A Multi-modal Toolkit to Support DIY Assistive Technology Creation for Blind and Low Vision People

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ABSTRACT

We design and build *A11yBits*, a tangible toolkit that empowers blind and low vision (BLV) people to easily create personalized do-it-yourself assistive technologies (DIY-ATs). A11yBits includes (1) a series of *Sensing* modules to detect both environmental information and user commands, (2) a set of *Feedback* modules to send multi-modal feedback, and (3) two *Base* modules (*Sensing Base* and *Feedback Base*) to power and connect the sensing and feedback modules. The toolkit enables accessible and easy assembly via a "plug-and-play" mechanism. BLV users can select and assemble their preferred modules to create personalized DIY-ATs.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility systems and tools**; **User interface toolkits**.

KEYWORDS

Accessibility, blind and low vision, DIY toolkit, tangible modules

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1 INTRODUCTION

Blind and low vision (BLV) people encounter difficulties in various daily tasks. While specialized assistive technologies (ATs) are designed [1], they mostly focus on generic solutions targeting the whole BLV population, without considering users' individual differences. The needs of BLV people can vary due to different visual abilities, living context, and prior experiences [9]. They thus have to spend time and effort to adapt to the 'universally designed' ATs, ending up with a high abandonment rate [5]. Moreover, their needs may change over time due to the changes of their ability and life priorities, making originally suitable ATs not usable anymore [10].

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Do-it-yourself (DIY) technology is a promising solution that empowers users to create personalized ATs with low cost and tailored functionalities [4–7]. However, non-professionals, especially those with disabilities, face challenges in DIY-AT creation due to inaccessible makerspace and tools [2, 8], lack of confidence [4], and lack of sufficient technical knowledge [3]. More technologies are needed to make 'making' accessible and easy for BLV users [5, 11].

We design and develop *A11yBits*, a low-cost, tangible toolkit with a set of multi-modal sensing and feedback modules, enabling BLV users to easily and flexibly create DIY solutions to support various daily activities. A11yBits provides four *Sensing* modules, including timing, temperature, motion, and voice sensors to detect environmental changes and the user's direct input. It also supports four *Feedback* modules, including audio, speech, vibrotactile, and visual feedback, allowing BLV users to select and combine their preferred notification methods. An accessible and safe "plug-and-play" mechanism is designed to enable easy assembly without requirements for technical skills. Tactile symbols and labels are created to ensure the accessibility of the modules for BLV users. We conduct preliminary workshop studies to iterate on the design of A11yBits.

2 A11YBITS

A11yBits includes three sets of modules (Figure 1): *Sensing* modules, *Feedback* modules, and *Base* modules.

Sensing Modules. Four sensing modules are created to interpret user commands or environmental changes: (1) a *Motion* module that detects the movement of nearby objects or people via an HC-SR501 passive infrared (PIR) sensor, (2) a *Temperature* module with a DS18B20 temperature sensor to detect surrounding temperature, (3) a *Timer* module that incorporates a potentiometer and a push button to enable users to control the built-in timer in the microcontroller in the base module (described below), and (4) a *Voice* module to allow speech input via a DFR0715 speech recognition component that can recognize up to 50 pre-programmed phrases.

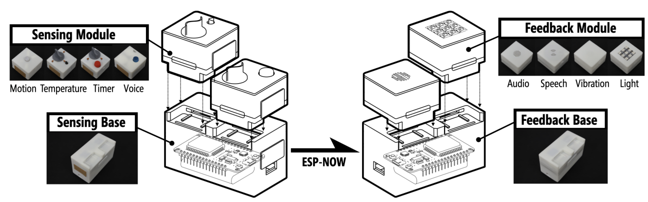

Figure 1: Sensing, Feedback, and Base modules in A11yBits.

Feedback Modules. Four feedback modules are created to provide audio, speech, vibration, and visual feedback. They include: (1)

a *Audio* module that generates beeping sound via an active buzzer, (2) a *Speech* module that generates pre-recorded speech feedback via a DFR0299 MP3 player, (3) a *Vibration* module that generates vibrotactile feedback via an ELB060416 coin vibration motor, and (4) a *Light* module to generate visual cues for low vision people via a WS2812 3×3 LED matrix.

Base Modules. To optimize the size of assembled DIY-ATs, we adopt a "shared power and computation" method, where all sensing/feedback modules share the same power supply and microcontroller in their corresponding base. The base thus serves as the "brain" of the modules—the sensing/feedback modules only work when connected to the base. In the current prototype, each base module can house two sensing/feedback modules simultaneously.

We provide two base modules—a *Sensing Base* and a *Feedback Base*—to house the sensing and feedback modules respectively. Each base module integrates an SXT103450 3.7V/2000mAh LiPo battery as the power and an ESP 32-based microcontroller board to process the signals from the sensing modules or control the behaviors of the feedback modules. The sensing/feedback modules will function right after being connected to the base. The sensing base and feedback base are pre-programmed to pair and communicate with each other via the ESP-NOW protocol on the Data Link Layer based on the fixed MAC address of each microcontroller. The sensing base can thus send the detection results from the sensing modules to the feedback base to trigger proper feedback via the feedback modules.

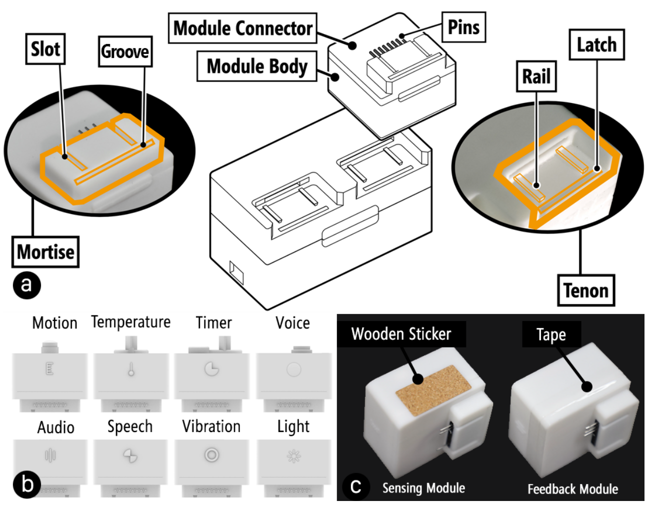

Figure 2: Connector design and tactile labels in A11yBits.

Connector Design. We enable BLV users to easily connect sensing/feedback modules to the base via a "plug-and-play" mechanism. To do so, we design mortise and tenon structure-based connectors so that the modules can be slid into the base and locked in position via a latching mechanism (Figure 2a). The mortise-based connector on the sensing/feedback module has two paralleled chamfered slots. The tenon-based connector on the base module has two paralleled sliding rails with a wedged-shape cross section, limiting the module to sliding only in one linear trajectory into the base. Additionally, a half-cylinder "latching" groove at the endpoint of each sliding rail is used to lock the two connectors together after the module is fully slid in. The latching mechanism makes a clicking sound at its full-in position, enabling BLV users to confirm the connection completion via this audio indicator. To unlock and disconnect the modules from the base, the user can pull the two connectors apart with slightly more effort to release the latch. Finally, we install a row of pins in the connector of the sensing/feedback modules to establish electrical connection with the base.

Tactile Labels. To make the modules recognizable for BLV users, we design and add tactile textures and symbols on each module to label the module type and functionality. First, we 3D print protruded non-lexical tactile symbols on each module case to represent its functionality (Figure 2b). For example, a two-concentric-tori symbol mimicking the water ripples is used to represent the vibration module, while a sun-shape symbol is used to indicate the light module. Moreover, we use tactile textures (smooth, clear plastic tape vs. grainy, wood-textured stickers) to distinguish the sensing and feedback modules/base (Figure 2c).

With A11yBits, a BLV user can feel and select their preferred sensing and feedback modules, assemble them to the corresponding base modules to generate a DIY-AT, and use the DIY-AT by deploying the assembled sensing and feedback packs in the real-world environment (e.g., attach to physical surfaces, user body).

3 PRELIMINARY EVALUATION

We conducted six mini-workshops with 13 BLV users (3 female, 10 male, age: 22-44) to evaluate the feasibility of A11yBits and iterate on the toolkit design. Each workshop consisted of 2-3 participants. Participants first freely explored each module and discussed whether they could easily learn, recognize, and assemble the modules. We then asked them to discuss their challenges in daily life and brainstorm how they wanted to use A11yBits to create solutions. Participants then assembled their desired solutions with A11yBits and suggested improvements for A11yBits at the end.

In the study, participants came up with 12 use cases and assembled 33 DIY solutions with A11yBits, demonstrating the potential of A11yBits as an accessible, tangible toolkit to support DIY creations. Participants also found the toolkit easy to learn and assemble.

Meanwhile, participants pointed out the drawbacks of A11yBits and suggested valuable improvements. First, more sensing and feedback modules were suggested to support a broader range of complex and diverse daily tasks, such as a Camera module for text and object recognition, an Inertial Measurement Unit (IMU) module to track the user's behaviors, and a Spotlight module to illuminate the environment. Beyond incorporating basic modules, participants also suggested the capability of connecting to existing smart-home devices, such as smart speakers. Moreover, we found that participants wanted to use different methods to integrate their DIY creations into the real world, such as wearables attached to the user's body, portables held in the user's hand, and decorations attached to real-world surfaces (e.g., stovetop, doors). They thus hoped that the toolkit would include tools to support such integration, such as glue, bandage, or magnetic components.

4 CONCLUSION AND FUTURE WORK

We present the design and implementation of A11yBits, a tangible toolkit that enables BLV users to create personalized DIT-ATs for daily tasks, as well as a preliminary study to investigate the potential of A11yBits. In the future, we will improve A11yBits by involving more useful modules, refining the base to allow more modules at a time, and adding deployment supports to facilitate real-world integration. Formal long-term studies will be conducted to evaluate the effectiveness and performance of A11yBits in users' daily life.

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