Wed: Bring the 3D printed ultrasonic + servo holder
Historical Development of UI

From Where the Action Is (Dourish, 2001)
• Special purpose devices (e.g., automatic calculation of missile trajectories, patterns in coded messages)
• Held a sequence of instructions in its memory.
• To program the machine for different tasks, electrical circuits need to be changed
• Interacting with the system required a thorough understanding of the electronic design

The Small Scale Experimental Machine, AKA “Baby” built at Manchester University in 1948.
• Introduction of programming systems (e.g., assemblers)
• Symbolic forms of interaction is not textual (e.g., punched cards)
• More regularized instructions available across a wider range of machines
• Takes advantage of the best-developed form of symbolic interaction: written language

• More like a “dialog”

E.g., early UNIX, DOS
Turning interaction into two-dimensional space rather than a one-dimensional stream of characters

Macintosh System 4.2, 1987
Graphical

Exploit more sets of human skills:

- Peripheral Attention
  Primary space, secondary space (e.g., windows and dashboards)
- Pattern recognition and spatial reasoning
  Opportunities to arrange data spatially
- Information density
  A picture really can be worth a thousand words (e.g., diagrams)
- Visual metaphors
  File cabinets, trash cans, desktop tools
Tangible

Computation that moves beyond desktop

- Interaction is incorporated more richly in our daily experience of the physical world
What drives Design?

- **Technology Driven Design**
  - begin with an innovative technology, apply it in an application/field

- **Need Driven Design**
  - identify an existing problem/set of problems, shape process around solving these problems

- **Concept / Vision Driven Design**
  - define a new concept, design artifacts which embody that concept, and test it
1997: Ishii: long term vision for Tangible User Interfaces
ABSTRACT
This paper presents our vision of Human Computer Interaction (HCI): "Tangible Bits." Tangible Bits allows users to "grasp & manipulate" bits in the center of users’ attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities.
One example
UIST 1997
metaDesk by Ullmer + Ishii
Tangible User Interface

Coupling of **Bits** and **Atoms**

Users interact with digital information *through a physical form*
Is this a tangible UI?

Tangible User Interface
Coupling of **Bits** and **Atoms**
Users interact with digital information **through a physical form**
Is the abacus a tangible UI?

no, it’s analog, there’s no coupling to digital information

Ishii met a highly successful PDA (Personal Digital Assistant) called the "abacus" when he was 2 years old. This simple abacus-PDA was not merely a computational device, but also a musical instrument, imaginary toy train, and a back scratcher. He was captivated by the sound and tactile interaction with this simple artifact. When his mother kept household accounts, he was aware of her activities by the sound of her abacus, knowing he could not ask for her to play with him while her abacus made its music. We strongly believe this abacus is suggesting to us a direction for the next generation of HCI.

Tangible User Interface
Coupling of Bits and Atoms
Users interact with digital information through a physical form
Is this a tangible UI?

Yes, users interact with a physical representation that represents digital information

(digital brush & painting color)
Why tangible?
world with **objects, tools, toys, and people.**
but we stare at a single glowing screen attached to an array of buttons and a mouse (or a piece of glass).
how your computer sees you:

$\text{(x, y)}$

$\rightarrow$ very limited bandwidth for interaction
Sensory Homunculus
A) Separating LEGO bricks
Tangible UI:
a vision of **how human and machine** should come together
not like (x,y) but with full bandwidth
actions representing a result

images representing a concept

symbolic describing the concept
symbolic came first: command line interfaces
iconic: graphical user interfaces with desktop metaphor
but control is always separate from its (iconic) representation
Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

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ABSTRACT
This paper presents our vision of Human Computer Interaction (HCI): "Tangible Bits." Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enable users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities.

This paper describes three key concepts of Tangible Bits: interactive surfaces; the coupling of bits with graspable physical objects; and ambient media for background awareness. We illustrate these concepts with three prototype systems — the metaDESK, transBOARD, and ambientROOM — to identify underlying research issues.

Keywords
tangible user interface, ambient media, graspable user interface, augmented reality, ubiquitous computing, center and periphery, foreground and background

INTRODUCTION: FROM THE MUSEUM
Long before the invention of personal computers, our ancestors developed a variety of specialized physical artifacts to measure the passage of time, to predict the movement of planets, to draw geometric shapes, and to compute [10]. We can find these beautiful artifacts made of oak and brass in museums such as the Collection of Historic Scientific Instruments at Harvard University.

Although we have developed various skills and work practices for processing information through haptic interactions with physical objects (e.g., scribbling messages on Post-it® notes and spatially manipulating them on a wall) as well as peripheral sensors (e.g., being...
What kind of information/scenario is suitable for tangible interface?
Many early ideas start with coupling digital information with physical tokens on a computational desktop
Urban planning and design desk
3D Shape and geometry representation

The physical clay model conveys spatial relationships that can be intuitively and directly manipulated by the user’s hands --- quickly create and understand highly complex topologies

The user is free to use any object, material or form to interface with the computer

2002: Ben Piper and Hiroshi Ishii: Illuminating Clay
Physical tokens later became active
CurlyBot

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curlybot: Designing a New Class of Computational Toys

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ABSTRACT
We introduce an educational toy, called curlybot, as the basis for a new class of toys aimed at children in their early stages of development - ages four and up. curlybot is an autonomous, two-wheeled vehicle with embedded sensors that can perceive its position on a flat surface and then play back that motion accurately and repeatedly. Children can use curlybot to develop situations for advanced mathematical and computational concepts, like differential geometry, through play away from a traditional computer.

In our preliminary studies, we found that children learn to use curlybot quickly. They readily establish an effective and body-synched connection with curlybot, because of its ability to remember all of the movements of their original motion sequence; even the slightest movement of their hand is recorded. Programming by example in this context makes the educational ideas explicit in the design of curlybot accessible to young children.

Keywords: Education, learning, children, tangible interface, toy

INTRODUCTION
The role of physical objects in the development of young children has been studied extensively in the past. In particular, it has been shown that a careful choice of materials can enhance children's learning. A particularly notable example of such materials is Friedrich Froebel's collection of twenty physical objects (so called "gifts"), each designed with the purpose of making a particular concept accessible to and manipulable by children [1]. The presence of objects inspired by Froebel is almost all kindergartens today is a reflection of their recognized value in the development of young children.

1999: Frei et.al

Figure 1: Three personalized curlybots (with a large record/playback button and a small red indicator light) are ready. Much like Froebel's gifts, these tools attempt to open new domains of knowledge accessible to children.

In this paper, we introduce to this initiative a new class of computational toys that is aimed at children in young age four. curlybot, the first instantiation of this class of toys, is a two-wheeled toy that can record and play back physical motion reproducing every nuance of the original notion. It is a smooth, curvilinearly curved object with a button and an LED for indicating whether the device is in record (red) or playback (green) mode. To record a gesture, a child presses the button and moves curlybot through a desired path. A child presses the button a second time, to stop recording and begin playback of the recorded gesture. The playback mode matches the gesture indefinitely until the button is pressed again. Because of the simplicity of the interface, children quickly learn to create intricate gestures with curlybot, which they can refine through an iterative process.
The Actuated Workbench: Computer-Controlled Actuation in Tabletop Tangible Interfaces

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ABSTRACT
The Actuated Workbench is a device that uses magnetic forces to move objects on a table in two dimensions. It is intended for use with existing tabletop tangible interfaces, providing an additional feedback loop for computer output, and helping to resolve inconsistencies that otherwise arise from the computer’s inability to move objects on the table.
We describe the Actuated Workbench in detail as an enabling technology, and then propose several applications in which this technology could be useful.

KEYWORDS: Tangible user interfaces, physical interaction, actuation, synchronization, interactive surface, object tracking, computer supported cooperative work.

INTRODUCTION
Interactive tabletop surfaces are a promising avenue of research in Tangible User Interfaces. These systems, which we will refer to as “interactive workbenches,” track the position and movement of objects on a flat surface and respond to users’ physical input with graphical output. Systems such as the DigitalDesk [18], Bricks [7], Senseable [13], and Urp [17] offer many advantages over purely graphical interfaces, including the ability for users to organize objects spatially to aid problem solving, the

2002: Pangaro: Actuated Workbench
Mechanical Constraints as Computational Constraints in Tabletop Tangible Interfaces

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ABSTRACT
This paper presents a new type of human-computer interface called Pico (Physical Intervention in Computational Optimization) based on mechanical constraints that combines some of the tactile feedback and affordances of mechanical systems with the abstract computational power of modern computers. The interface is based on a tabletop interaction surface that can sense and move small objects on top of it. The positions of these physical objects represent and control parameters inside a software application, such as a system for optimizing the configuration of radio towers in a cellular telephone network. The computer autonomously attempts to optimize the network, moving the objects on the table as it changes their corresponding parameters in software. As these objects move, the user can constrain their motion with his or her hands, or many other kinds of physical objects. The interface provides ample opportunities for improvisation by allowing the user to employ a rich variety of everyday physical objects as mechanical constraints. This approach leverages the user’s mechanical intuition for how objects respond to physical forces. As well, it allows the user to balance the numerical optimization performed by the computer with other goals that are difficult to quantify. Subjects in an evaluation were more effective at solving a complex spatial layout problem using this system than with either of two alternative interfaces that did not feature actuation.

Author Keywords
tangible interfaces, physical interaction, interactive surface, improvisation, actuation.

ACM Classification Keywords

Zooids: Building Blocks for Swarm User Interfaces

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Figure 1. Zooids can be held as tokens, manipulated collectively or individually, behave as physical pixels, act as handles and controllers, and can move dynamically under machine control. They are building blocks for a new class of user interface we call swarm user interfaces.

ABSTRACT

This paper introduces swarm user interfaces, a new class of human-computer interfaces comprised of many autonomous robots that handle both display and interaction. We describe the design of Zooids, an open-source open-hardware platform for developing tabletop swarm interfaces. The platform consists of a collection of custom-designed wheeled micro robots each 2.6 cm in diameter, a radio base-station, a high-speed DLP structured light projector for optical tracking, and a software framework for application development and control. We illustrate the potential of tabletop swarm user interfaces through a set of application scenarios developed with Zooids, and discuss general design considerations unique to swarm user interfaces.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

interprets with “a new kind of matter capable of changing form dynamically” [26].

Several significant steps have been recently made towards Sutherland’s and Ishii’s visions, particularly through research on actuated tangibles [48, 50, 78] and shape displays [55, 56, 15]. However, current systems suffer from a number of limitations. First, actuated tabletop tangibles generally only support the manipulation and actuation of a few (e.g., 3-4) solid objects, which is not enough to emulate physical matter that can change form. On the other hand, shape displays try to achieve surfaces that can be deformed and actuated, but current implementations do not support arbitrary physical topologies. Furthermore, both types of systems traditionally use physical objects primarily as input, while output is almost always provided through separate pixel-based display technology. Although video-projected overlays allow input and output to spatially coincide [12], they provide only a limited sense of objectivity [5]. Likewise, many such systems require heavy
ZeroN: Mid-Air Tangible Interaction Enabled by Computer Controlled Magnetic Levitation

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ABSTRACT

This paper presents ZeroN, a new tangible interface element that can be levitated and moved freely by computer in a three-dimensional space. ZeroN serves as a tangible representation of a 3D coordinate of the virtual world through which users can see, feel, and control components. To accomplish this, we developed a magnetic control system that can levitate and rotate a permanent magnet in a predefined 3D volume. This is combined with an optical tracking and display system that projects images on the levitating object. We present applications that explore this new interaction modality. Users are invited to place or move the 3D virtual object as if they can place objects in space or move objects on a surface. For example, users can place the 3D virtual object on a table and manipulate it with their fingers by tapping, pushing, and rotating based on simulated physical conditions. We describe the technology: interaction scenarios and challenges. This work was supported by the National Science Foundation grant IIS-1016982 and DTM CCF-1018426.

INTRODUCTION

Tangible interfaces attempt to bridge the gap between virtual and physical spaces by activating the digital in the physical world [7]. Despite tangible interfaces have demonstrated a wide range of interaction possibilities and utilities, users still perceive tangible interfaces as abstract and contextually distant from physical objects. For example, in video games, virtual objects are represented as two-dimensional icons, making their interactions less tangible and immersive. In some cases, interaction events that are intended to occur in virtual space are triggered by physical gestures, creating a mixed reality space where the boundaries between virtual and physical worlds are blurred. This is accomplished by interfacing input devices with computational software that enable manipulation of virtual objects. Nevertheless, these interaction models still require users to perceive objects within their two-dimensional representations [32].

Figure 1: What if users could take a physical object off the surface and place it in the air? ZeroN enables such mid-air tangible interaction with computer-controlled magnetic levitation. Various 3D applications can be reimagined with this interaction modality: 3D architectural simulation, 3D physics simulation, 3D entertainment: tangible 3D pin-pong game.
What is missing in Tangible Bits?

Physical atoms are not as “flexible” as digital bits
“active” physical interface?

Physical atoms are not as “flexible” as digital bits
2012: Hiroshi Ishii’s vision: Radical Atoms
**Radical Atoms** goes beyond Tangible Bits by assuming a hypothetical generation of materials that can change form and appearance dynamically, becoming as reconfigurable as pixels on a screen.
2004: Claytronics vision (not implemented)
“The ultimate display would, of course, be a room within which the computer can control the existence of matter.”

ChainFORM: A Linear Integrated Modular Hardware System for Shape Changing Interfaces

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ABSTRACT
This paper presents ChainFORM, a linear, modular, actuated hardware system as a novel type of shape changing interface. Using rich sensing and actuation capability, this modular hardware system allows users to construct and customize a wide range of interactive applications. Inspired by modular and serpentine robotics, our prototype comprises identical modules that connect in a chain. Modules are equipped with rich input and output capability: touch detection on multiple surfaces, angular detection, visual output, and motor actuation. Each module includes a servo motor wrapped with a flexible circuit board with an embedded microcontroller. Leveraging the modular functionality, we introduce novel interaction capability with shape changing interfaces, such as rearranging the shape/configuration and attaching to passive objects and bodies. To demonstrate the capability and interaction design space of ChainFORM, we implemented a variety of applications for both computer interfaces and hands-on prototyping tools.

INTRODUCTION
As shape changing interfaces being an emerging field in HCI, a lot of actuation techniques have been introduced to provide physical shapes to represent digital data and to embody spatial interactions [9, 35]. Researchers are continuously seeking techniques that have a variety of transformational capabilities in different geometries and scales [14, 24]. To extend the sensing and display capability of such shape-changing interfaces, extra sensors or cameras and projectors have been installed for detecting human input and displaying information on the active surfaces. However, this strategy poses a challenge for scaling the system, which presents a problem, especially for mobile applications. To push the boundaries of shape-changing interface research, another approach calls for self-contained systems that integrate sensing, actuation and display across different scales, geometries, and transformations.

We present ChainFORM, a modular integrated hardware system that has a chained, linear form factor (Figure 1). The hardware comprises identical actuated modules connected in series, which allows the user to customize the length and the configuration of devices they construct. The form-factor of line and the modularity expands the possibility of transformation for both shapes and scales. In addition, each module inte-
inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation

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ABSTRACT
Past research on shape displays has primarily focused on rendering context and user interface elements through shape output, with less emphasis on dynamically changing UIs. We propose utilizing shape displays in three different ways to mediate interaction: to facilitate by providing dynamic physical affordances through shape change, to restrict by guiding users with dynamic physical constraints, and to manipulate by actuating physical objects. We outline potential interaction techniques and introduce Dynamic Physical Affordances and Constraints with our inFORM system, built on top of a state-of-the-art shape display, which provides for variable stiffness rendering and real-time user input through direct touch and tangible interaction. A set of motivating examples demonstrates how dynamic affordances, constraints and object actuation can create novel interaction possibilities.

INTRODUCTION
The rich variety of physical forms found in everyday life often serve both functional and aesthetic roles. These physical objects have features that not only provide functionality, but also suggest possible uses, or configure the ways we may interact with them; Norman labels these as perceived affordances [30]. This notion of perceived affordances has been long appropriated by the HCI field, particularly in the context of Graphical User Interfaces (GUI) and Tangible User Interfaces (TUI) [17]. While GUIs have the ability to change perceived affordances rapidly to adapt them to different content and context, TUIs primarily exploit the affordances inherent in physical form, as well as their physiological and cognitive advantages [21]. For example, the Token and Constraint framework introduced by Ullmer uses mechanical constraints to provide physical affordances for interacting with tangible controllers, such as tokens [38]. However, TUIs, such as those outlined by Ullmer, are often limited by the static nature of most man-made physical artifacts, and thus cannot easily change their form. Therefore, many projects in

2013: Leithinger, Ishii: inForm shape display
Some of the key technologies
Two Motors for Lateral Actuation
Linear Actuator
Electromagnet
Hall-effect Sensor
 Levitated Object
Driving Circuit
Mechanical Constraints as Computational Constraints in Tabletop Tangible Interfaces

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Objects on the Pico table are moved not only under software control using electromagnets but also by users standing around the table. The combination of these interactions, all governed by the friction and mass of the objects themselves, directly affects the result of the task being performed. Additional information is graphically projected onto the table from above. In this sense we will show how this technique

Author Keywords
Tabletop interfaces, physical interaction, interactive surface, improvisation, actuators.

ACM Classification Keywords

Figure 1: A flexible “artist’s curve” constraining the motion of a cellphone tower in the Pico system.
Figure 3. The components of each module (a: circuit board with flexible hinges, b: 3D printed bracket, c: HS-5035HD Servo Motor.)

**ABSTRACT**

This paper presents ChainFORM, a linear, modular, actuated hardware system as a novel type of shape changing interface. Using rich sensing and actuation capability, this modular hardware system allows users to construct and customize a wide range of interactive applications. Inspired by modular and serpentine robotics, our prototype comprises identical modules that connect in a chain. Modules are equipped with rich input and output capability: touch detection on multiple surfaces, angular detection, visual output, and motor actuation. Each module includes a servo motor wrapped with a flexible circuit board with an embedded microcontroller.

Leveraging the modular functionality, we introduce novel interaction capability with shape changing interfaces, such as reconfiguring the shape/configuration and attaching to passive objects and bodies. To demonstrate the capability and interaction design space of ChainFORM, we implemented a variety of applications for both computer interfaces and hand-on prototyping tools.

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As shape-changing interfaces being an emerging field in HCI, a lot of actuation techniques have been introduced to provide physical shapes to represent digital data and to embody spatial interactions [9, 45]. Researchers are continually seeking techniques that have a variety of transformational capabilities in different geometries and scales [14, 24]. To extend the sensing and display capability of such shape-changing interfaces, extra sensors or cameras and projectors have been installed for detecting human input and displaying information on the active surfaces. However, this strategy poses a challenge for scaling the system, which presents a problem, especially for mobile applications. To push the boundaries of shape-changing interface research, another approach calls for self-contained systems that integrate sensing, actuation and display across different scales, geometries, and transformations.

We present ChainFORM, a modular integrated hardware system that has a chained, linear form factor (Figure 1). The hardware comprises identical actuated modules connected in series, which allows the user to customize the length and the configuration of devices they construct. The form-factor of line and the modularity expands the possibility of transformation for both shapes and scales. In addition, each module inte
Zooids: Building Blocks for Swarm User Interfaces

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Figure 1. Zooids can be held as tokens, manipulated collectively or individually, behave as physical objects, act as handles and controllers, and can move dynamically under machine control. They are building blocks for a new class of user interface we call swarm user interfaces.

ABSTRACT

This paper introduces swarm user interfaces, a new class of human-computer interfaces comprised of many autonomous robots that handle both display and interaction. We describe the design of Zooids, an open-source open-hardware platform for developing tabletop swarm interfaces. The platform consists of a collection of custom-designed wheeled micro robots each 2.6 cm in diameter, a radio base-station, a high-speed DLP structured light projector for optical tracking, and a software framework for application development and control. We illustrate the potential of tabletop swarm user interfaces through a set of application scenarios developed with Zooids, and discuss general design considerations unique to swarm user interfaces.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

UIST 2016

Goc et al.
2012: Hiroshi Ishii’s vision: Radical Atoms
“Practical” Use?
Teaching Computer Science to 5-7 year-olds: An initial study with Scratch, Cubelets and unplugged computing

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ABSTRACT
Changes to school curriculums increasingly require the inclusion of computer science. Despite this, many teachers feel inadequately prepared, making the task of teaching computing to young children, which is not a requirement of the curriculum, a challenge. We have therefore undertaken an initial study focusing on teaching computer science to 5-7 year-olds. Our hypothesis is that learning through play can help teachers acquire the necessary skills to teach computing to young children. This study is the first stage of a larger project involving working with primary schools and observing the effectiveness of different teaching methods. Here we report on an initial intervention involving three different techniques for teaching about computer science: unplugged computing, tangible computing and using Scratch. The results of this initial teaching intervention have been promising, and we are now planning to develop an educational program that includes a fully developed, age-appropriate curriculum. This work is supported by the British Computer Society (BCS) and the National Centre for Excellence in the Teaching of Computer Science (NCETCS).

1. INTRODUCTION

Several major organizations such as Computing at Schools (CaS), have been working to improve computer science education in the UK for several years. In September 2015, it was revealed that 15,000 primary schools in England will receive training in computer science, and that this training will be mandatory for all schools by 2018. Although a positive development, many primary schools lack the necessary skills to teach computer science effectively. This study has explored how to teach computer science concepts to children at the age of 5-7. As part of this study, we have developed a curriculum that can be used by teachers to teach computer science concepts to young children.

2. RELATED WORK

A recent study in Norway has shown that computer science concepts can be taught to 5-7 year-olds. In this study, children were taught computer science concepts using a game-based approach. The results showed that children were able to learn basic computer science concepts, such as programming and problem-solving, using this approach. This study provides evidence that computer science concepts can be taught to young children using a game-based approach. However, this study did not focus on the development of a curriculum that could be used by teachers to teach computer science concepts to young children.

3. Conclusion

In conclusion, we have developed a curriculum that can be used by teachers to teach computer science concepts to young children. This curriculum includes games and activities that can be used to teach computer science concepts, such as programming and problem-solving. We believe that this curriculum can be used by teachers to teach computer science concepts to young children in a way that is engaging and effective.

Keywords: computing education, programming, computer science, young children

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Data availability statement: The data generated during the current study are available from the corresponding author on reasonable request.

References:


shapeCAD: An Accessible 3D Modelling Workflow for the Blind and Visually-Impaired Via 2.5D Shape Displays

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ABSTRACT
Affordable, rapid 3D printing technologies have become key tools for creating custom physical products. However, existing software and hardware interfaces are inaccessible to people with blindness and visual impairment (VI). We present shapeCAD: an adaptable and accessible 3D modelling software platform that supports interactive tangible and intuitive models of virtual programming ability, we identify accessibility challenges to existing 3D modelling software tools and shape interactions to support dynamic feedback of a variety of 3D print-able shapes. With these insights, we implement shapeCAD. Consistent with shapeCAD, 3D printers are often in inaccessible environments, such as school classrooms or living rooms. In shapeCAD, users can physically explore and manipulate virtual models, and to author new models. We further validate shapeCAD and user experiences through an evaluation with the VI community. It is a short period of time, users were able to design a range of fabricated 3D models, and it is important to increase accessibility to tools that enable the community to also participate as designers.

ACM Classification Keywords
Human-Computer Interaction: Accessibility systems and tools, Authoring tools: Accessible 3D Printing, Tangible Graphics, Haptic, Tangible Displays; 2.5D Shape Displays

Introduction
Despite advances in technology and the capabilities of 3D printing, only a few tools have been designed with accessibility in mind. 3D printing tools, such as 3D printers and easy-to-use microcontrollers, have evolved to support a wide range of applications in various industries. However, the accessibility of these tools remains a critical issue, as many individuals with disabilities are left out of the 3D printing community. In this paper, we explore the challenges and potential solutions for making 3D printing accessible for individuals with visual impairments.

Methodology
Our methodology involves selecting and evaluating existing 3D modeling tools with accessibility features, and developing new tools that are specifically designed for the VI community. We conducted user tests with individuals who are blind or visually impaired, who were able to design and print 3D models using shapeCAD.

Figure 1: An image of the shapeCAD interface with 3D models generated through shapeCAD and printed via 3D printing.
TangibleGrid: Tangible Web Layout Design for Blind Users

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ABSTRACT
We present TangibleGrid, a novel device that allows blind users to understand and design the layout of a web page with real-time tangible feedback. We conducted semi-structured interviews and a series of co-design sessions with blind users to design tangible feedback that guided the design of TangibleGrid. Our final prototype contains shape-changing haptic components representing web elements and a baseboard representing the web page. Blind users can design a web page layout through creating and editing web elements by moving or adjusting tangible haptic components on top of the baseboard. The haptic feedback uses the users’ touch, eye, and location to coordinate the information, and renders the web page on the display screen. Through a formative user study, we found that blind users could understand a web page layout through TangibleGrid. They were able to design a new web page from scratch without the help of sighted people.

CCS CONCEPTS
- Human-centered computing → Accessibility systems and tools.

KEYWORDS
Accessible web design, tangible feedback, tangible user interface, visual impairment, accessibility

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1 INTRODUCTION
Accessibility technologies have greatly changed the lives of blind and visually impaired people. Beyond Internet consumers, blind users are now able to share stories and life events on social media sites such as YouTube [22] and Instagram [18]. Some blind users have also created and maintained their own web pages for blogging and knowledge sharing [14, 30]. Indeed, the stories and daily experiences of the blind media influencers have become an important source of support to the blind community. Mastering skills like building websites has also led to new employment opportunities for blind and visually impaired people [1, 16].

Unfortunately, creating a web page is still challenging for many blind users despite the strong need for it [23, 30]. For one, web
Take My Hand: Automated Hand-Based Spatial Guidance for the Visually Impaired

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ABSTRACT
Tasks that involve locating objects and then moving hands to those specific locations, such as using two hands to guiding objects on a desk, are challenging for the visually impaired. Over the years, audio guidance and haptic feedback have been a staple in hand navigation-based assistive technologies. However, these methods require the users to interpret the generated directional cues and then manually perform the hand motions. In this paper, we present automated hand-based spatial guidance to bridge the gap between visual and hand-based exploration of the visually impaired. Our approach builds on the FingerTracker framework and incorporates automated hand-based spatial guidance using a miniature robot. We evaluate our approach in a laboratory setting with participants with visual impairments. The results of our user study show the potential of our technique in improving the interaction capabilities of people with visual impairments.

Figure 1: This paper presents automated hand-based spatial guidance, a technique that allows visually impaired users to reach targets on a surface using their hands without the need for interpreting directional cues. We facilitate this technique using FingerTracker, an on-finger miniature robot.

CSC Concepts
- Human-centered computing — Accessibility systems and tools

KEYWORDS
visual impairment, automated guidance, spatial guidance, miniature guiding robot, accessibility

1 INTRODUCTION
Hand-based spatial navigation has been a long-standing and pervasive problem for people with visual impairments. What appears to be a simple task of picking up a phone from a desk involves heavy cognitive processing that we perform subconsciously: detecting the phone in the environment, estimating its location relative to us, planning the optical path to reach the phone, and finally moving the hand along the planned path to pick up the phone. The lack of visual modality in users with such single tasks is extremely challenging. More so, activities that require hand navigation to vary

CHI 2023: Rahman et al.
Optional readings

**CHI 1997**

Ishii et.al. from MIT

**CHI 2021**

Schmitz et.al.

Material is in part based on the lectures by Prof. Stefanie Mueller @ MIT and Prof. Kimiko Ryokai @ UCB