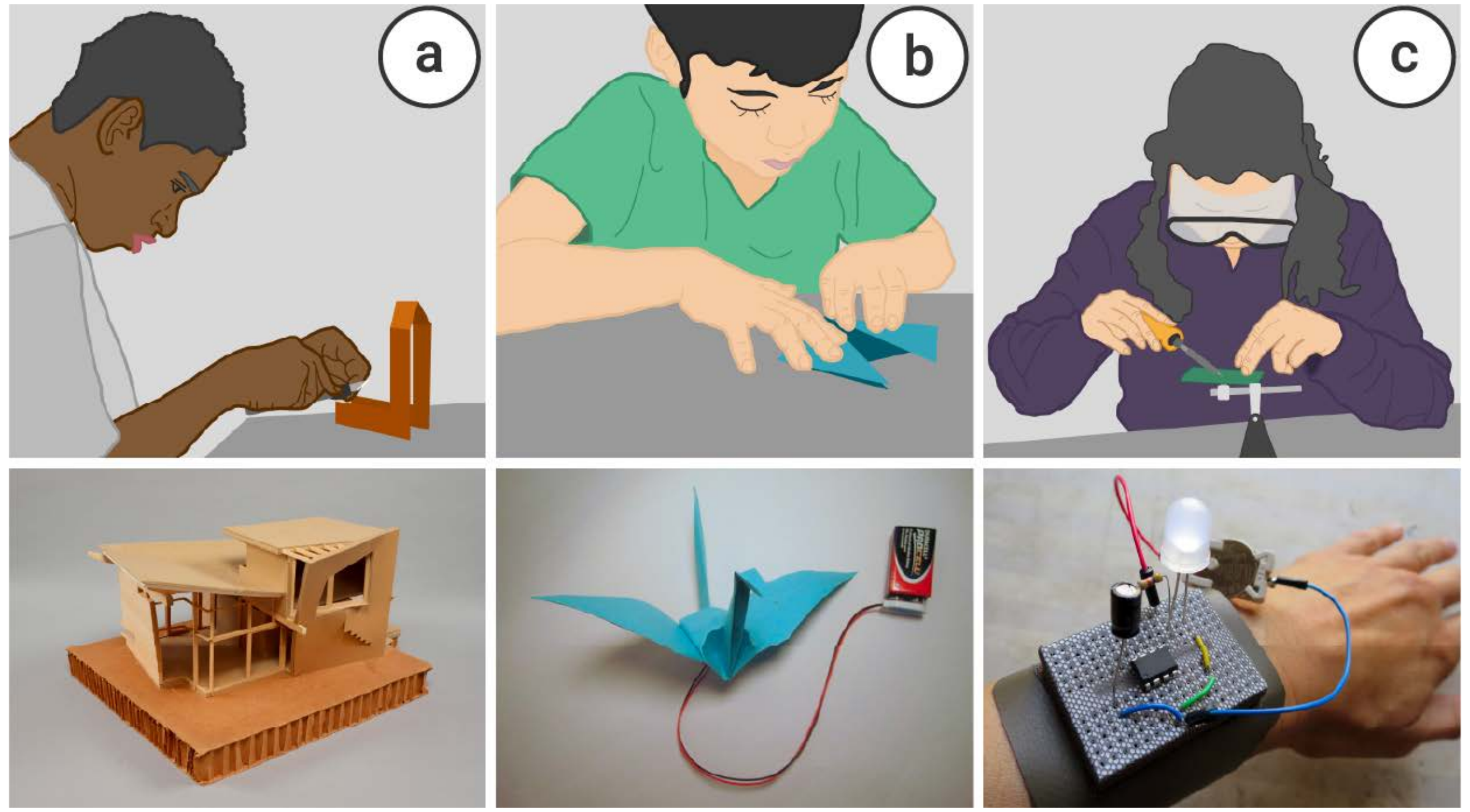
CONTRIBUTIONS

In this paper, we expanded on the prior work on integrating fabrication events with existing digital games. We first analyzed the results from the prior study from a game design perspective, using the Mechanics-Dynamics-Aesthetics framework, that we modified to f-MDA to incorporate the fabrication components.

THEMATIC ANALYSIS

VISION

Makerspaces persist as formal and informal spaces of learning for youth, promoting a continued interest in studying how design can support the variety of learning opportunities within these spaces. However, much of the current research examining learning in makerspaces neglects the perspectives of educators. This not only hinders our understanding of educators' goals and how educators navigate makerspaces, but also constrains how we frame design problems within the HCI community.

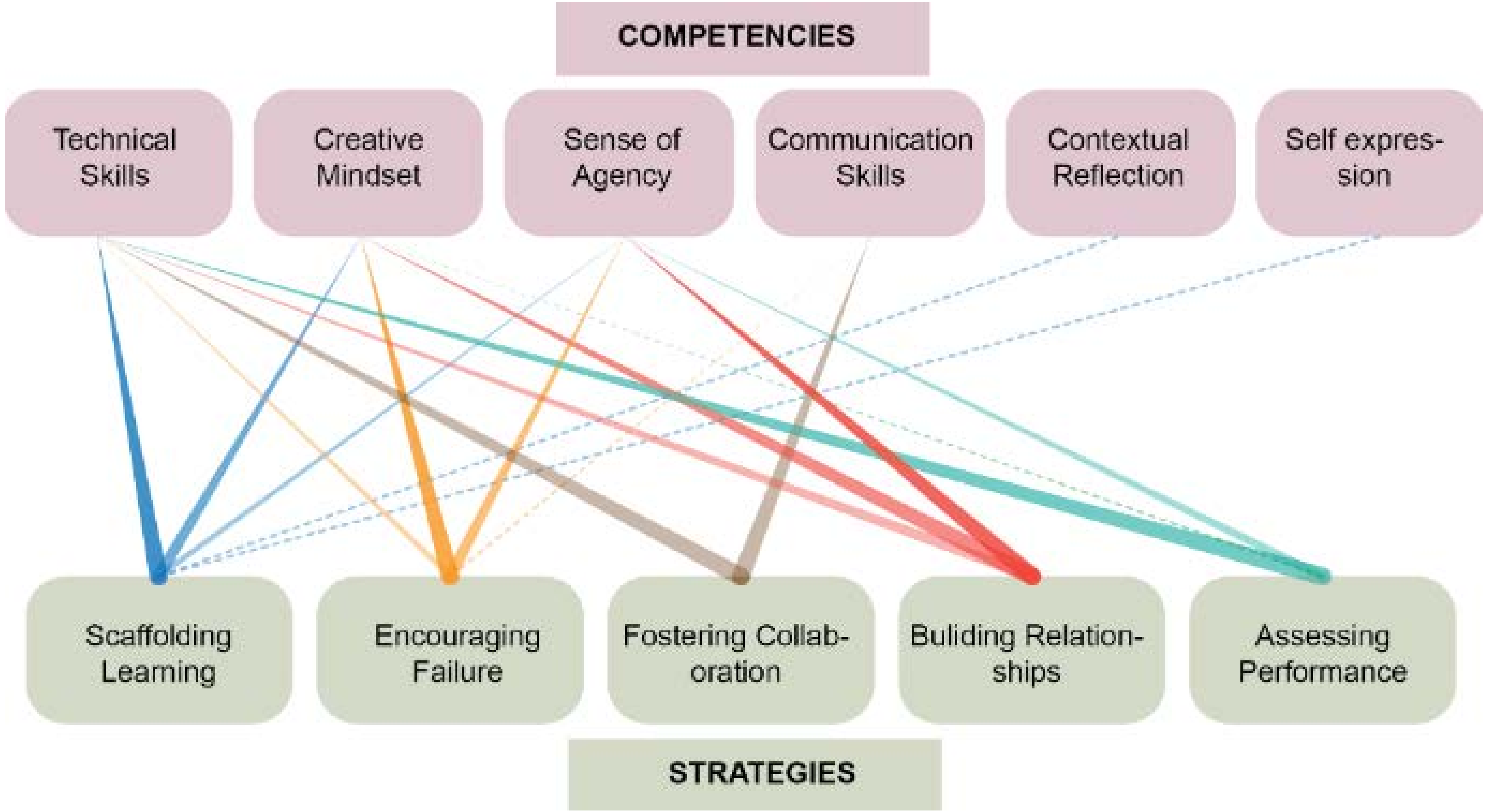


What are the educator practices within makerspaces that scaffold skill-learning?

QUALITATIVE RESEARCH

RESEARCH

To address this, we engaged in a set of semi-structured interviews to examine the contexts, goals, values, and practices of seven educators across five makerspaces. A thematic analysis of the data identified six key categories of competencies that these educators prioritize including a range of skills, practices, and knowledge, such as technical proficiency, communication, and contextual reflection. The analysis also identified five categories of strategies to accomplish certain goals, such as scaffolding, collaboration, and relationship building. Last, it also shed light on three categories of challenges faced at the student-level, teacher-level, and institutional level.



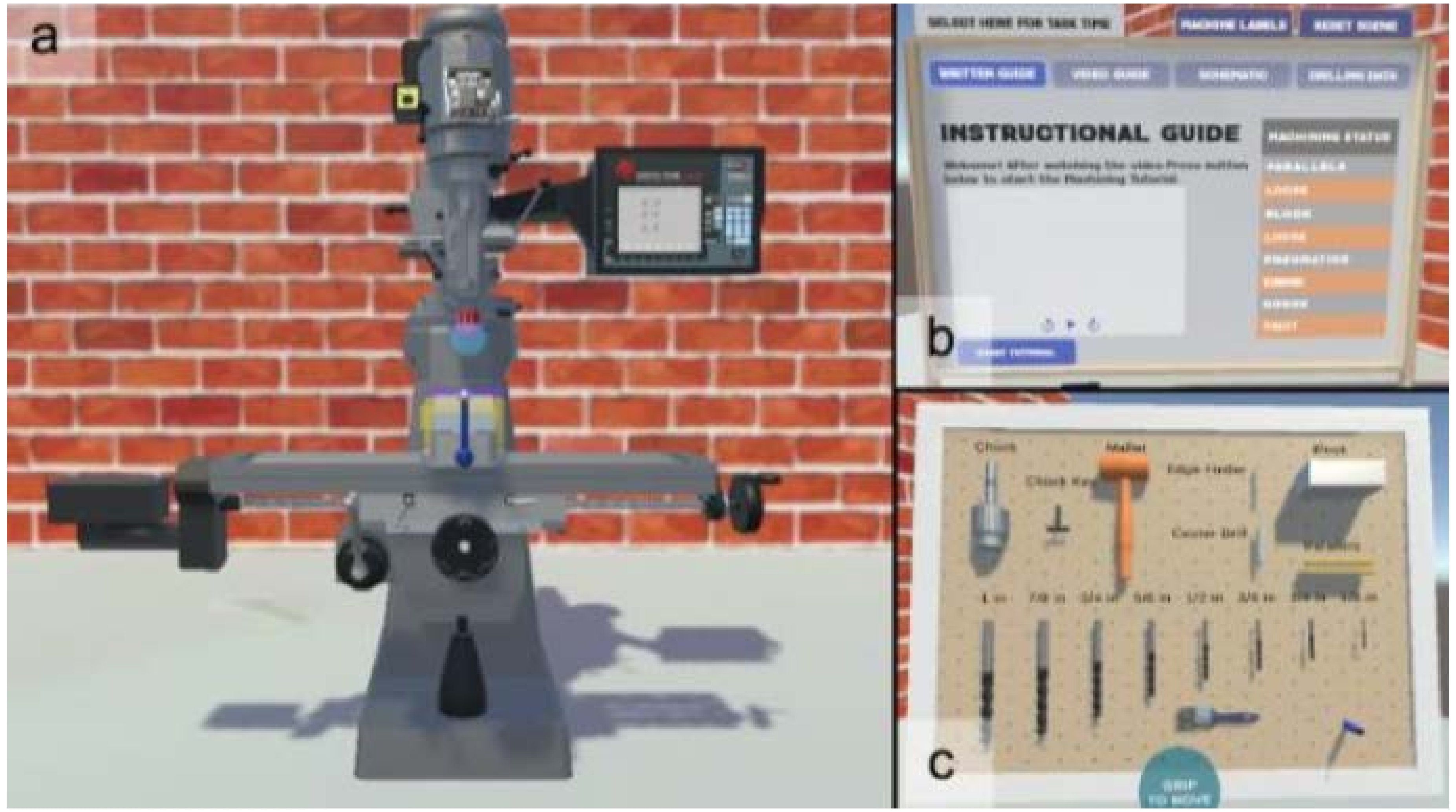
CONTRIBUTIONS

The way educators understand learning opportunities is central to how they structure activities and thus central to how learning occurs in these spaces. Building our understanding of how educators scope and prioritize learning within their environments is central to how we design for learning. By better understanding the perspectives and practices of educators, we can create more supportive learning environments that allow for effective pedagogical practices.

LEARNING MACHINING IN VR

VISION

Virtual Reality (VR) can support effective and scalable training of psychomotor skills in manufacturing. However, many industry training modules offer experiences that are close-ended and do not allow for human error. We aim to address this gap in VR training tools for psychomotor skills training by exploring an open-ended approach to the system design.



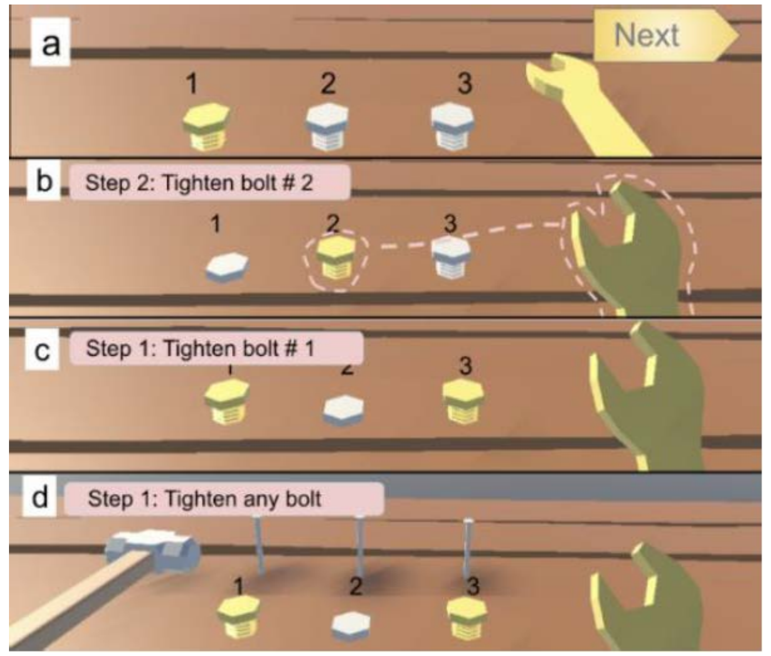
How can we train novices on machining tasks using open-ended systems in Virtual Reality?

LEARNING STUDY

APPLICATION

An open-ended VR system to train users to drill using a 3-axis milling machine. Our system allowed for multiple pathways to achieve the goal wherever possible and restricted the users to a single pathway wherever the tool required a strict protocol for operation. Arrows indicate pathways through tasks, a bracket indicates multiple pathways through tasks within one skill, with interchangeability between the tasks in vice set up and chuck set up.

We designed a VR training simulation prototype to perform open-ended practice of drilling using a 3-axis milling machine. The simulation employs near "end-to-end" instruction through a safety module, a setup and drilling tutorial, open-ended practice complete with warnings of mistakes and failures, and a function to assess the geometries and locations of drilled holes against an engineering drawing. We developed and conducted a user study within an undergraduate-level introductory fabrication course to investigate the impact of open-ended VR practice on learning outcomes.



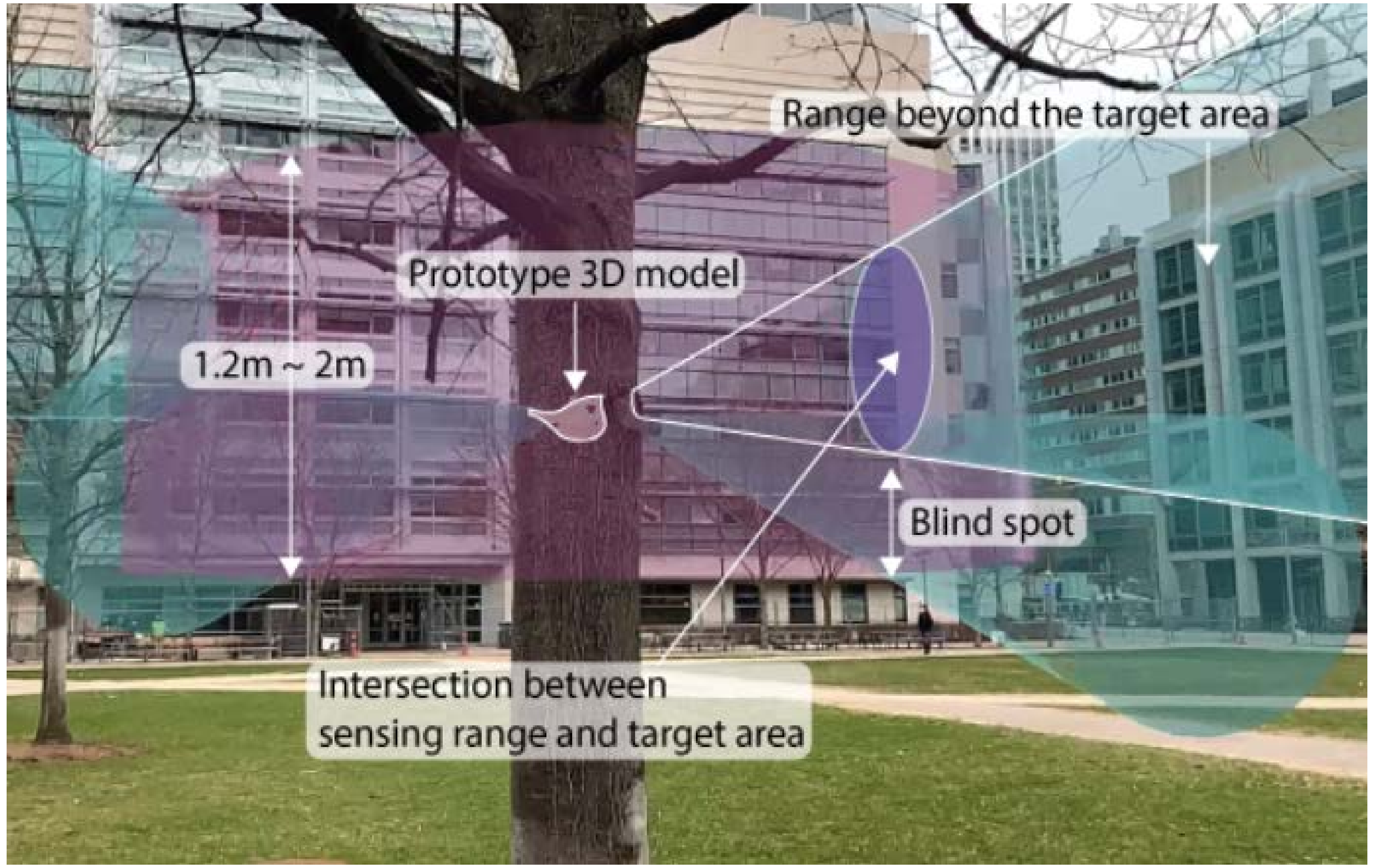
CONTRIBUTIONS

Designing open-ended virtual reality (VR) training systems presents both limitations and design opportunities that have the potential to shape the future of training of hands-on skills. In this section, we discuss some of the big takeaways of our work and how the design implications from our study can inform the design of open-ended training systems in VR.

SENSORVIZ

VISION

Over the past decades, the availability of sensors has increased substantially and enabled makers and designers to prototype interactive objects rapidly and at low cost. However, this large variety of components also comes with the challenge of selecting the right sensor from many similar components to fnd the one that best fts the use case at hand. Since each sensor has its own specifcation, understanding what each sensor can sense and how it will work on a prototype can be a time-consuming process.



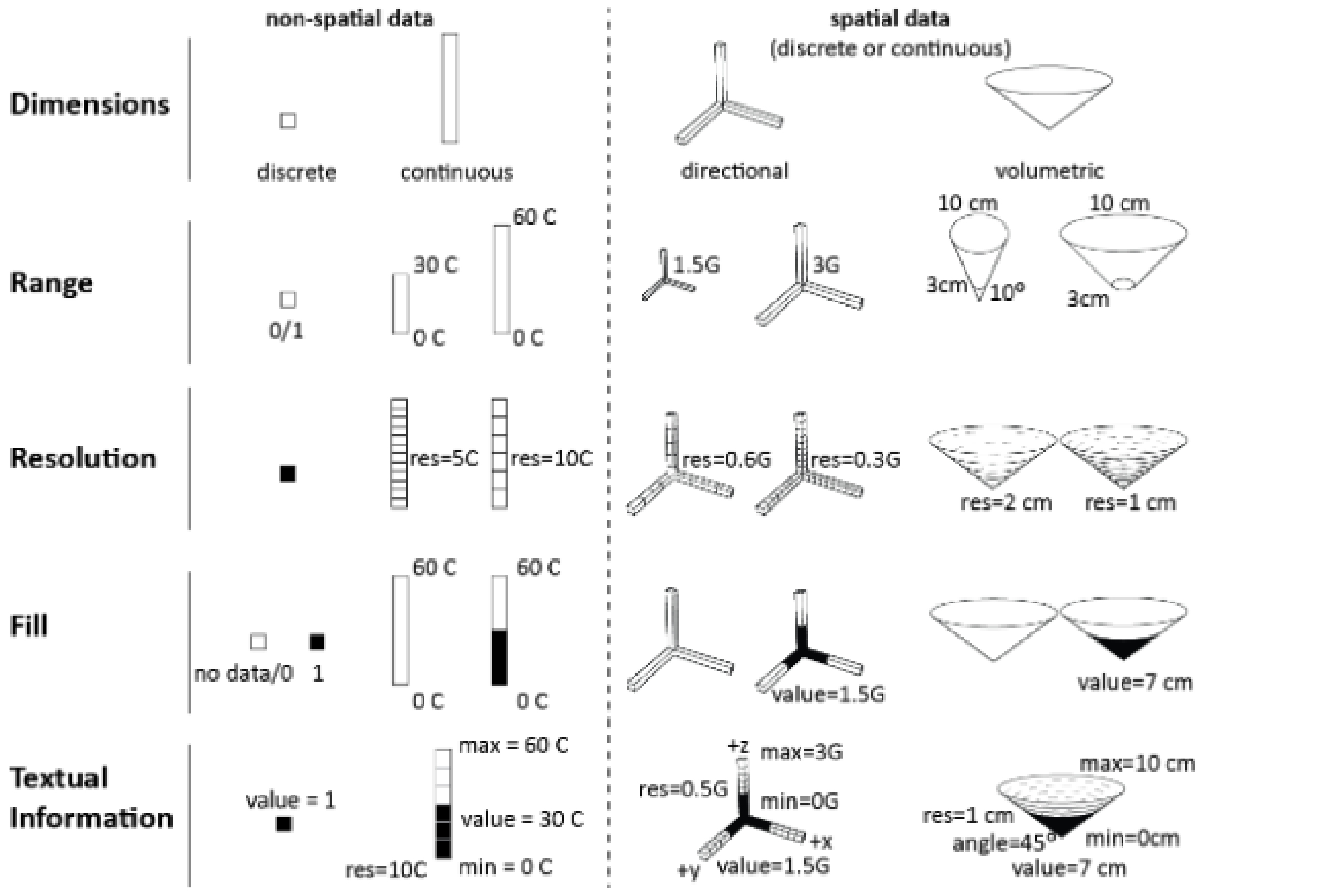
How can we support novices in the design of interactive objects using visualization in Augmented Reality?

TOOLKIT DESIGN

APPLICATION

SensorViz, a visualization tool that supports novice makers during diferent stages of prototyping with sensors. SensorViz provides three modes of visualization: (1) visualizing datasheet specifcations before buying sensors, (2) visualizing sensor interaction with the environment via AR before building the physical prototype, and (3) visualizing live/recorded sensor data to test the assembled prototype. SensorViz includes a library of visualization primitives for diferent types of sensor data and a sensor database builder, which once a new sensor is added automatically creates a matching visualization by composing visualization primitives.

LIBRARY OF VISUALIZATION PRIMITIVES



CONTRIBUTIONS

To visualize sensor information in a coherent manner, SensorViz contains a library of visualization primitives that can be composed into more complex visualizations for various sensors.

CURVEBOARDS

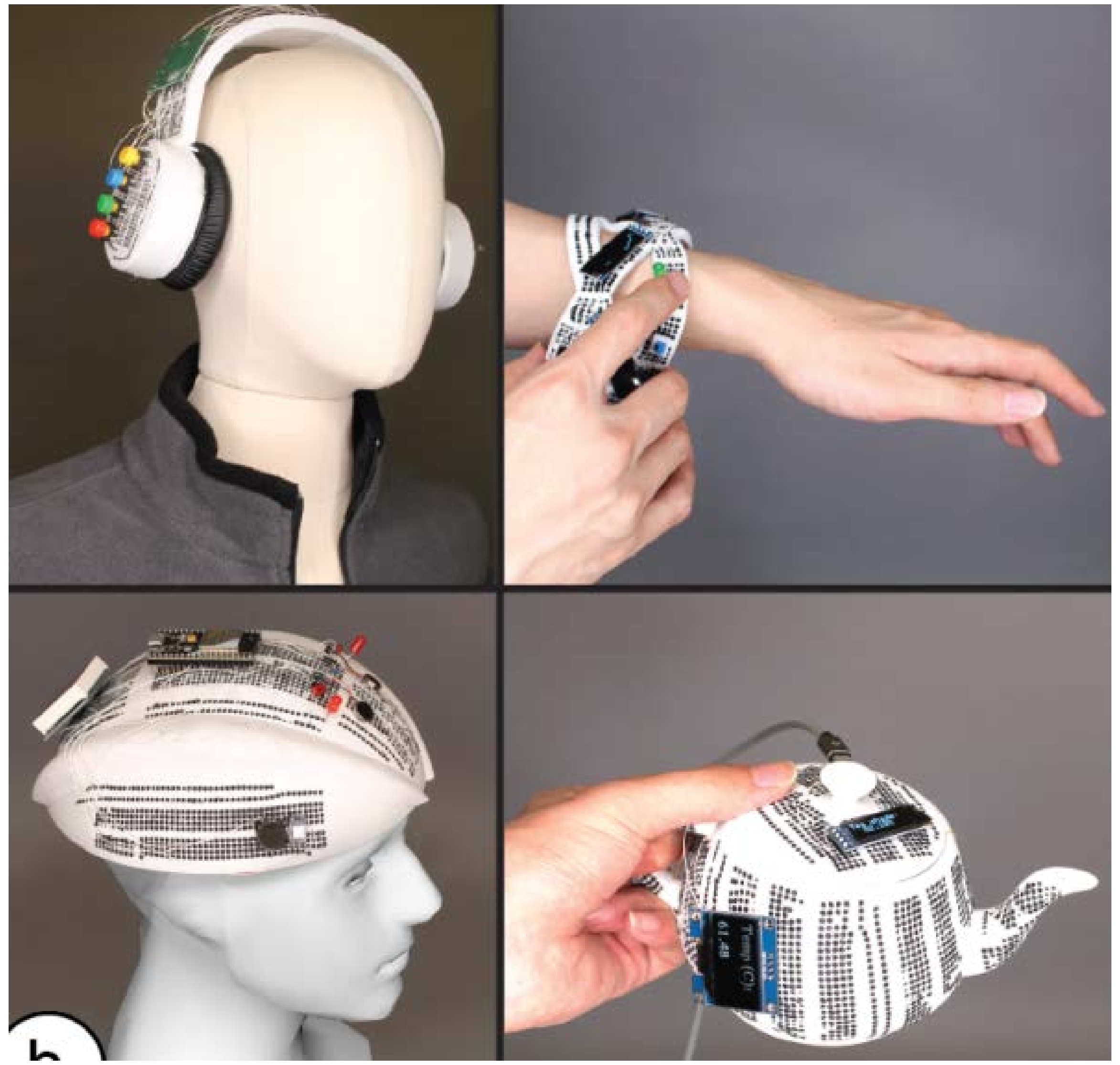
VISION

While breadboards offer great support for circuit construction, they are difficult to use when circuits have to be tested on a physical prototype. In this paper, we present a new electronic prototyping technique called CurveBoard that embeds the structure of abreadboard into the surface of a physical prototype.

How can morph the rigid shape of breadboards into more flexible forms using fabrication?

APPLICATION

CurveBoards are breadboards integrated into physical objects. In contrast to traditional breadboards, CurveBoards better preserve the object's look and feel while maintaining high circuit fluidity, which enables designers to exchange and reposition components during design iteration. Since Curve-Boards are fully functional, i.e., the screens are displaying content and the buttons take user input, designers can test interactive scenarios and log interaction data on the physical prototype while still being able to make changes to the component layout and circuit design as needed.



CONTRIBUTIONS

We present an interactive editor that enables users to convert 3D models into CurveBoards and discuss our fabrication technique for making CurveBoard prototypes.

PART B

COMPUTATIONAL DESIGN

CLICK HERE FOR
PART A

DESIGN + APPLICATION

CONTENTS

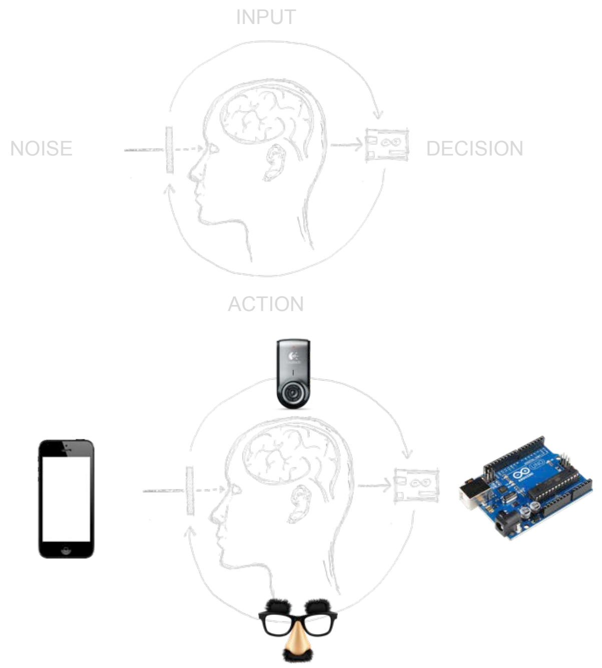
THEORY + RESEARCH

MINIMALISION

VISION

In today's age of ubiquitous advertising, we are constantly bombarded by bits of information vying for our attention. The "noise" of our environment has reached a fever pitch for almost all of our senses. We believe that combining this filtering process with technology in a human-machine symbiotic intervention can help augment our ability to focus - and, in turn, help us kick the bad habit of constantly diverting our attention to technology. Our intervention is an eyewear that is designed to block the user's view whenever he or she is distracted by mobile phones. The eyewear recognizes when the user looks at the mobile phone screens and actively shuts the eyewear lenses.

The concept of a device that enforces concentration by isolating surrounding sensory noise was creatively applied in **Hugo Gernsback's The Isolator.** This multimodal work from 1925 involved both hearing and vision, as it rendered the user deaf and restricted vision to tiny apertures. Oxygen is piped in via tube.



How can we use sensor technology to detect distractions and block it?

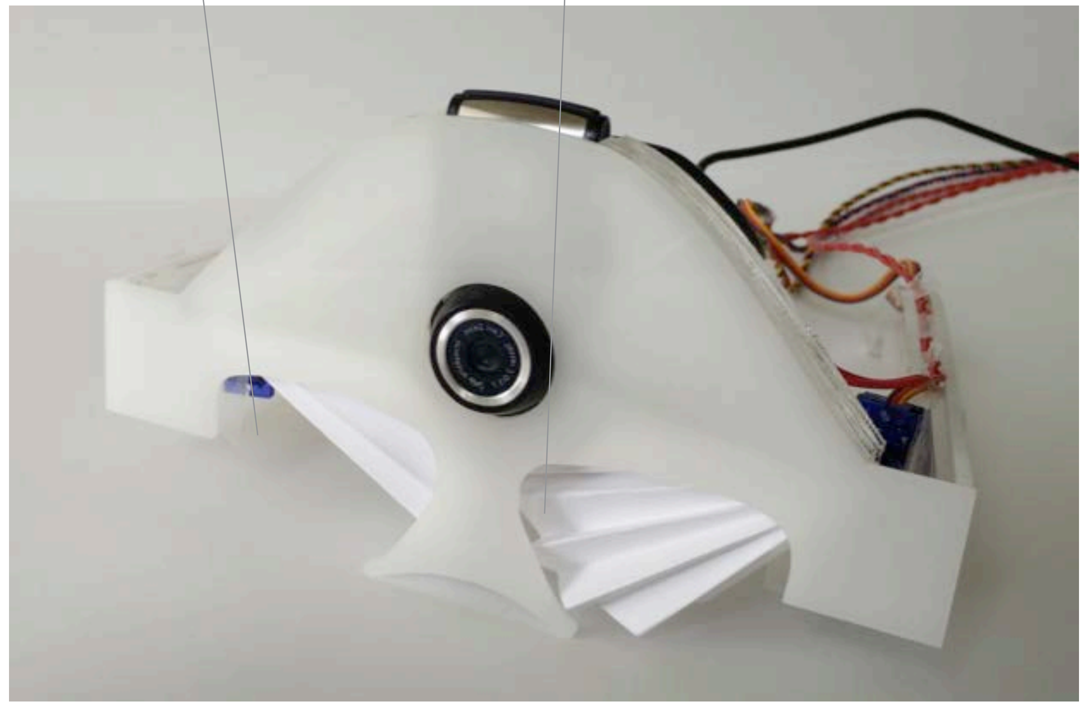
APPLICATION

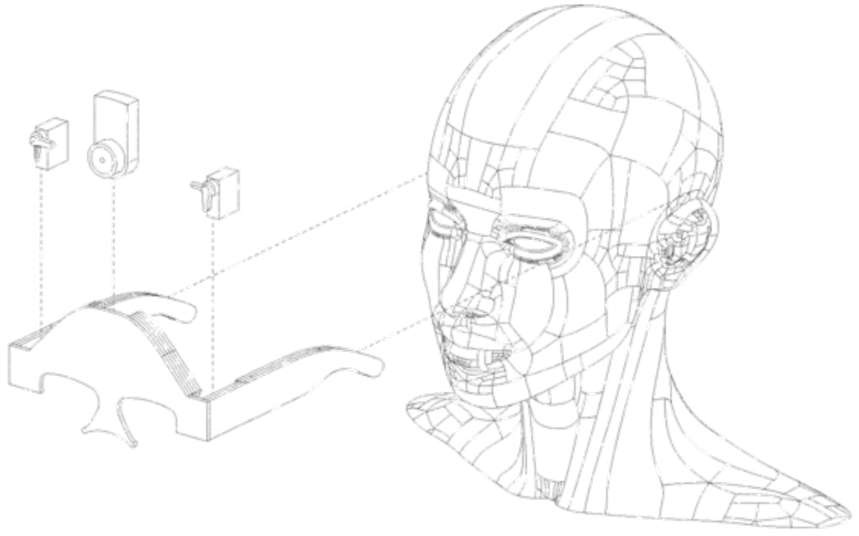
The diagram for the system is simple. The decision of what to filter (in this case, cell phones) is offloaded to a CPU. A webcam captures what the user is seeing; that information is passed to the CPU, which determines whether or not a cell phone is present; and this ON/OFF decision is sent via Arduino to two servo motors that raise and lower lenses at the front of the armature. The device is thus a filtering interface that recognizes distractions and blocks the user from diverting their attention away from object of focus.

From multi-tasking to focused uni-tasking using noise filters

Shutters open while reading

Shutters closed on phone screen detection





CONTRIBUTIONS

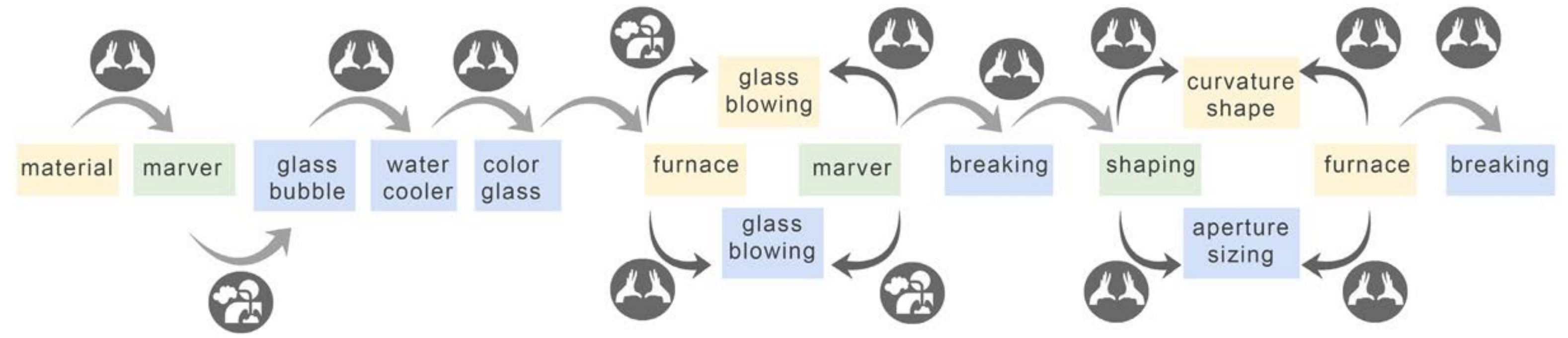
We provided a provocation-of-concept in the form of eyewear that transforms to publicly block the wearer's vision when he or she looks at a phone. This project is part of a larger vision: by cognitively offloading our filtering ability to machines, we can actively tune out what we consider to be "noise" in our lives, and enjoy the augmented quiet that results.

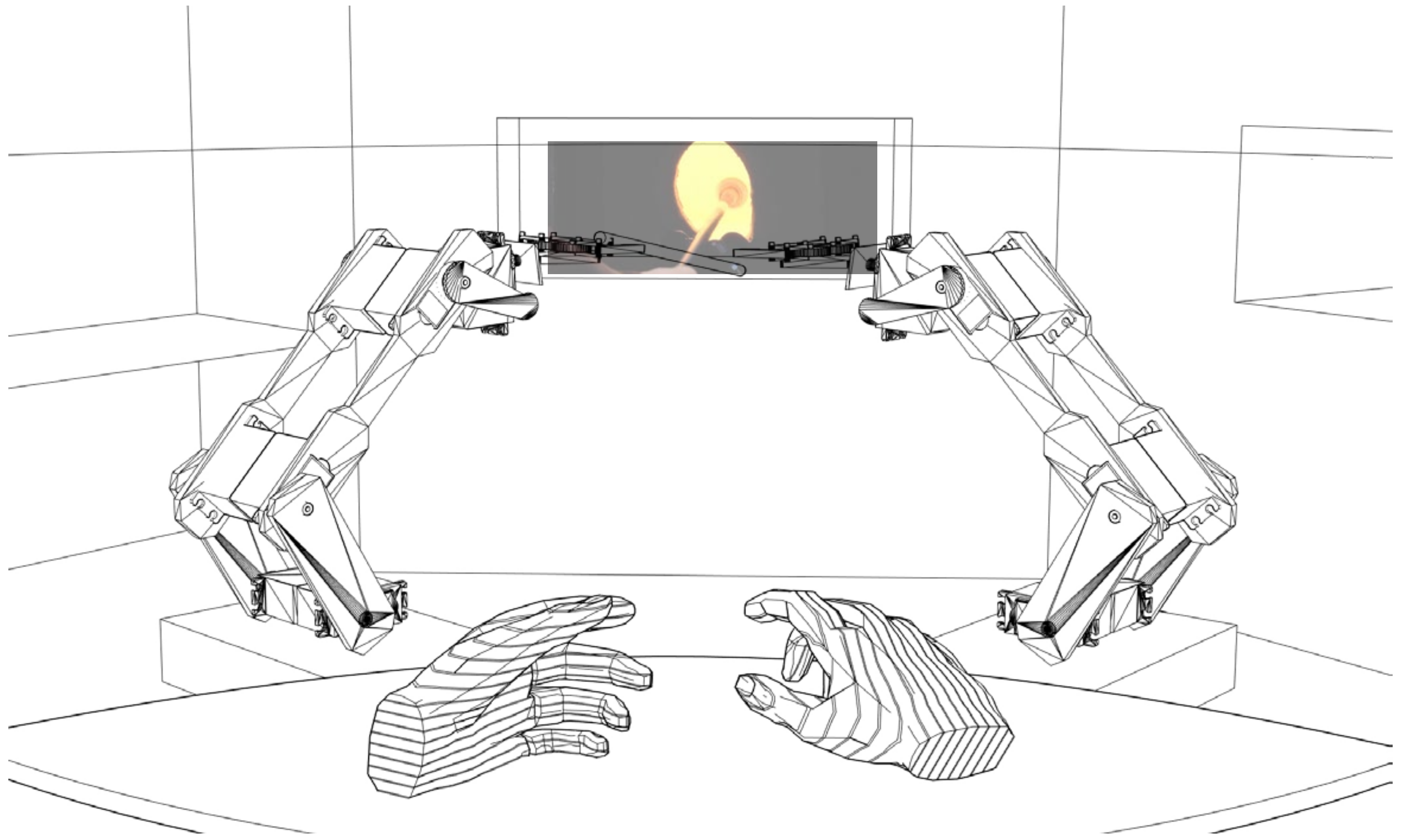
Project Type - Design Project
Category - Tangible Interfaces
Location - MIT Media Lab
Role - Computational Designer
Highlights - Arduino + Prototyping

HAND IN GLOVE

VISION

What is the nature of an artist's knowledge? Is it in the making? According to social scientists, expert knowledge is tacit in nature intertwined within layers of conscious and subconscious understanding of expertise. Through our interface, we use technology to study, extract and augment the art of making complex art - for example glass blowing.

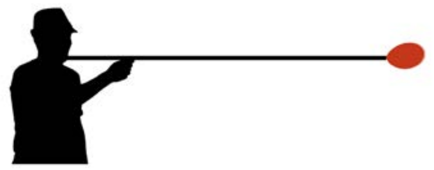


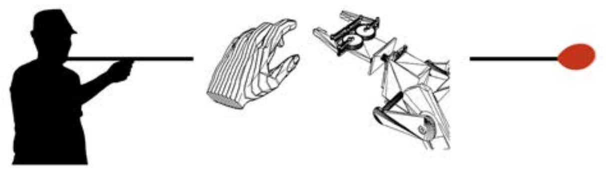


Can the artistry of glass-blowing be augmented using sensor gloves and robotic arms?

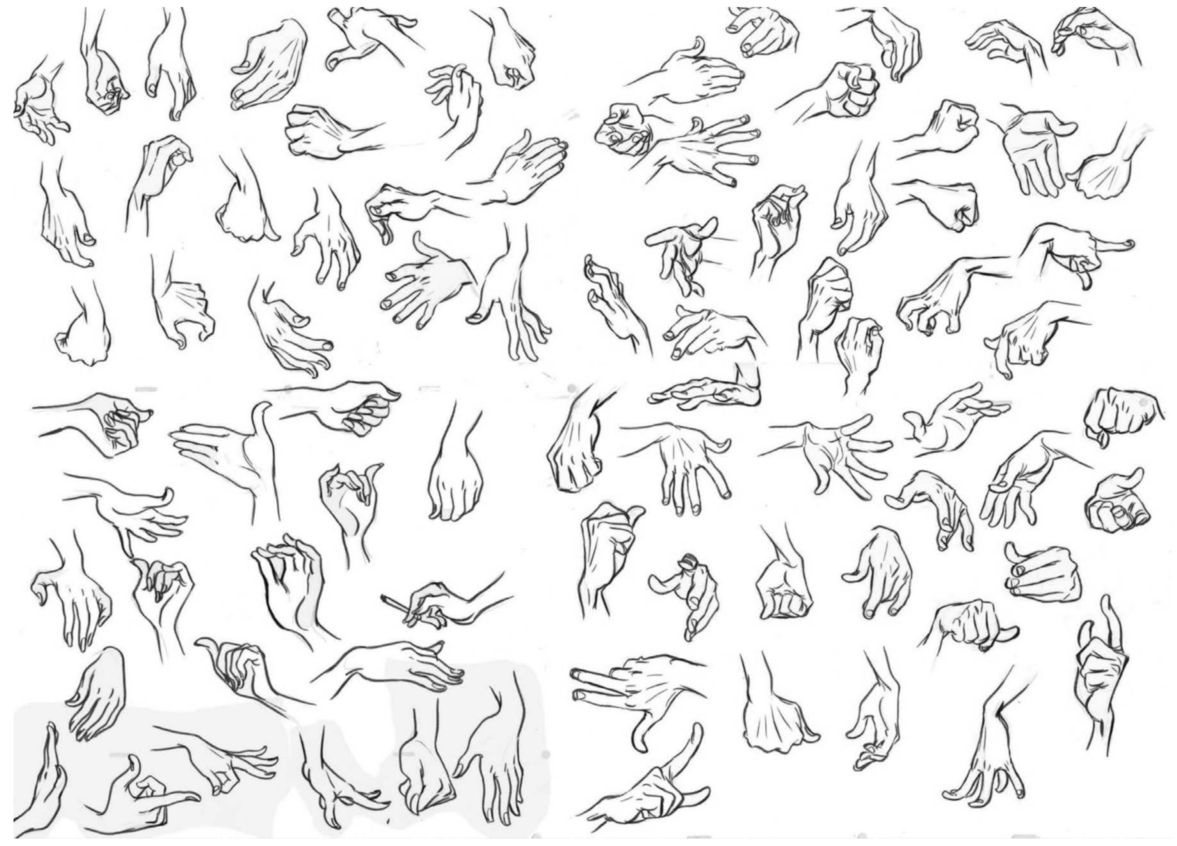
In this project we designed tangible interface that can be multisensory in nature - glows that can see, feel and make. Much of glass blowing artists' knowledge is implicit in nature. By making multisensory glove, the aim of this project is convert this expert knowledge from being tacit to tangible. We designed hand gloves that function as an intermediary interface between glassblower's palms and glass material. The gloves can detect sublte nuances in palm gestures, pressure and temperature changes while providing constant feedback to and from robotic arms that make the glass artifacts.

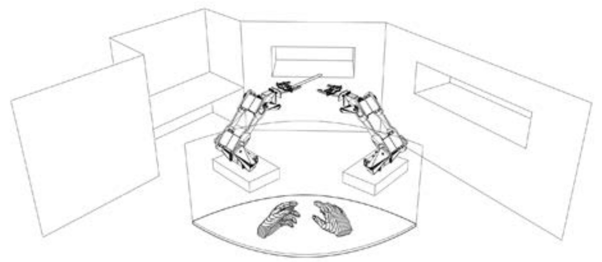
APPLICATION

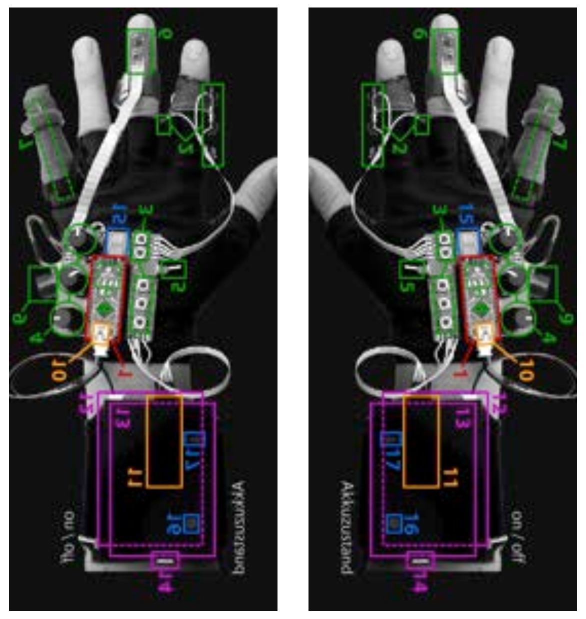




Using sensor based gloves to track artist's gestures during glass blowing process







CONTRIBUTIONS

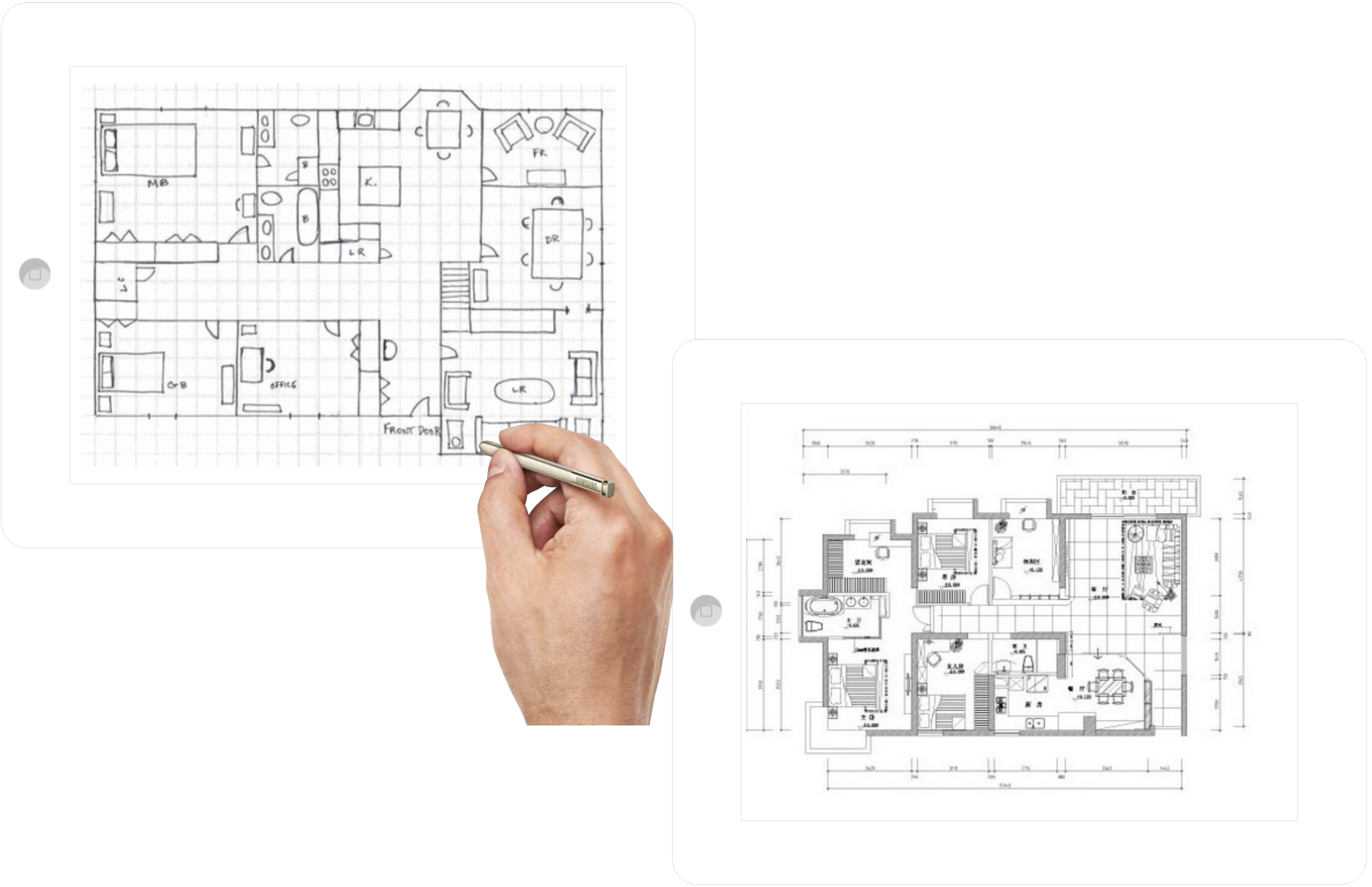
We demonstrated the potential of using advanced technology to study nuanced art of making. We also highlighted the limitations of using this technology in its current form. The main contribution of this project was enquiry in creative art of making and investigation in ways to capture expert knowledge.

Project Type - Design Project
Category - Tangible Interfaces
Location - MIT
Role - Computational Designer
Highlights - Sensor Technologies, Augmented Reality

sketchCAD (Finalist - Startup Challenge)

VISION

Can Machine Learning be used to make drawing and designing more intuitive? The vision of this project was to use machine learning to bring back the joy of designing through sketching in architectural offices. Architects spend a significant amount of time in converting their ideas into CAD drawings - a process that can be easily automated using technology.

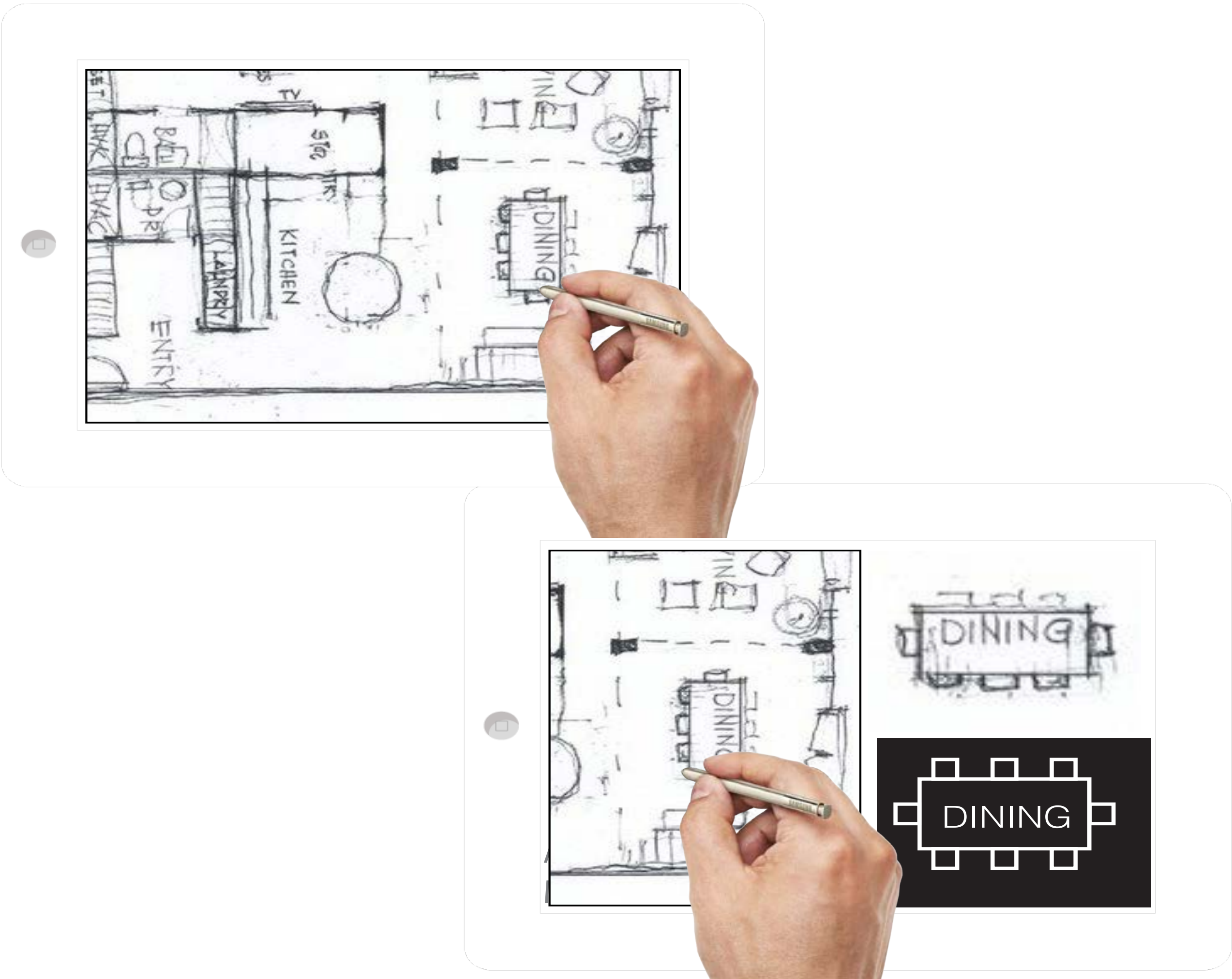


How can we use technology to automate the mundane parts of drafting and increase efficiency?

DESIGN + APPLICATION

APPLICATION

The concept of the application was two staged - first stage algorithm would recognize the sketch of the designer real-time and classify/label it to an existing library object. This label is mapped to an existing CAD block library that gets generated in the drafted version of the drawing real-time.



How can we make human-computer interaction more intuitive?

Ivan Sutherland - the inventor of sketchpad says, ***"the screen is a window through which one sees virtual world. The challenge is to make that world look real, act real, sound real, feel real".*** This challenge of making a virtual interface feel more tangible still holds true.

CONTRIBUTIONS

I developed the idea of the application, produced UI prototype, and conducted paper prototype tests on users. This application was chosen for final pitching round of DesignX - MIT's Accelerator for design community. For the startup pitch, I collaborated with management from MIT Sloan and computer science graduate from Stanford University. In addition to being the design lead of the founding team, I was also responsible for market research, and product development.

Project Type - Startup Application
Category - Tangible Interfaces
Location - MIT DesignX Accelerator
Role - Founder, Design Lead
Highlights - Machine Learning, Image Recognition

COMPUTING THOUGHTS AS SHAPES

VISION

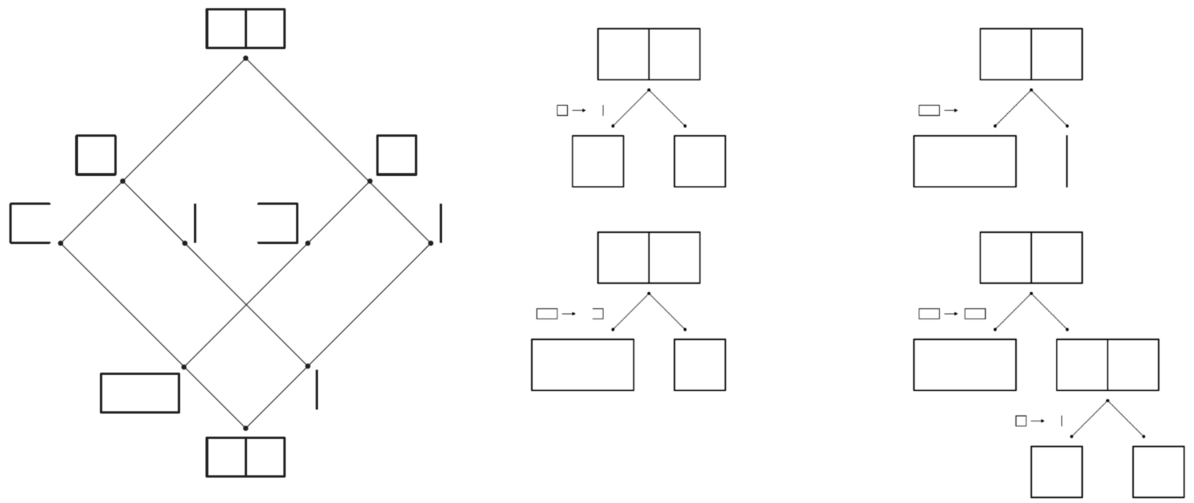
The hypothesis of this research is that we are creative as humans because we are different in how we perceive the world from each other. **Creativity** is enhanced by advancing the ability to perceive the world in new ways, to find hidden patterns, or as Minsky posits, **to understand things in more than one-way.** The two key factors that contribute to creativity are cognitive diversity of human mind and interactions between these diverse minds.

Cognitive diversity emerges from the ability to encode information differently by using unique (i)perspectives to frame problems, (ii)heuristics to solve them, (iii)interpretations to propose solutions and (iv)predictions to evaluate the proposed this solutions. Furthermore, our interactions with other humans with cognitively diverse mental models influence our thinking and problem solving abilities.

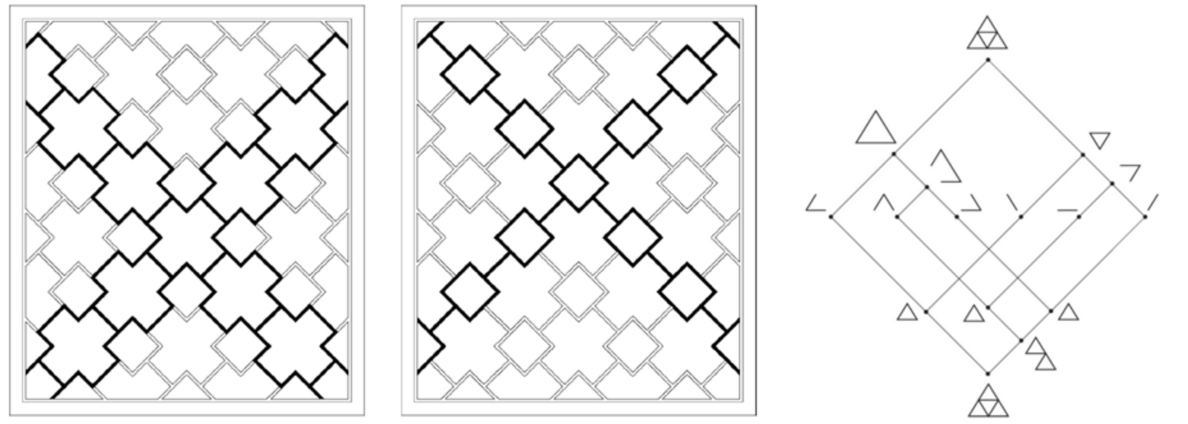
How do different people perceive the same thing differenty? What does it mean to be *cognitively diverse?*

RESEARCH

I propose a new way of understanding our thoughts - as shapes. If we imagine our thoughts and concepts as shapes, complex ideas as spatial relations, we can argue that the process of creative thinking is computationally shape grammarian. This means that by defining set rules, we can work with our thoughts in novel ways to generate complex ideas. These ideas can be considered as complex assembly of shapes that can be decomposed, fused and embdded with meanings - making the process of creation highly computational.



If thoughts were shapes, can designing be computationally shape grammarian?



Can we build machines capable of developing diverse perspectives?

CONTRIBUTIONS

The main contribution of this research is to propose that creativity can be incorporated in existing machine intelligence technology. Machines are not great at creating ideas, but they are farely sophisticated at working with shape grammars. If we can represent thoughts in terms of shapes, using shape grammar computation, we can use machines to create ideas.

Project Type - Thesis
Category - Human Cognition
Location - MIT
Role - Researcher
Highlights - Cognitive Science, Social Interaction, Artificial Intelligence

NUEROSCIENCE AND ARCHITECTURE

VISION

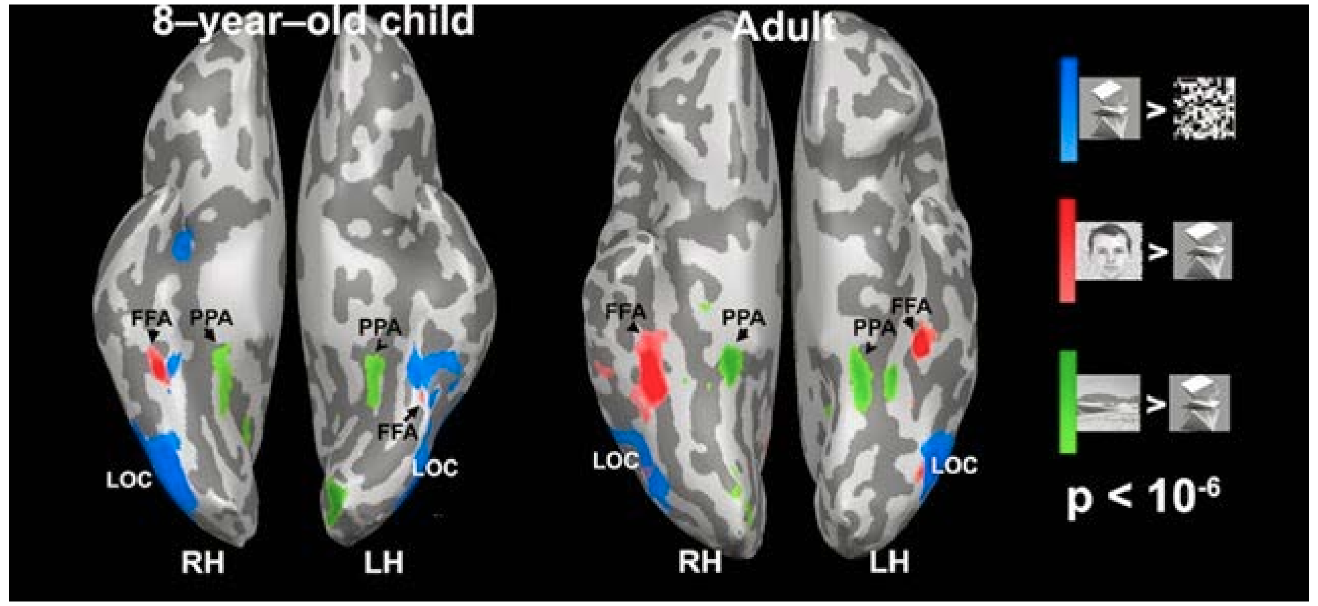
Architecture is a process of designing in mind, through making with our hands and experiencing through our sight, touch, smell, and other cognitive apparatus. Designers are experimenting with immersive VR environments to produce experiences previously unfathomable in actual spaces. These applications that emerge from interdisciplinary knowledge discourses at the intersections of psychology, artificial intelligence, engineering and design, are exemplary precedents of the architectural revolution in the age of digitization and data.

Human cognition is multimodal in nature – meaning we use our various senses of vision, sound, touch, smell etc to navigate in the physical world. But as we navigate, we also build spatial referential models – which are of two types – Allocentric and Egocentric models. Allocentric method of spatial coding represents information about object location with respect to other objects and is independent of the location and orientation of the observer. Egocentric frames of reference specify location, position and orientation of surrounding objects with respect to the observer and are highly dependent on individual sensory modalities like vision, position etc.

How do humans navigate spaces, build spatial memory and how can architecture augment spatial experience?

RESEARCH

Scientist Nancy Kanwisher and her lab have successfully located the region in our brains called PPA – the parahippocampal place area, which responds not only to spatial environment, but also images of scenes and places.



Hippocampus plays an important role in navigation and memory where the information processing is not just feed-forward, but bi-directional. Further, the observation that replay of small subset of cues reactivates an entire event suggests that spatial memory is not just navigational, but temporal and emotional. At a higher resolution level, hippocampus consists of four fundamental types of spatial cells, which are categorized based on their functions as – place cells, head direction cells, grid cells and boundary cells. The place cells [discovered by O'Keefe and Dostrovosky, 1971] fire corresponding for their place fields (location) in the given environment irrespective of orientation. Head direction cells represent the head direction regardless of the location. The grid cells [May-Britt, Edvard Moser, 2005] have 3 characteristics – scale, orientation and spatial phase that govern the firing rate and intensity of the cells. Boundary cells respond to– vertical surfaces and drop edges. This observation is highly noteworthy as architects and designers often engage with the notion of edges and boundaries while designing.

How can architectural design benefit from discoveries of neuroscience?

CONTRIBUTIONS

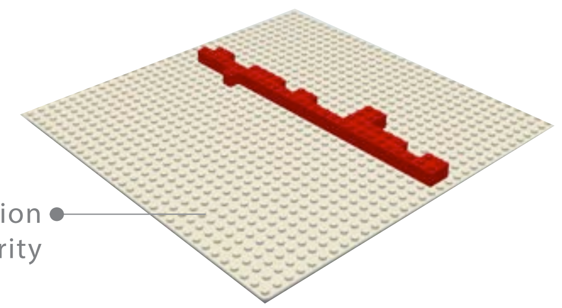
For the invited talk and paper, I argue that it is essential for architects to understand various scientific aspects of spatial cognition in order to design spaces that invoke the spatial experience intended by the designer. Further, I investigate the current literature on various aspects of human spatial cognition and highlight the implications of these findings in the process of spatial design and planning. I also summarize the different computational models of the cognitive process developed for applications - such as robotic exploration in unmapped regions and for human interactive interfaces.

Project Type - Research Paper
Category - Human Cognition
Location - MIT + Salk Institute
Role - Researcher
Highlights - Neuroscience, Spatial Cognition

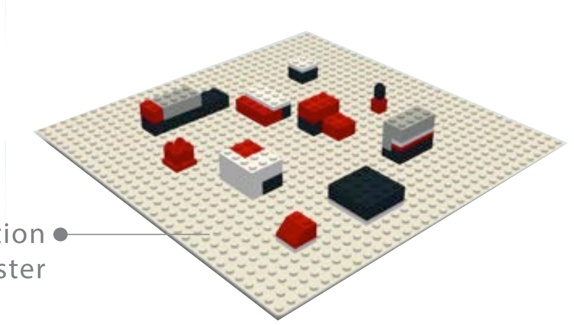
SILENT GAME

VISION

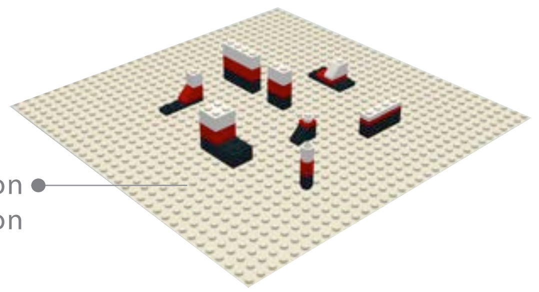
In order to study the social cognition between people, we designed a collaborative silent lego game. The goal of this exercise was to evaluate how well people interpret each other's intentions without verbal communication. Further, we wanted to study how players change their behavior to engage in collaborative goals. We then tested performance of Bayesian inference algorithms in interpreting player goals by translating the game in virtual environment. The goal of the experiment of this second part was to test if computational systems can learn from less data as humans do.



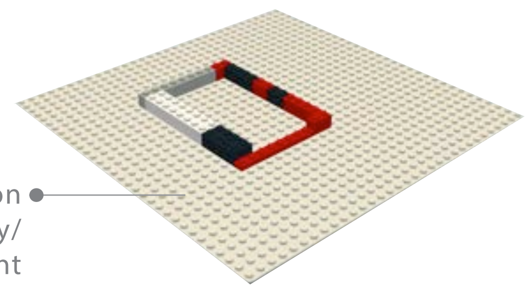
Player Intention Linearity



Player Intention Cluster



Player Intention Repetition



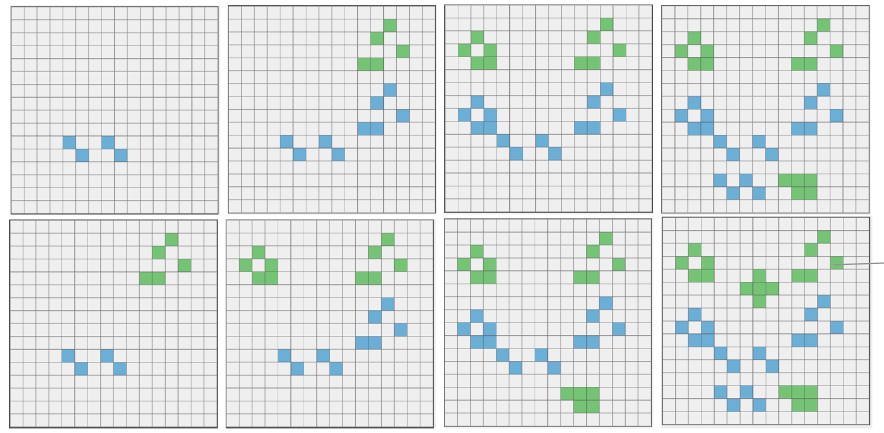
Player Intention Boundary/ Containment

Humans interpret each other's goals, desires and objectives through observations. How can machines develop this social cognitive abilities?

APPLICATION

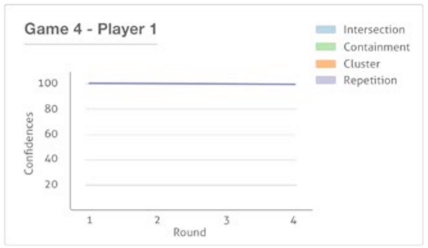
Game play: In order to win, design intents/goals of ALL the players have to be achieved. Thus either everyone wins or everyone loses. This is a cooperative/collaborative game. Rules: 1. It is a silent Lego game. 2. Players play turn by turn in each round. And there are 4 rounds before the game terminates. Thus there is limited time/opportunity/resources to play the game. 3. In each turn, a player plays two die that dictate a. the number of blocks the player has to work with in that turn and b. the action to be executed by the player (eg. Addition/subtraction/replacement) 4. Players have access to all the Lego blocks, as long as the chosen blocks/action satisfy the conditions acquired in the die play

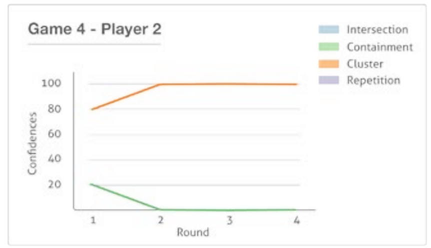
Testing how well algorithms interpret abstract actions and intentions of players in gameplay



Player Intention Repetition (Blue)

Player Intention Cluster (Green)





Bayesian Inference on guessing player's goals: Confidence of the algorithm based on data after every move (using webPPL)

CONTRIBUTIONS

In the first part the game play, each player is mainly focused on achieving their own personal goals and communicating them clearly to the other players. Towards the middle of the game play, the strategy changes to using their moves to ensure that combined goals are achieved, or such that their moves do not adversely affect other player's goals. The Bayesian Inference was fairly successful (using Hidden Markov Model) in infering player's goals after 3 turns.

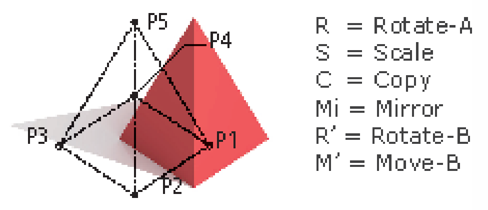
Project Type - Research Project
Category - Human Cognition
Location - MIT - Brain and Cog Sci
Role - Researcher
Highlights - Neuroscience, Spatial Cognition, Artificial Intelligence

COMPUTATIONAL CREATIVITY

VISION

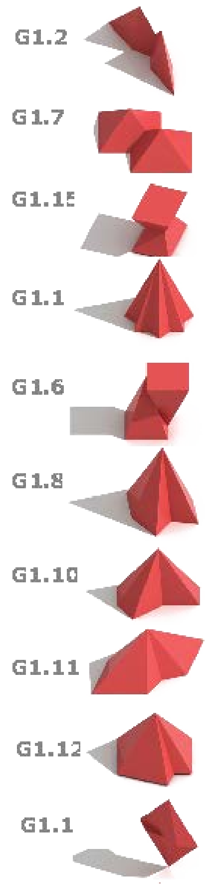
The goal of this study was to test how genetic algorithms can be used to create complex geometry assemblies from simple modules. The goal of this study was to test how design of complex designs and architecture can be automated using computational algorithms.

Body Plan



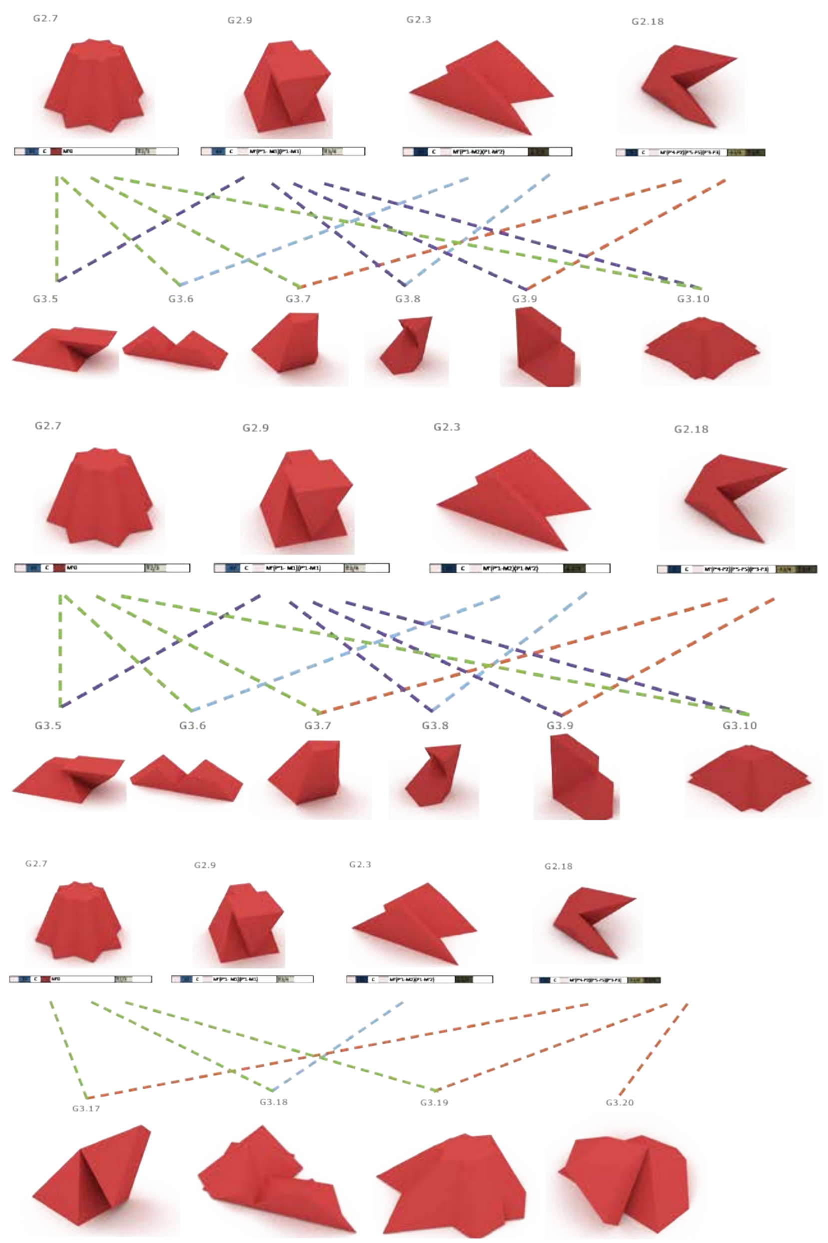
R = Rotate-A
S = Scale
C = Copy
Mi = Mirror
R' = Rotate-B
M' = Move-B

Ranking



Genome Code

Rotation	Scale	L
0	0.5	XY
15	0.75	YZ
45	1.5	XZ
60	2.5	
90		

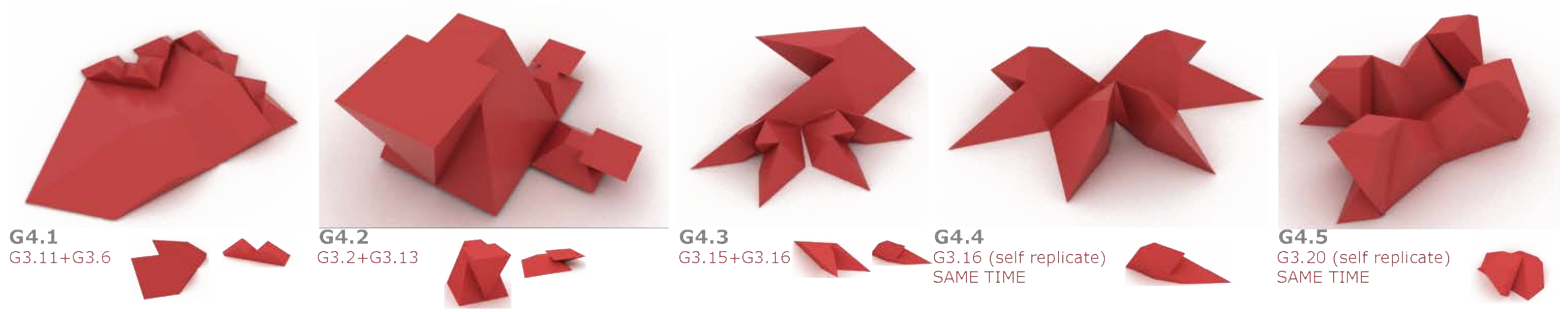


How can evolutionary algorithms generate complex geometries with simple rules?

RESEARCH

The research focussed mainly on extracting the rules and sequence of steps that lead to "good" design solutions and automatically discard unusable assemblies.

Can algorithms design using computation?



In this research, I demonstrated how using simple rules, machines can generate complex usable designs if the rules of evaluation are embdded well in genome. This algorithm can be deployed to design complex designs in architecture, structures and design.

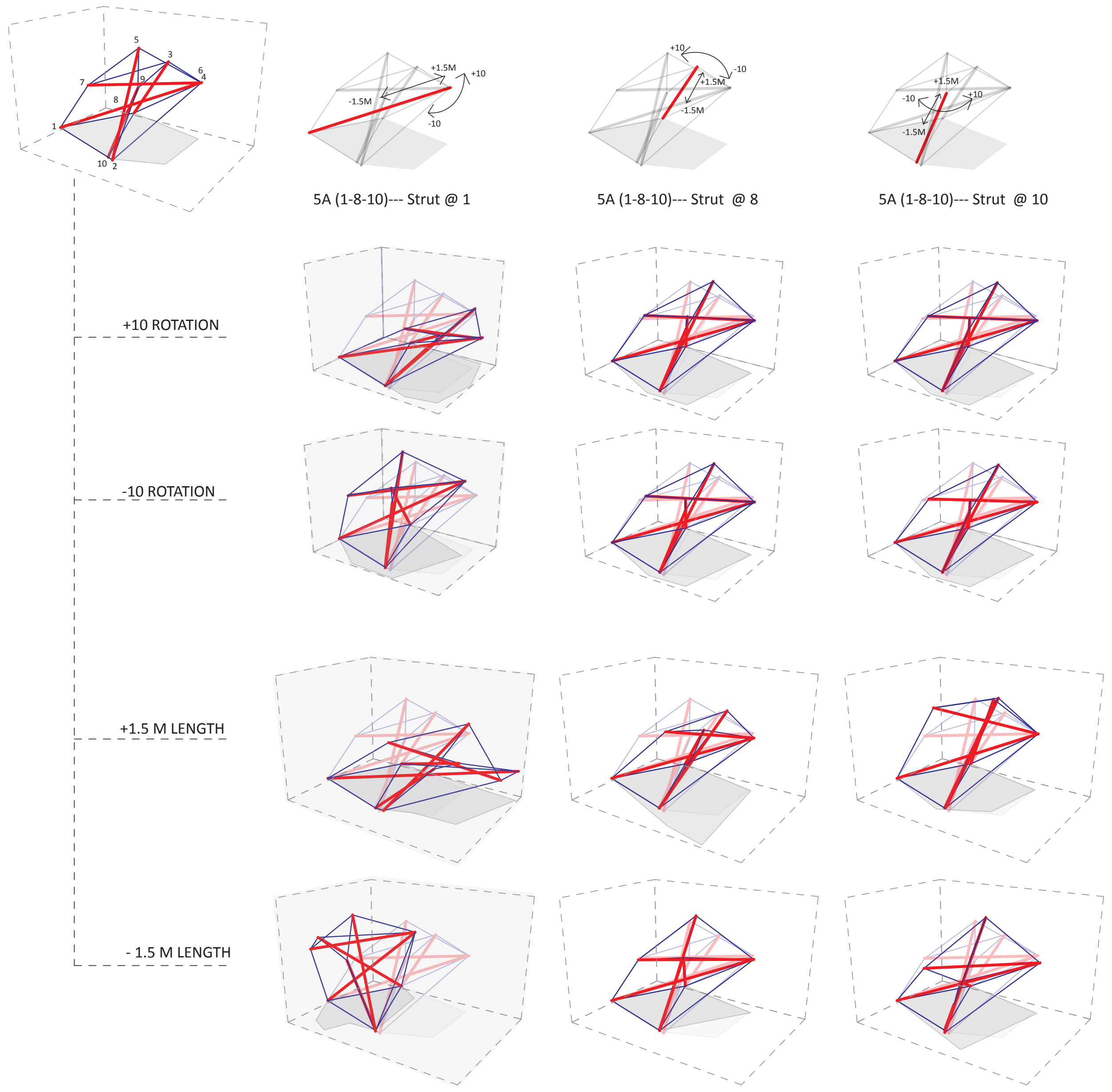
CONTRIBUTIONS

Project Type - Research Paper
Category - Computational Creativity
Location - AA School of Architecture
Role - Computational Designer
Highlights - Generative Design, Evolutionary Algorithms

DYNAMIC TENSEGRITY SYSTEMS

VISION

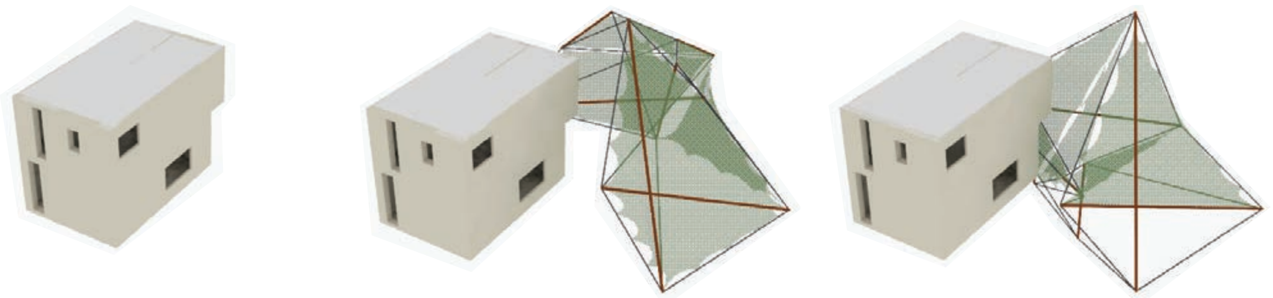
Tensegrity structures exhibit an exceptionally high strength-to-weight ratio and possess the unique property of being stable in zero-gravity spaces. I used Evolutionary Algorithmic to thoroughly investigate a set of arbitrary Tensegrity Structures which are tedious to design using traditional methods and determine new irregular and architecturally optimal forms.

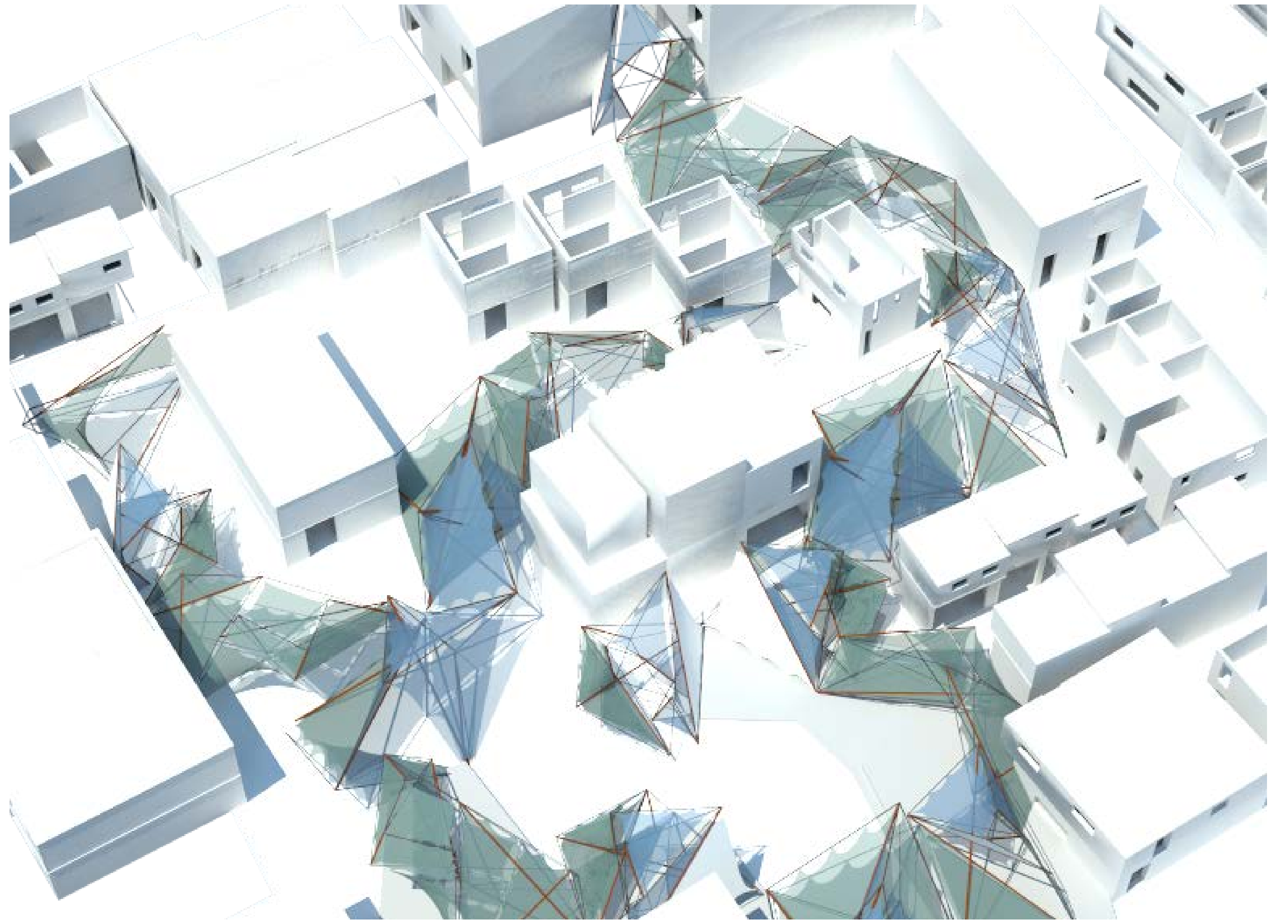


How can we use computation to design dynamic habitable spaces that respond to changing user needs?

RESEARCH

The proposed design in the informal settlements of Dharavi, the largest slum in Asia, was aimed at addressing this issue of congestion by developing organization strategies of the design dynamic Tensegrity modules evolved using algorithmic design process. By day, these structures were designed to be commercial spaces and by night they would serve several purposes such as sleeping shelters and night workshops.





CONTRIBUTIONS

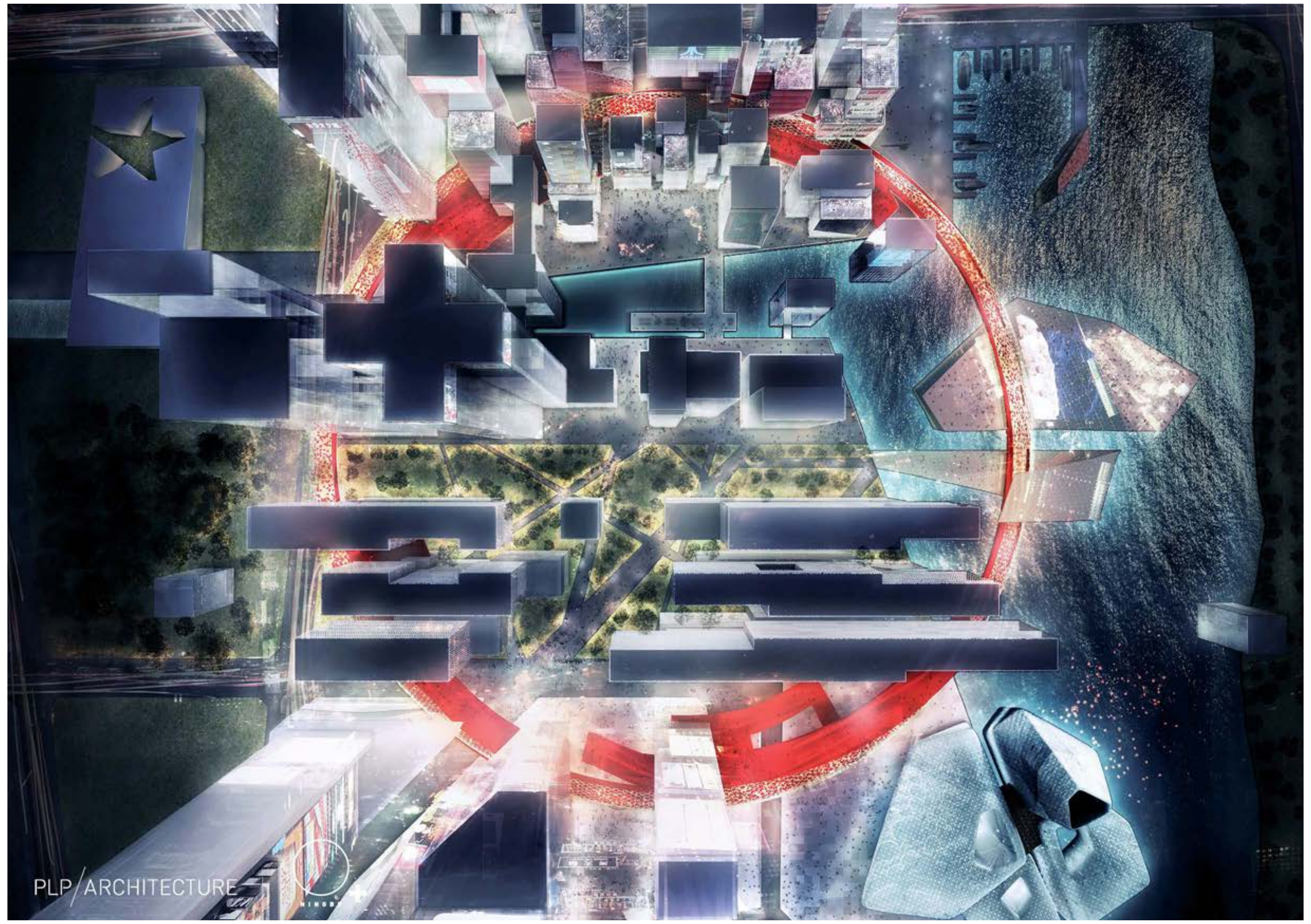
I used Dynamic Relaxation methods for simulating the material properties based on the mechanical constraints and kinetic freedom. The rigorous analysis, evaluation, elimination and selection procedure aims at achieving optimal set of digitally tested modules. The assembly logics were re-embedded in the digitally iterative design process to have a efficient spatial design. The result was developing a structurally adaptive system through various material tests, physical models and digital structural analysis.

Project Type - Research Paper
Category - Computational Creativity
Location - AA School of Architecture
Role - Computational Designer
Highlights - Dynamic Structures, Generative Design

SMART CITY DESIGN (Award winning project)

VISION

The master-planning of Ningbo,the emerging fashion hub of China caters to urgent need of designing urban areas as self-sustaining ecosystems. The extensive research and case studies on the natural environments and resources provided a comprehensive base for developing the architectural language for the urban fabric.

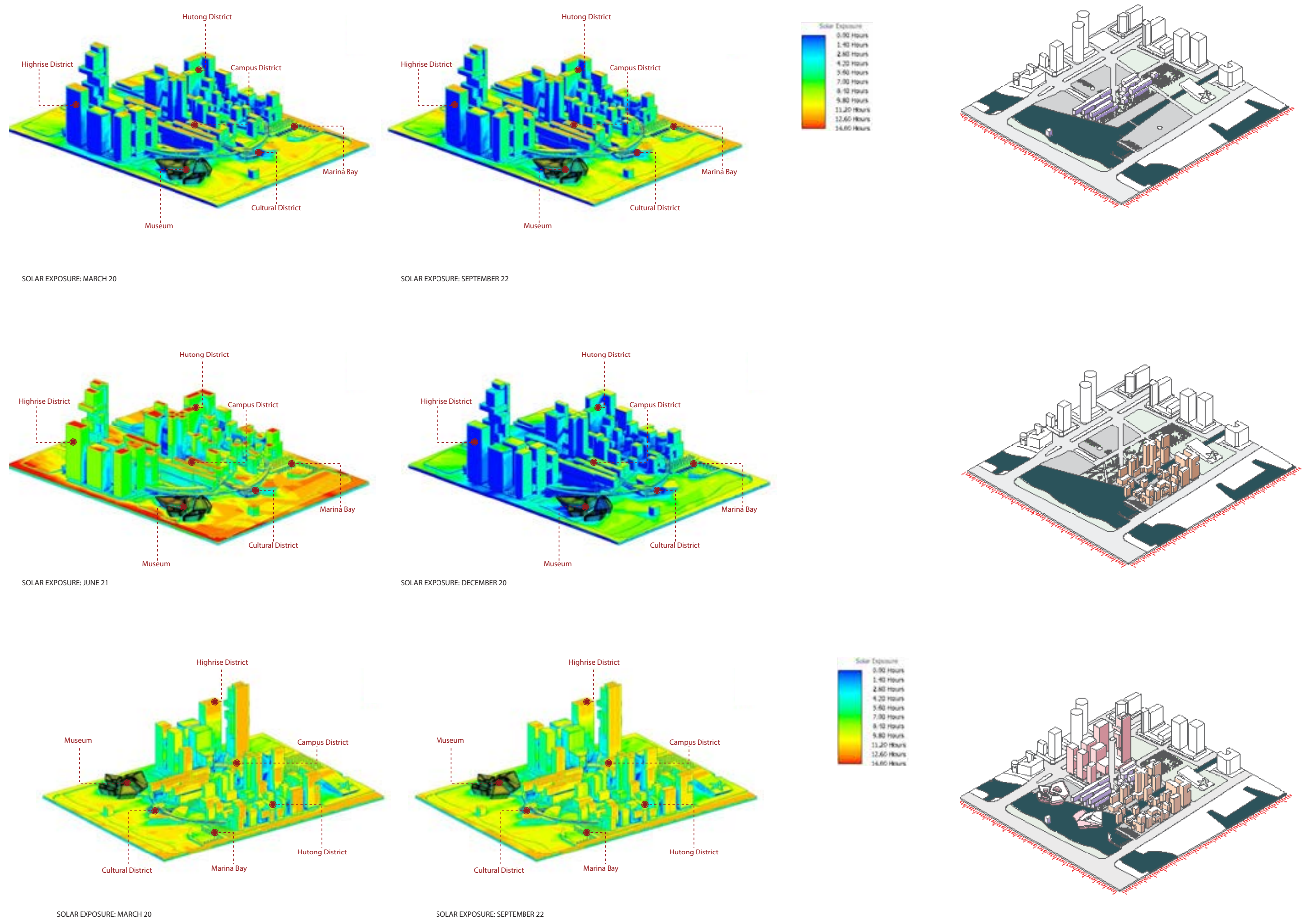


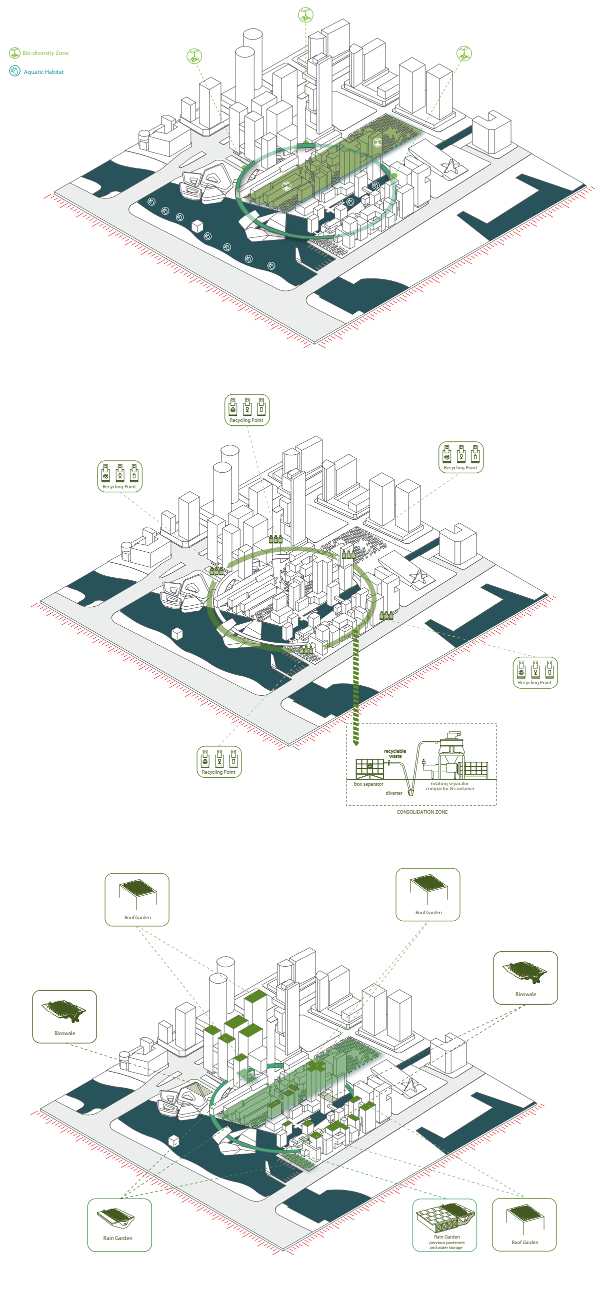
How can we design sustainable cities using climatic and city logistic data?

DESIGN + APPLICATION

APPLICATION

In order to make the design into a self-sustaining ecosystem, various studies for accommodation of water purification plants, sewage and sanitation systems, flora and fauna in the green and aquatic zones were conducted. These systems were embedded within the master planning and program zoning of the urban design. Numerous solar radiation studies were carried out on the massing volumes and designs were tested for optimized behaviour under various climatic variations and weather changes. Wind movements and ventilation patterns were also studied and incorporated within the design guidelines followed for the master-plan.





CONTRIBUTIONS

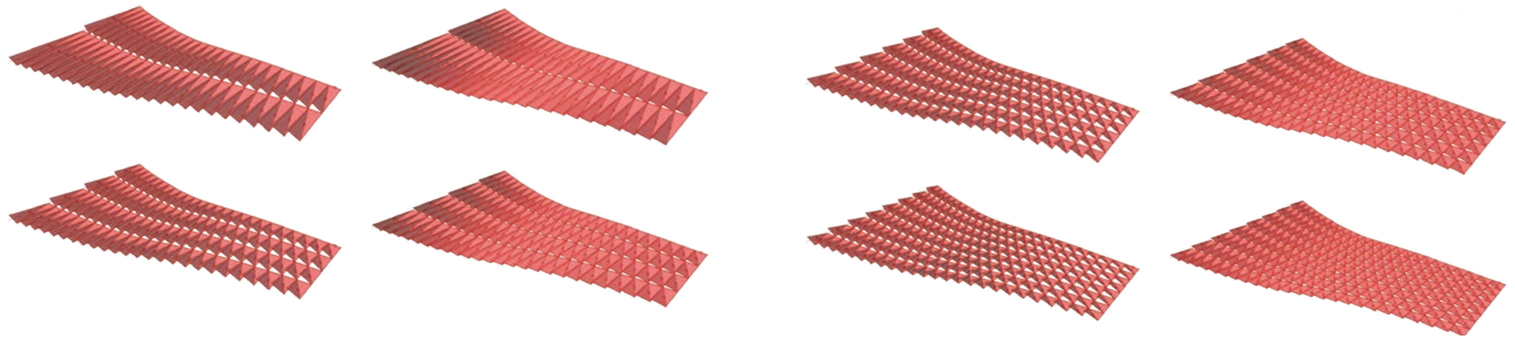
I worked as computational researcher for this award-winning project at PLP architecture. I used computational tools for analysis to generate simulations of the master planning and massing of the city based on climatic data. Multiple design iterations were tested for best performance and selected designs were further tested for environmental impact.

Project Type - Urban Design Project
Category - Design with Data
Location - PLP Architecture, London
Role - Computational Designer
Highlights - Climate Analysis, ANSYS, Ecotect

COMPUTATIONAL DESIGN

VISION

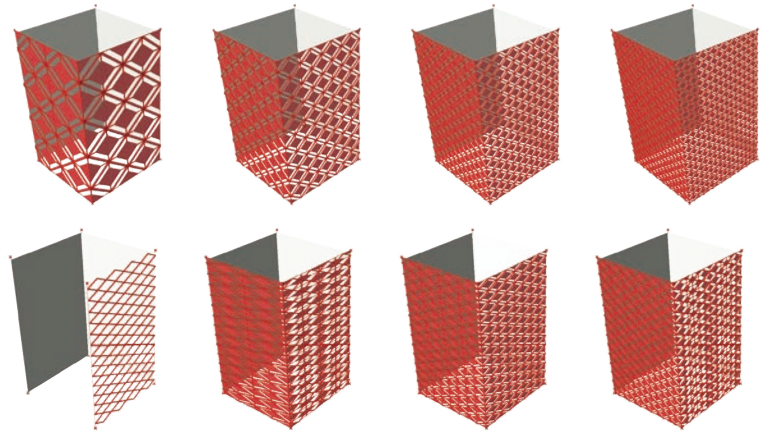
The two projects shown below were designed from concept to final stage through rigorous iterative process of parametric design. The use of algorithmic script for design made production of multiple iterations. As a computational designer, my role in this project was to program the scripts in GH and use rapid prototyping of making physical models.

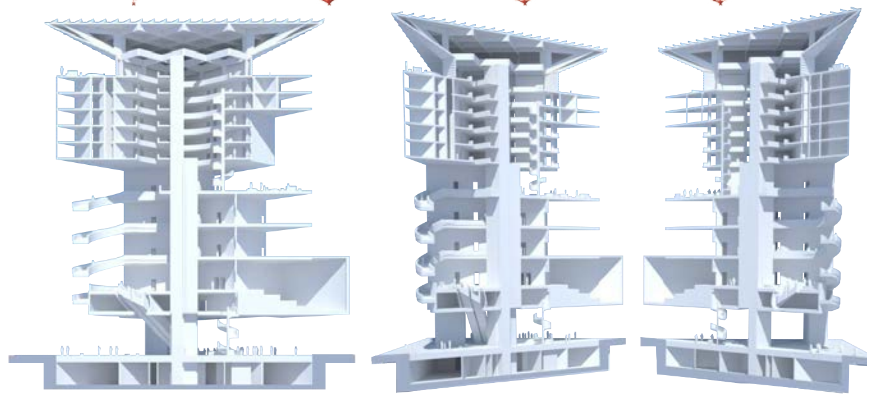


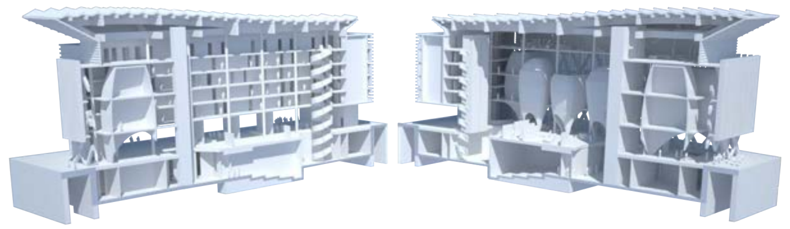
How can algorithms be used to generate and optimize design iterations?

APPLICATION

The different components of the buildings were designed using different parameters in scripts. Multiple iterations were produced both digitally and physically using computational tools. The following images show two of the many components generated using this design method - roof structure and facade skin for buildings of academic complex in Abu Dhabi.







CONTRIBUTIONS

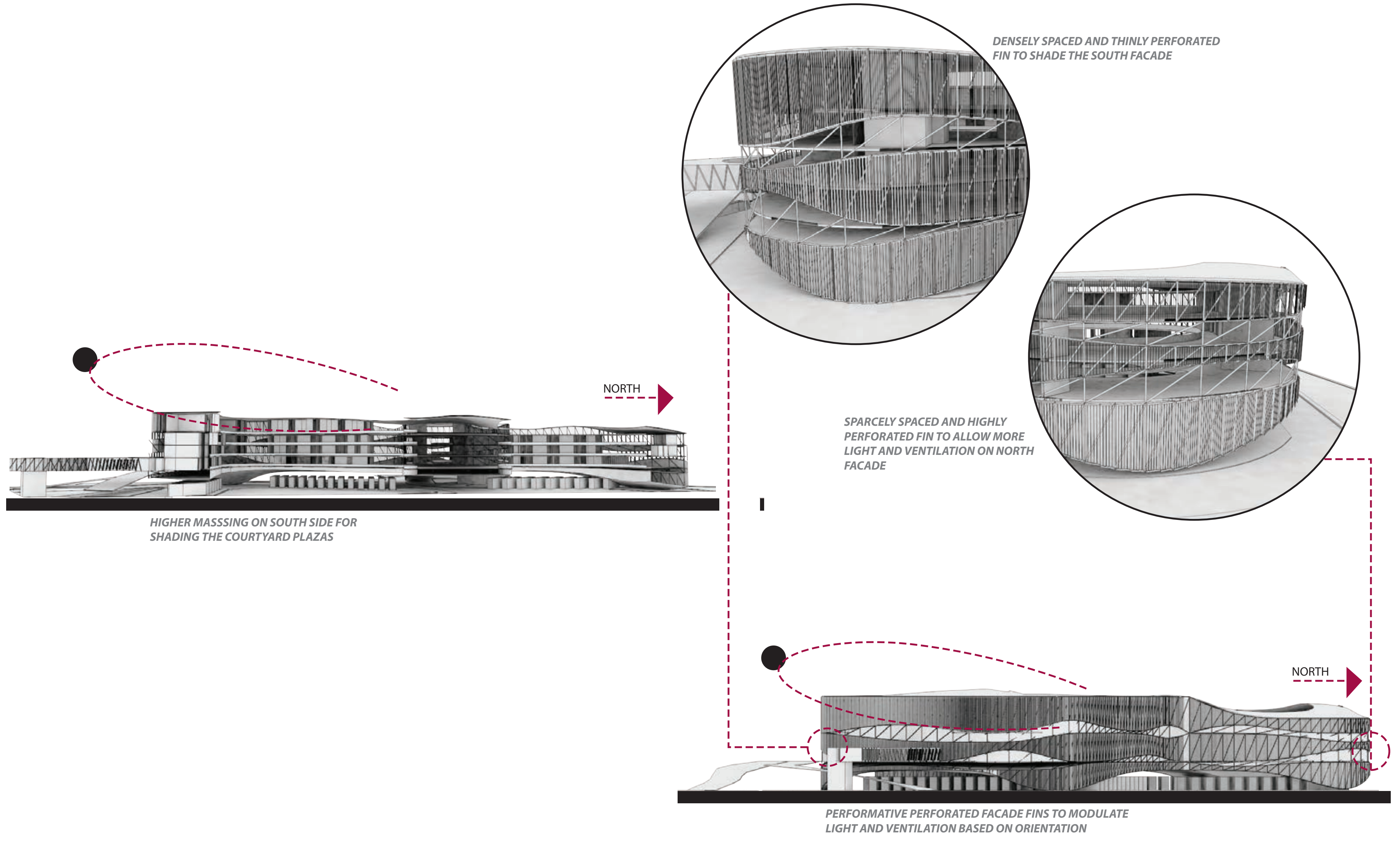
As a computational designer at PLP Architecture, I worked on the parametric design aspect of the project with lead architect and other designers in the team. Frequently structural testing and shadow analysis was conducted on these designs to evaluate their performance.

Project Type - Architecture Design
Category - Comoutational Design
Location - PLP Architecture
Role - Computational Designer
Highlights - Parametric Design, Structural Optimization

URBAN DUNES

VISION

Jaipur, the desert city of India, is renowned for its beautiful sand dunes and traditional designs. Inculcating the notion of Jaipur to the weary traveler was the inspiration behind the volumetric design of this bus-terminal project.



How can we save energy by designing building skins that respond to changing climate?

DESIGN + APPLICATION

APPLICATION

The bus terminal, an oasis for millions of travelers, is one of the major transport hubs in the city. The curvature of the organic form is a function of the vehicular traffic movements. The elevations were created based on the sun-paths to provide self-shade to the central public plaza.

Inspired by the magnificent design of Hawa Mahal, a palace in Jaipur, the structure was enveloped with a “breathing skin” of perforated and uniquely oriented sandstone panels allowed maximum visibility, ventilation and shading. The design prototypes were digitally tested for environmental and structural performance in Ecotect and ANSYS. The green roof naturally cooled the building and provided breathing space in the congested urban desert.

Can buildings breathe?

CONTRIBUTIONS

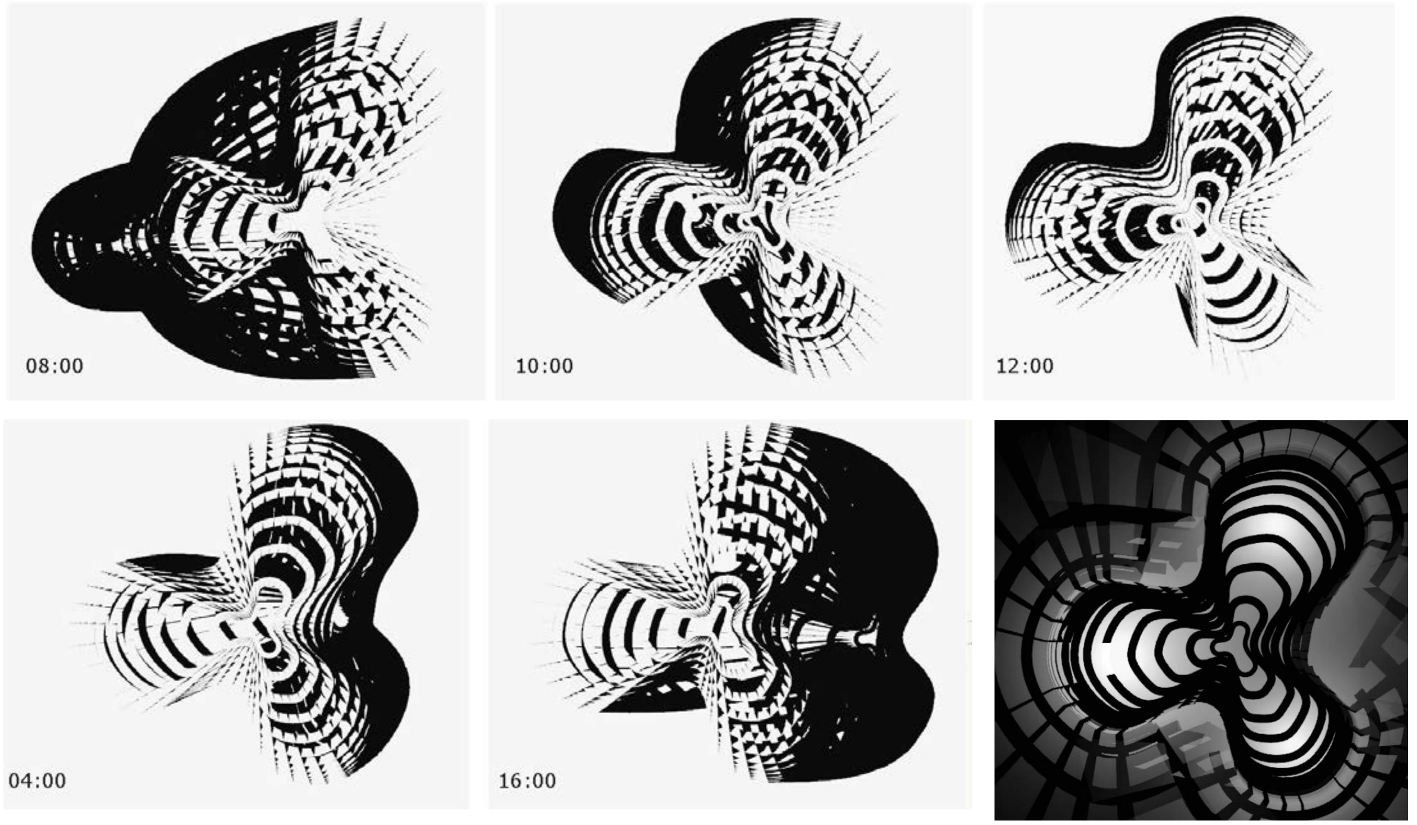
The main contribution of this project is the unique design of facade developed to regulate the internal temperatures of spaces. The project was designed using climatic data, sun paths and wind movements for spatial comfort. Use of algorithms to simulate building behavior enabled careful evaluation of design iterations.

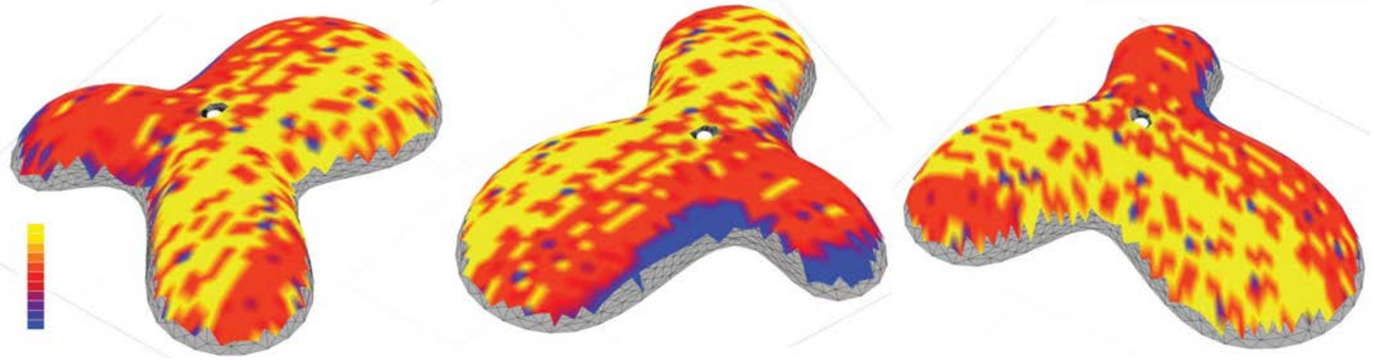
Project Type - Design Project
Category - Responsive Environments
Location - SP+A
Role - Computational Designer
Highlights - Parametric Design

PNEUMATIC ALIEN

VISION

The project brief was to design the mechanism for an active and climatically responsive architectural system for public plaza in Athens, Greece. The temperature differences during day and night; and also during summer and winter are quite considerable and hence the use of this parameter to bring about variation in the spatial conditions was the main theme of the project.



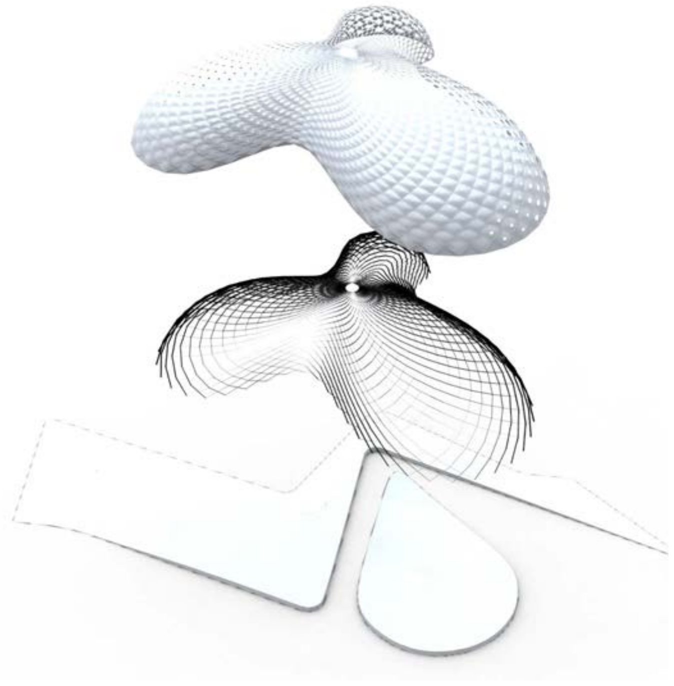


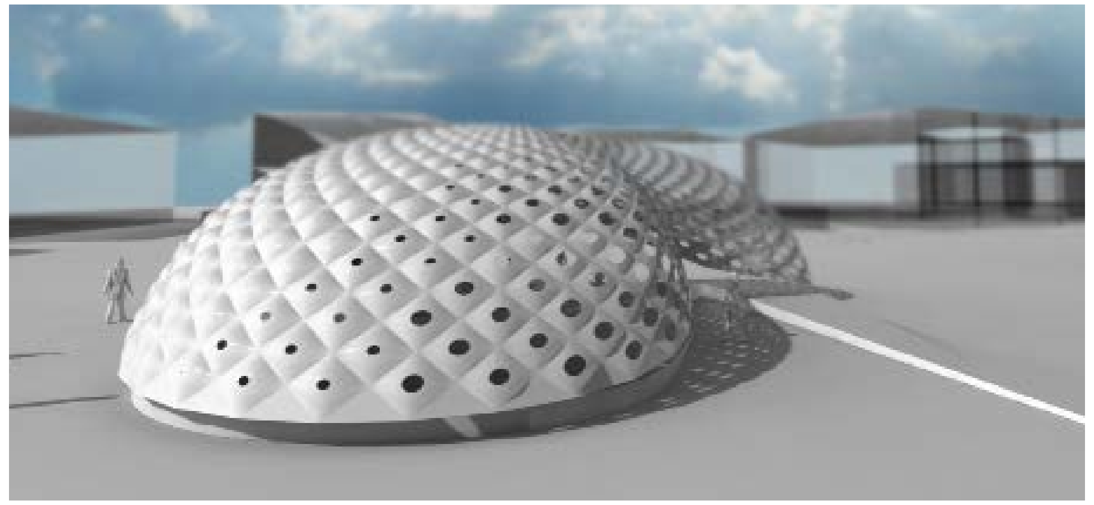
How can change in external temperature be used to control light and thermal comfort of interior spaces?

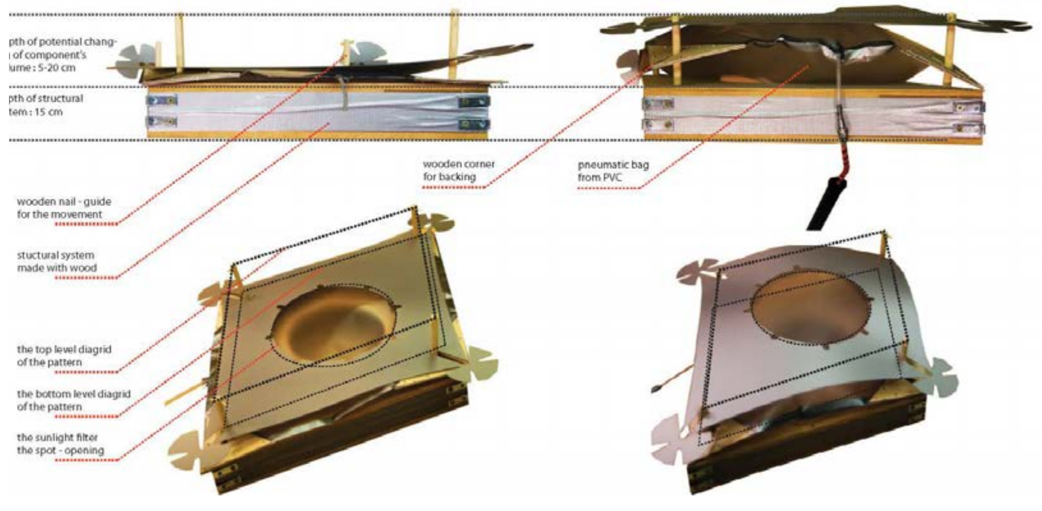
DESIGN + APPLICATION

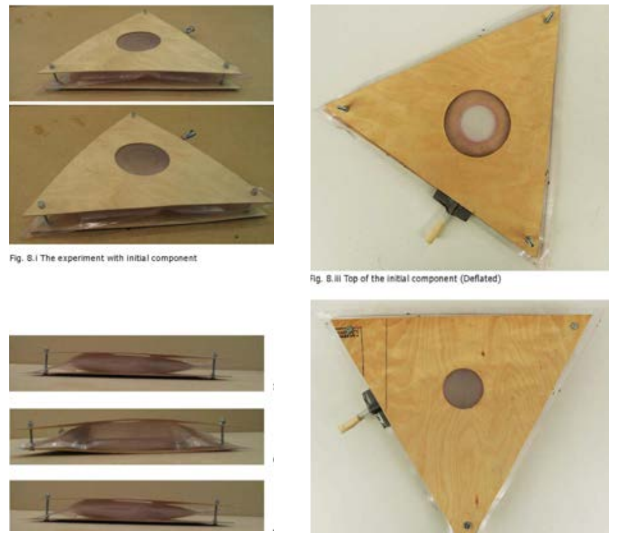
APPLICATION

The dia-grid structure of the pavilion was enveloped with a pneumatic cushion layer which provided insulation between the internal and external environments. The cushioned panels were filled with helium gas that would display large volumetric variations in relatively smaller temperature changes. These volumetric changes would help in regulating the amount of sunlight that would enter the internal spaces. Furthermore, my providing apertures in these cushions, and changing the aperture sizes based on light requirements of different internal spaces, the ambience of the enclosure could be varied.









This wide range of seasonal temperature variations was used as the parameter for activating the dynamic architectural system. The sun-angles, sun-paths and temperature variations were mapped over different time durations and used to design the aperture and cushion sizes. The behaviours of a number of pneumatic component prototypes were tested in order to achieve maximum variation in form with low temperature variations. The physical models of these prototypes were also tested for structural stability and organizational logics.

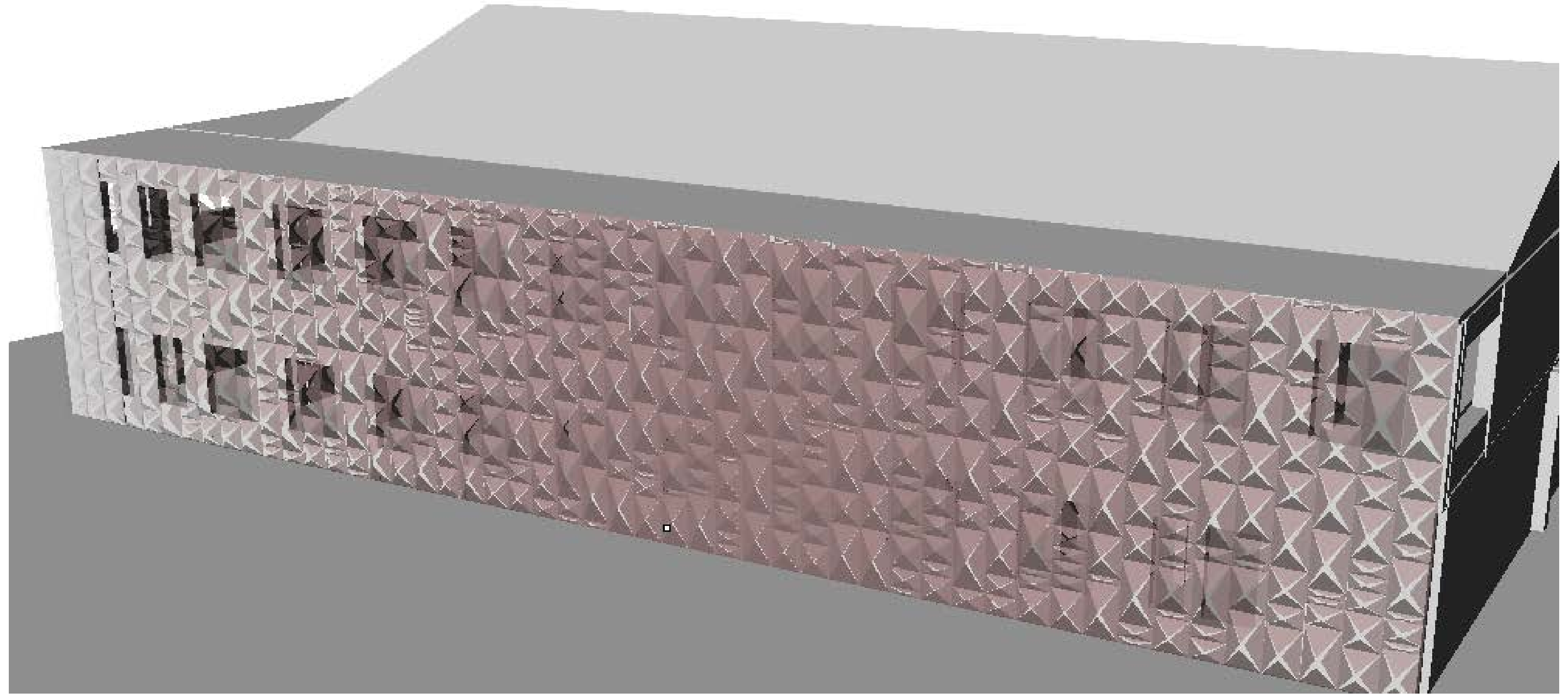
CONTRIBUTIONS

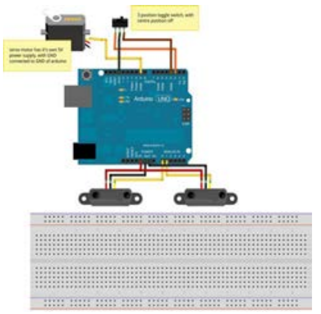
Project Type - Material Research
Category - Responsive Environments
Location - AA School of Architecture
Role - Researcher
Highlights - Pneumatic Systems, Dynamic Architecture

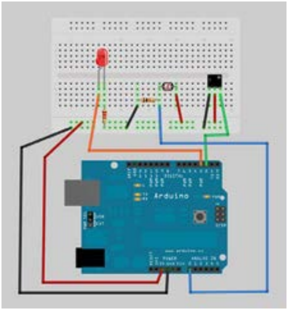
PLAYFUL FACADE

VISION

The idea of these projects was to have the facade engage the audience outside the building continuously based on the dynamic activities occuring inside the game zone. The motion sensors inside the building would map the activities inside and the facade outside would react dynamically by having openable panels that would form various visual configurations on the outside depicting the mood and activity levels on the inside.



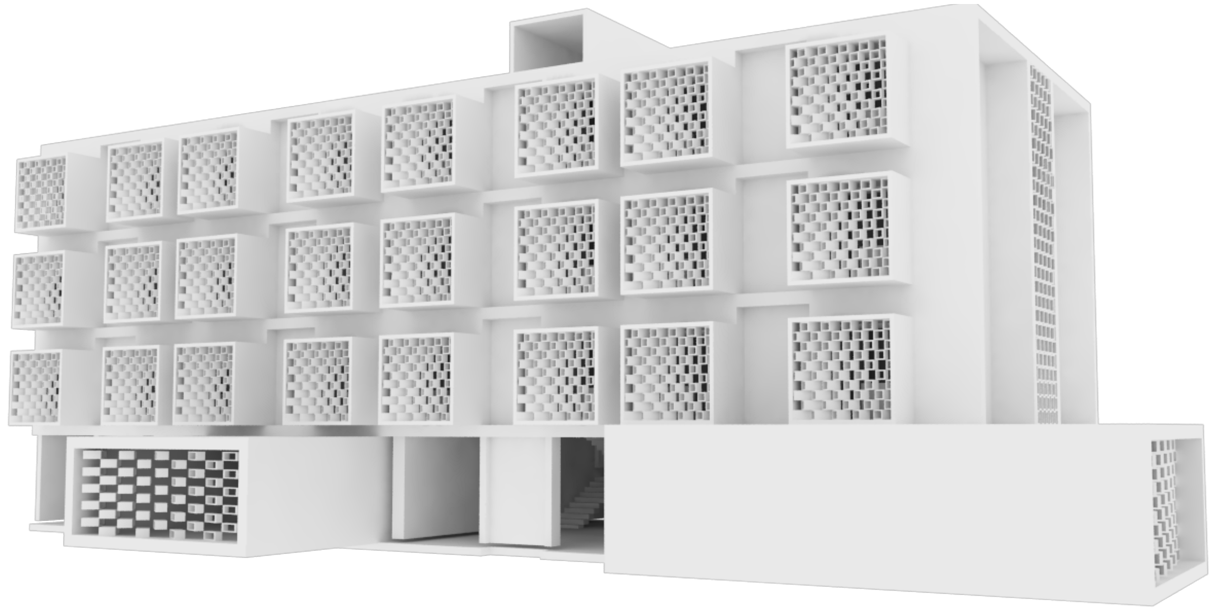




Using Arduino and motion sensors to simulate a playful facade that responds to user motion

APPLICATION

The circuit diagrams are the different sensory circuits tried out for testing the sensor based facade design. The first one has a motion sensor while the other two have infrared sensor detecting obstruction between the emitter and the receiver to trigger motion in the servo motors connected and resulting in opening and closing of panels. The renders show the different stages of the opening and closing of the panels based on arduino sensing and responsive design. The motion sensors in the circuit detect movement of users and result in dynamic behaviour of the facade panels.



How can we design architecture that is alive and responsive to sun and wind movements?

CONTRIBUTIONS

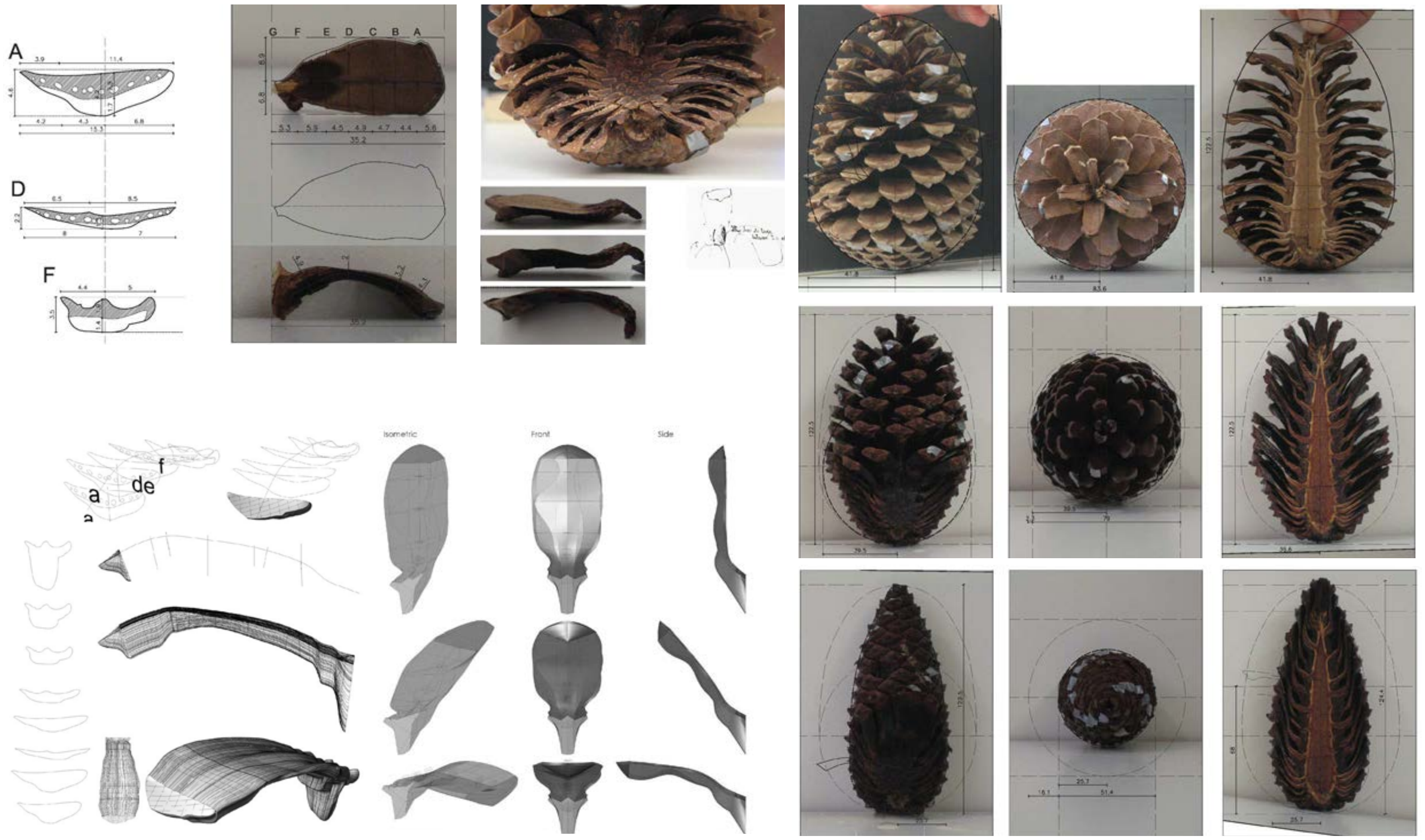
This project demonstrates how sensor technology can be combined with human data to create novel interactive user experiences.

Project Type - Design Project
Category - Responsive Environments
Location - AA School of Architecture
Role - Computational Designer
Highlights - Arduino + Prototyping, Parametric Design

HYGROMORPHISM

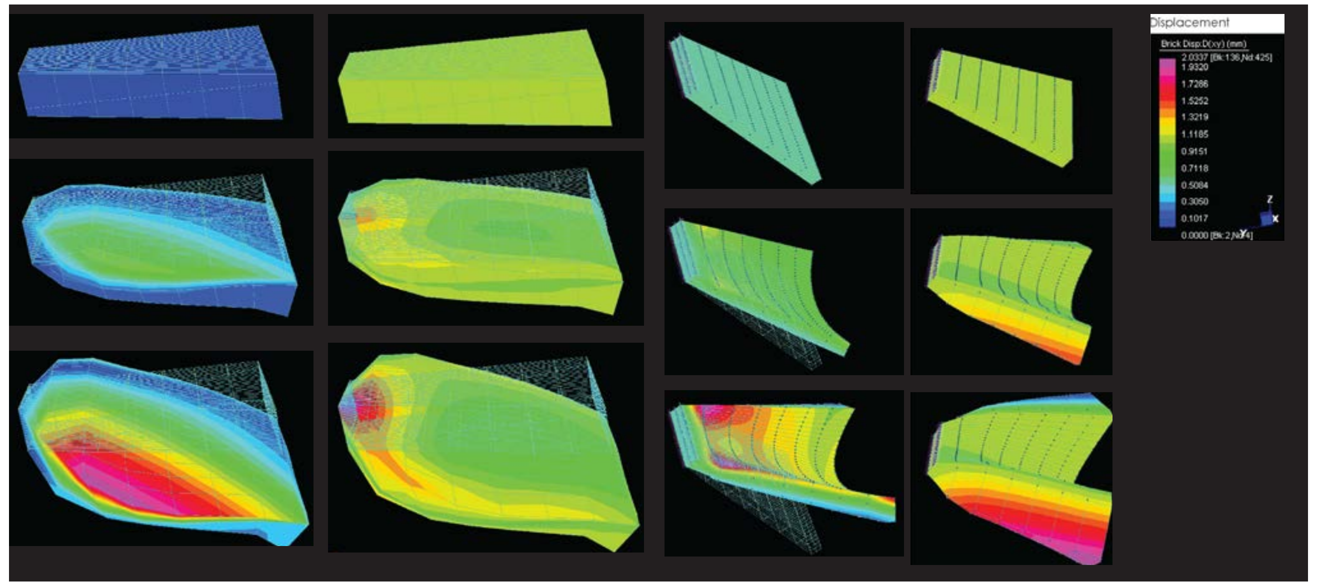
VISION

Natural systems exhibit responsive behavior in the most efficient ways. Biomimetics projects like these are aimed to study the structural and material properties that can be adopted to make dynamic environemnts. For example, using change of humidy to adjust the air circulation in the buildings can be an energy saving solution in places with inadequate access to power. This hygromorphism is exhibited seamlessly in pinecones that open and close its scales based on humidity levels. This simple but smart phenomenon inspired design of a hygromorphic hinge for facade system that can open and shut the shading components without any power supply, solely based on external environmental conditions.



Learning from nature: Pinecone inspired dynamic building facade systems that vary with humidy levels

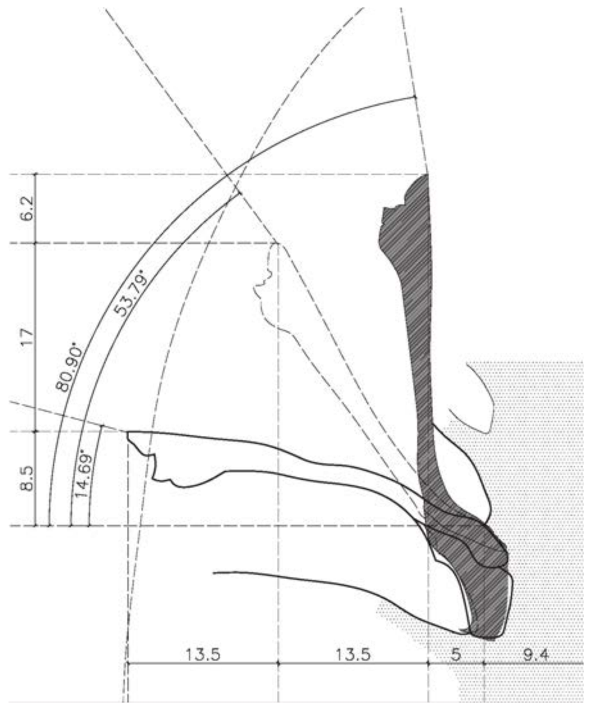
A common example of a robust natural hygromorph is the pine cone, famous for the static phyllotactic pattern of its scales. While tree bound cones are closed, fallen cones are invariably open. But when dead falled dry cones are moved into a humid environment, they close and open again when dried, an experiment that may be repeated many times. The mechanism leading to cone opening when dired relies on the bilayered structure of the individual scales that change conformation when the environmental humidity is changed. The deformation is localized to a small region close to where the scale is attached to the midrib of the cone while the rest of the scale simply amplifies this motion geometrically. In this active outer layer of the tissue, closely packed long parallel thick walled cells respond by expanding longitudinally when exposed to humidity and shrinking when dried, while the inner passive layer does not respond strongly. Consequently, the tissue behaves like a thermally actuated bimetallic strip of the differential expansion of the constituent strips that are glued together.

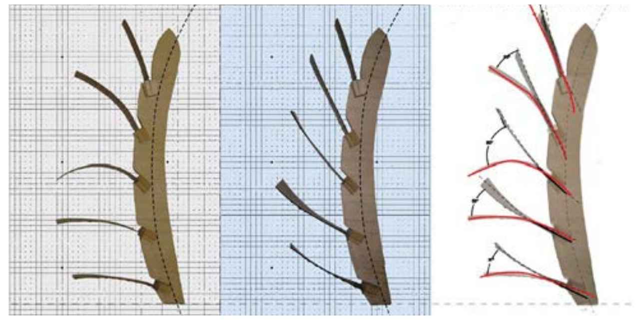


Can change in humidity be used to control air circulation in spaces?

Thus, a simple design principle of hygromorphic hinge and geometric amplification of motion can be applied on varied bio inspired sensors or actuators that respond to environmental variations using responsive materials. One such application developed was bilayered component façade system where the differential expansion properties lead to warping and straightening of the component based on thermal variation. This system could be developed into a dynamic façade for self shading of buildings or for variation in natural ventilation of the structures.

RESEARCH





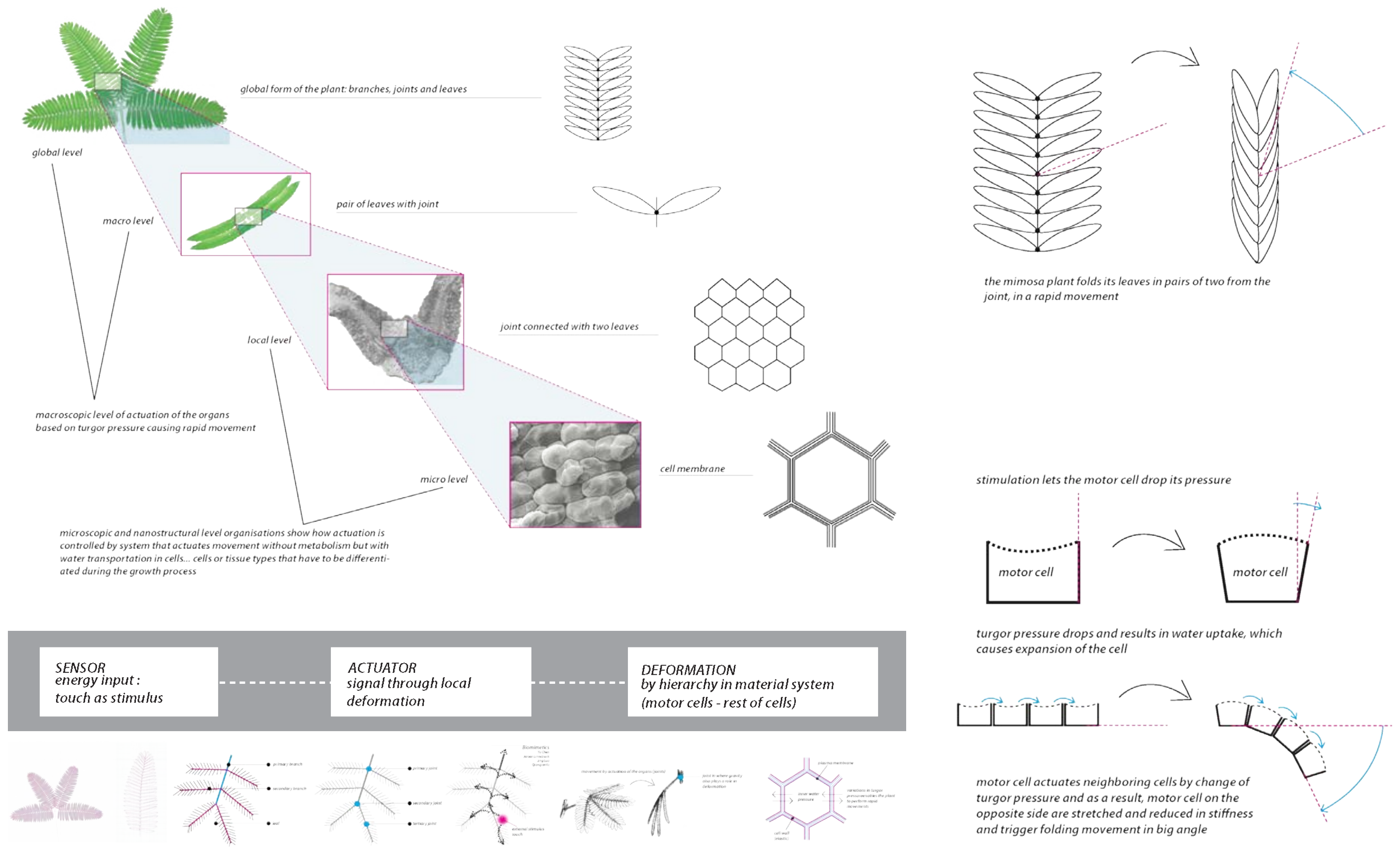
CONTRIBUTIONS

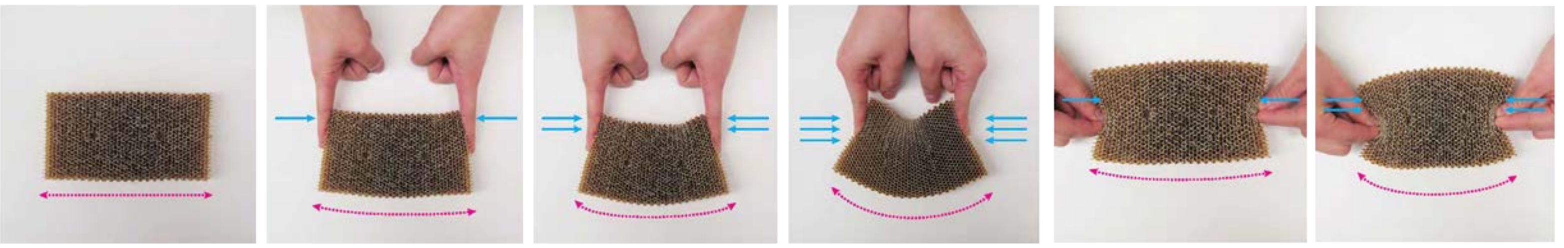
Project Type - Research Project
Category - Biomimetics
Location - AA School of Architecture
Role - Researcher
Highlights - Adaptive natural systems, Dynamic Facade

THIGMONASTIC MIMOSA

VISION

Thigmonastic movements in the sensitive plant Mimosa pudica L., associated with fast responses to environmental stimuli, appear to be regulated through electrical and chemical signal transductions. The thigmonastic responses of M. pudica can be considered in three stages: stimulus perception, electrical signal transmission and induction of mechanical, hydrodynamical and biochemical responses.

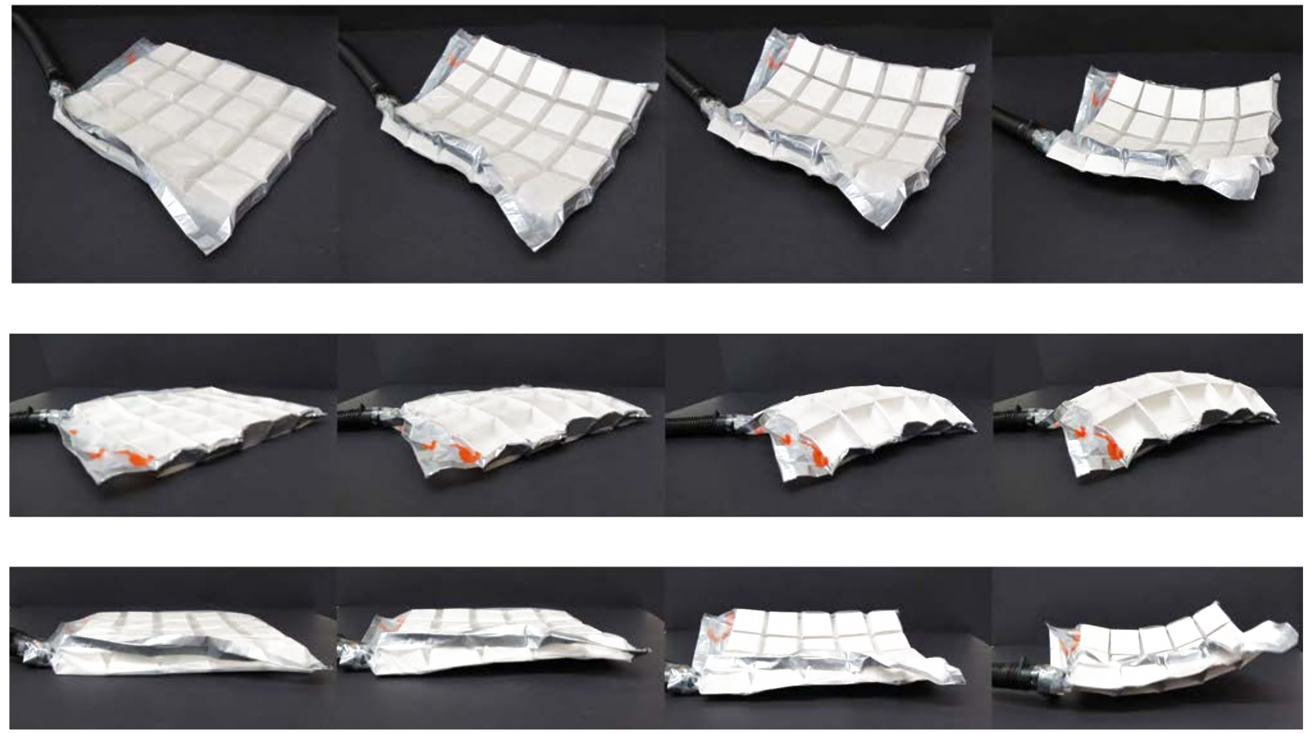


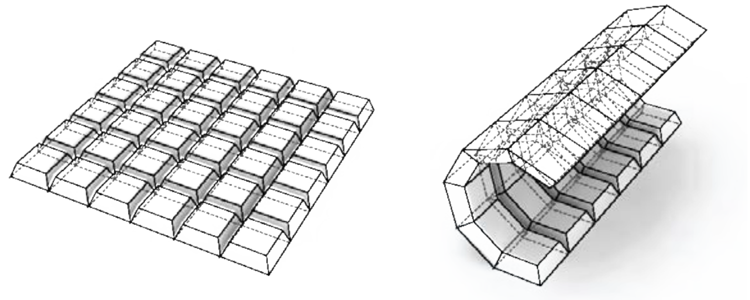


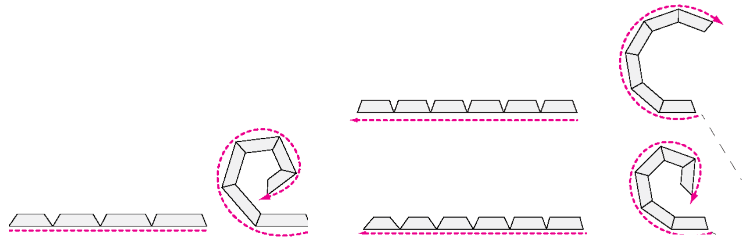
Learning from nature: Responsive materials actuated by pressure and touch

RESEARCH

The hydroelastic curvature mechanism closely describes the kinetics of M. pudica leaf movements. The specialized cells, called motor cells, are capable of changing their volume and shape very fast due to changes in cell turgor. Right after a touch stimulus, a first action potential transmits a signal from the stimulated site to the pulvinus. Another action potential triggers the rapid movement in the pulvinus, generating differential flows of K+ and Cl- between the symplasm and apoplasm that are followed by massive water flows, resulting in loss or gain of turgor by the cell. As the ions are pumped out of the extensor motor cells the internal water potential increases, leading to water loss and consequently to the shrinkage of these cells. At the same time, the opposite occurs with the flexor zone cells, leading them to a turgid condition and the leaflet folds up.







Can we design dynamic architecture inspired by mimosa behavior?

CONTRIBUTIONS

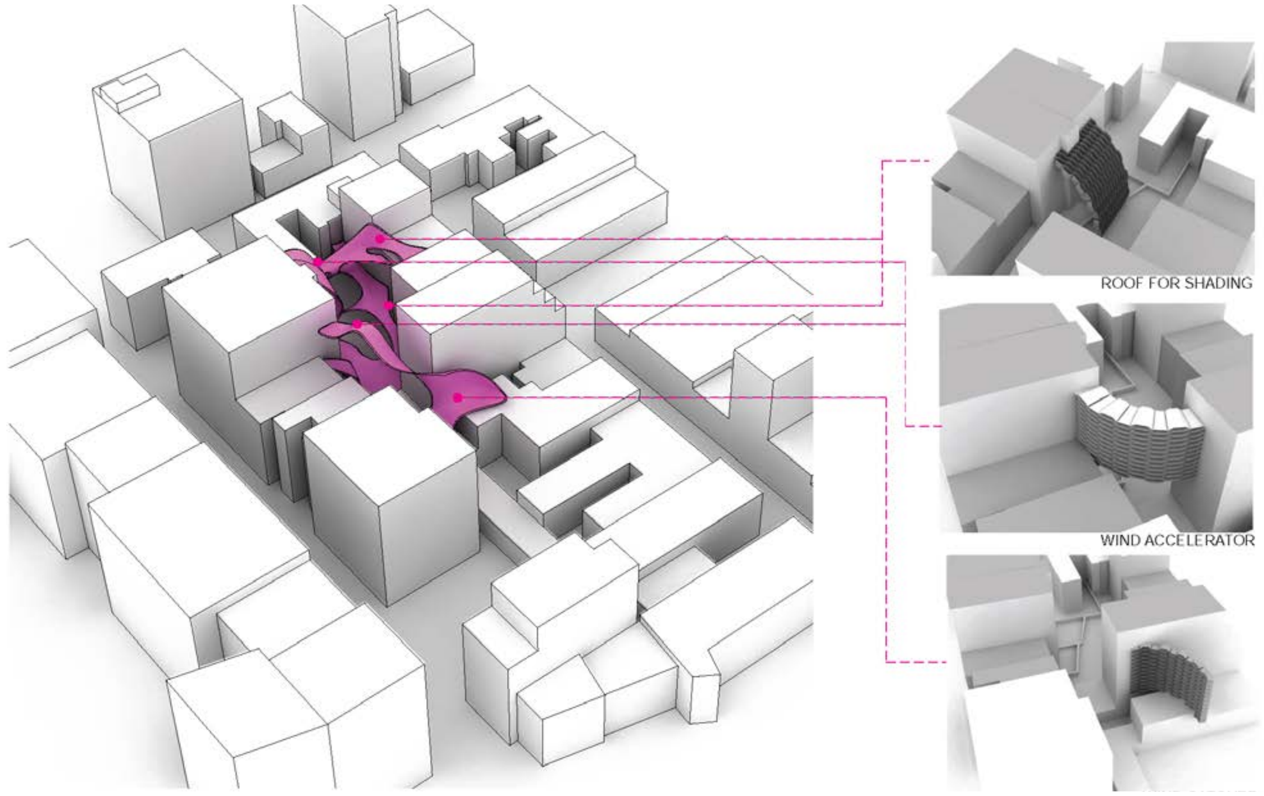
A detailed study above of deformation within certain special cells in a cellular packed structure and its subsequent result in the global form deformation sets base for developing architectural applications of the phenomenon. The concept of change in pressure leading to volumetric changes and resulting into dynamic behaviour of the global form can be applied on various architectural examples like self shading facades, openable windows, movable bridges etc.

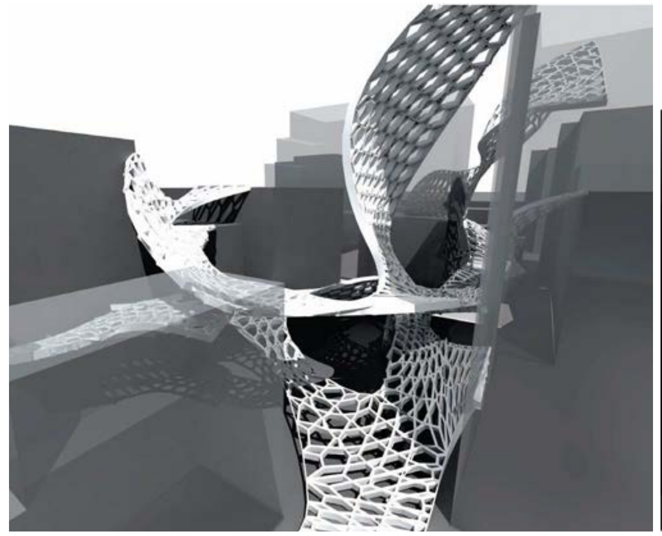
Project Type - Research Project
Category - Biomimetics
Location - AA School of Architecture
Role - Researcher
Highlights - Adaptive natural systems, Dynamic Architecture

WIND ACCELERATOR

VISION

Surface component morphology can be leveraged to influence microcliamtes in various ways. In this project, we used hexagonal components in different configurations to create different effects on the space and function as wind accelerator or wind catcher or sun shading surface.



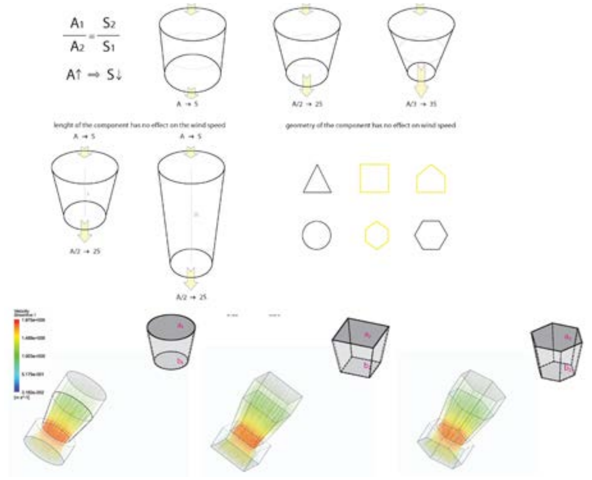


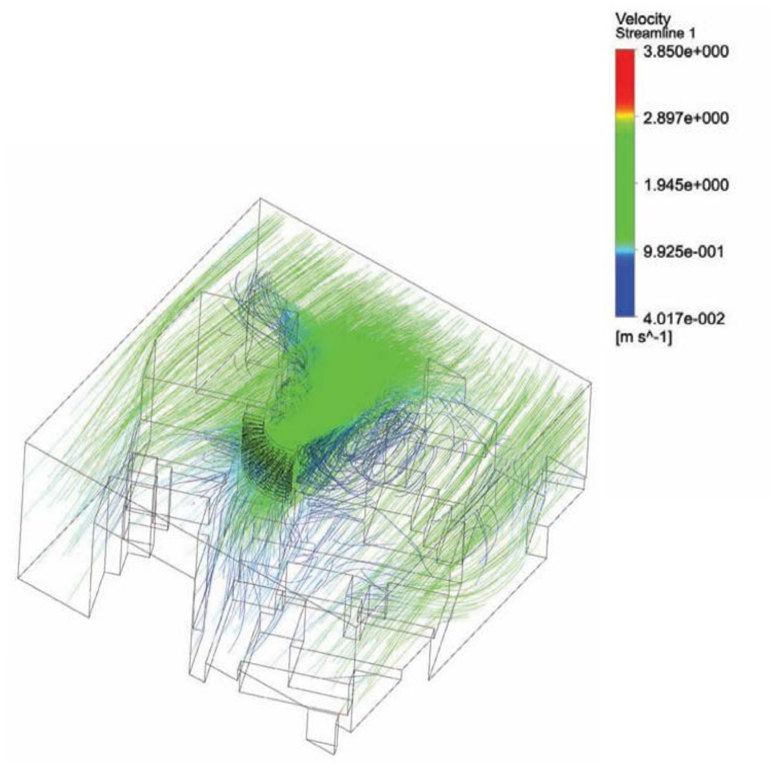
How can we use simulation programs to optimize micro-climate in design?

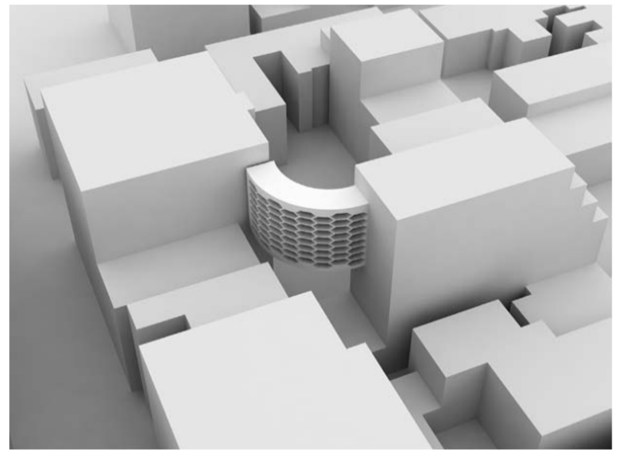
DESIGN + APPLICATION

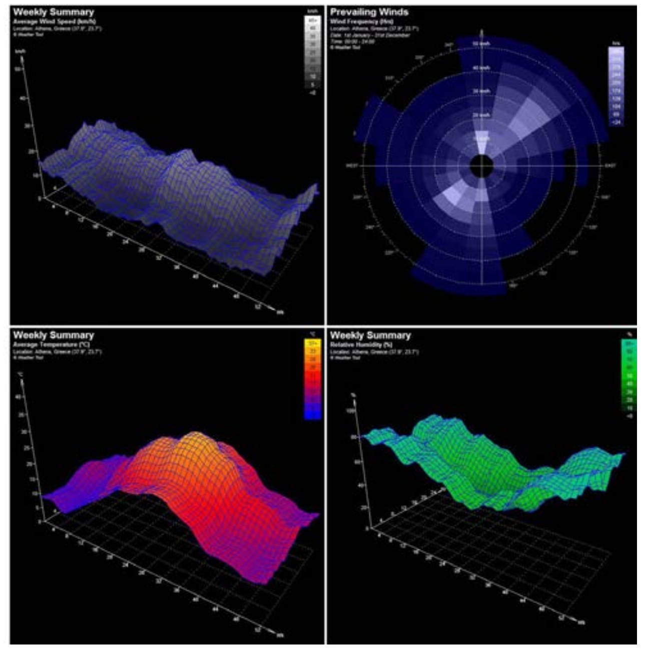
APPLICATION

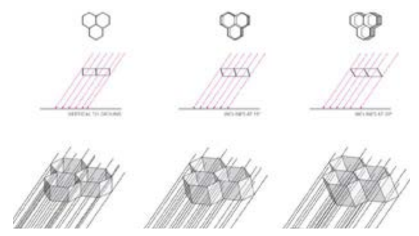
The diagrams below show how by modulating just the diameter of inlet and outlet apertures, the wind acceleration effect can be created in a microclimate. These components can then be assembled in different ways to crate surfaces that perform as wind catchers, shading surfaces or wind generators based on orientation.

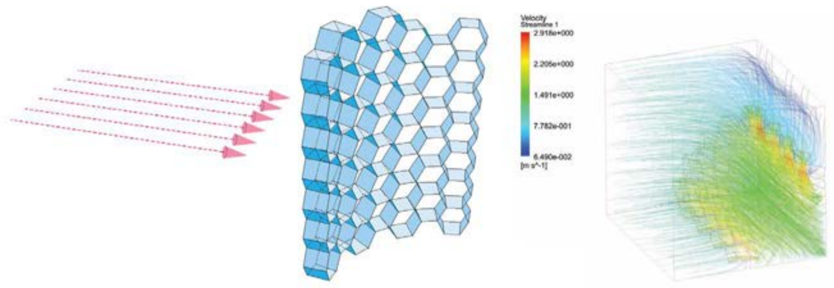












This project was an experiment in material and structural compositions to create ambient environment. Using cell packing as a structural technique and by modulating the porosity of the cells, an architectural surface was designed. The main contribution of this project is the proof of concept, simulations and rigorous tests for evaluating success of the proposal.

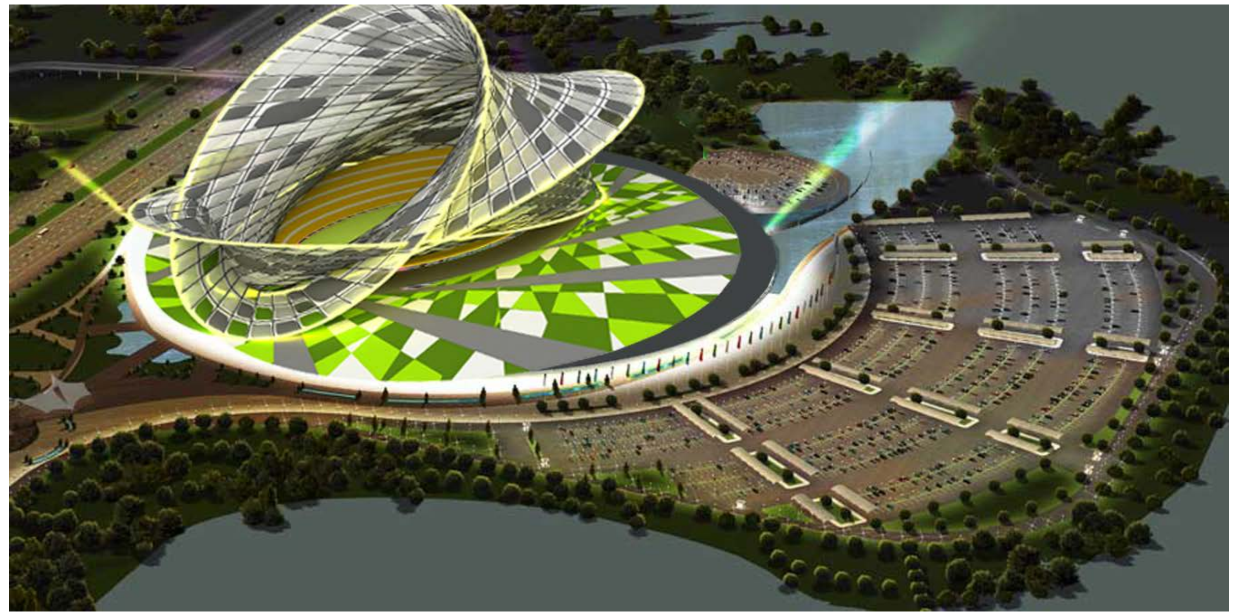
CONTRIBUTIONS

Project Type - Design Project
Category - Design with Data
Location - AA School of Architecture
Role - Computational Designer
Highlights - Wind Analysis

OTHER PUBLISHED PROJECTS

STADIUM DESIGN

For this stadium design, as a structural and design concept, we aimed at capturing the dynamic spirit and fortitude of the sports into the design of the stadium itself. The structure is primarily divided into 3 hierarchical layers that coalesce to constitute a dynamic structural icon. The 3 layers comprise of (i) 3 intertwined eccentric rings (ii) twisted secondary grid (iii) skin



OFFICE DESIGN

This theatrical office design is a dynamic space, invoking the observer's curiosity. Merging materiality with dramatic space, the design is a mould of two stark contrasting spaces – one being a rigid, rustic envelope with an earthy feel and the other being an organic, fluid and glossy enclosure both harmoniously meeting at the center of the office. This setup provides the opportunity to spatially divide the spaces with the minimal use of partitions and still provide relatively large user spaces.

How can we create unique user experiences in designs across scales?

OTHER WORKSHOP PROJECTS

SOLAR CANOPY

This doubly curved canopy that was exhibited at the prestigious Kala Ghoda art festival was a product of an intensive 7 day design workshop I conducted with architecture students. The porosity of this canopy is a design feature developed after studying the sun angles and shading patterns. This suspended structure brings together traditional jhaali art in Indian architecture with modern digital desig nand fabrication tools thus blending culture with technology through design.

PARAMETRIC PAVILION

A pavilion structure that functioned architecturally as a semi-shading enclosure in socially active spaces was created by fabricating digital designs into physical assembly models and then tested for strength, stability and flexibility. The results of the physical experiments were then embedded back into the digital analytical platforms for further design exploration and material optimization. The s-Pavilion design provided flexibility of space and was a light-weight installation that blended into the context.

How can we encourage the culture of making with mind and matter?