Designing Adaptive Tools for Motor Skill Training

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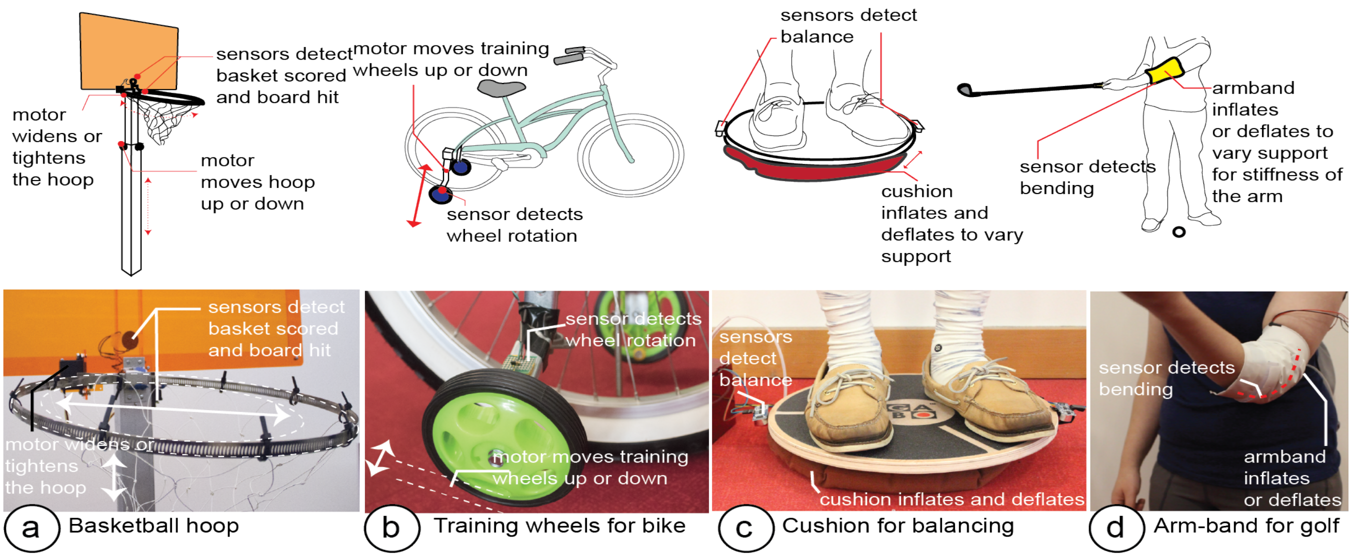

Figure 1: Adaptive training tools adjust the task difficulty according to the learner's current performance: (a) Adaptive basketball hoop that can be widened/tightened and raised/lowered. (b) Adaptive training wheels for a bike that can be raised/lowered. (c) Wobbleboard with inflatable/deflatable support cushion to increase/decrease stability. (d) An inflatable/deflatable golf arm band that increases/decreases restriction when bending the elbow.

ABSTRACT

We demonstrate the design of adaptive tools for motor skill training that use shape change to automatically vary task difficulty based on a learner's performance. Studies [1] have shown that automatically-adaptive tools lead to significantly higher learning gains when compared to non-adaptive and manually-adaptive tools. We demonstrate the use of Adapt2Learn [2] - a toolkit that supports designers in building adaptive training tools. Adapt2Learn auto-generates an algorithm that converts a learner's performance data into adaptation states during motor skill training. This algorithm, that maintains the training difficulty at the 'optimal challenge point', can be uploaded to the micro-controller to convert several shape-changing tools into adaptive tools for motor skill training. We demonstrate 7 prototypes of adaptive tools for motor-skill learning to show applications in sports, music, rehabilitation, and accessibility.

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CCS CONCEPTS

• **Human-centered computing → User interface toolkits.**

KEYWORDS

adaptive learning, physical interfaces, motor-skill learning, toolkit design

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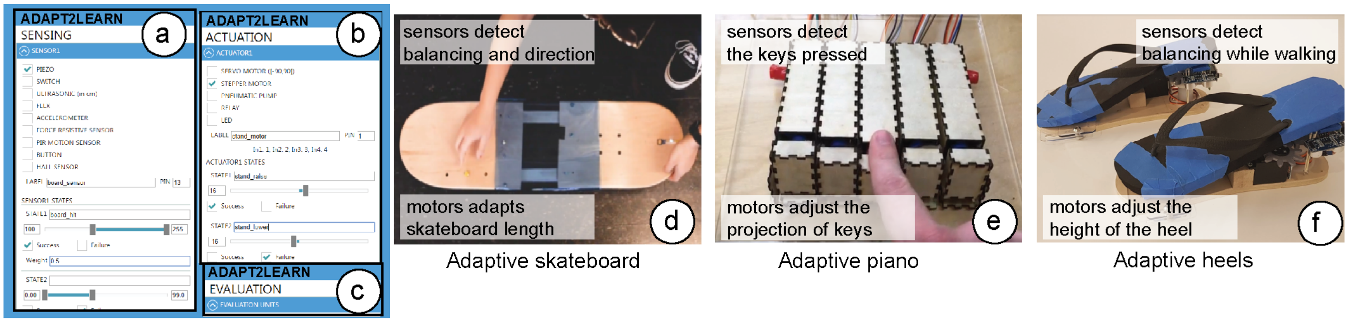

Figure 2: Designers use Adapt2Learn's user interface to configure the adaptation of their adaptive training tools by configuring the (a) sensing (b) actuation, and (c) evaluation settings. We also demonstrate examples of adaptive training tools developed by students in a studio setting with applications in (d) sports, such as an adaptive skateboard, (e) music, such as an adaptive piano board, and (f) other life skills, such as walking in heels.

1 INTRODUCTION

In contrast to feedback systems based on vibration or speech, adaptive tools vary the training difficulty by physically adapting their shape. Studies [1] have shown that automatically-adaptive tools lead to significantly higher learning gains when compared to static tools and manually-adaptive tools. Adapt2Learn toolkit [2] supports designers in designing and building physically adaptive tools. Adapt2Learn allows them to configure the sensors and actuators for training tools used in learning various motor skills. We demonstrate how this user interface helps to generalize our approach to design a range of adaptive tools covering areas, such as basic life skills (biking), sports equipment (basketball, golf), and health support tools, such as those used in physiotherapy (e.g., wobble board). We also demonstrate additional 3 prototypes built by students in a studio setting that further demonstrates the applicability of adaptive physical tools for motor skill training in a wide variety of different contexts ranging from sports and games, to accessibility and rehabilitation, and basic life skills (Figure 2).

2 SYSTEM OVERVIEW

The Adapt2Learn toolkit consists of two parts: (1) the Adapt2Learn user interface for configuring the learning algorithm for adaptive training tools, and (2) the Adapt2Learn visualization tool that helps designers assess when the tool adapts and how it affects the learner's performance.

2.1 Configuring the Learning Algorithm using Adapt2Learn's User Interface

To configure the learning algorithm, designers first register the sensors and then map the sensor values to success/failure states (Figure 2a). They then repeat the process for actuators by registering the actuators and mapping the actuator values to success/failure states(Figure 2b). Finally, they define how the performance should be evaluated by defining the evaluation unit and running average period (Figure 2c). After configuring the learning algorithm using the steps described above, designers can hit the 'export' button, which automatically generates the microcontroller code (Arduino script in .ino file format). After exporting, designers can then deploy the script onto the microcontroller integrated with their adaptive training tools.

2.2 Visualizing Performance and Adaptation

To provide tool designers with a way to assess the learner's performance and when the tool adapts, we developed a visualization tool. The visualization tool plots the learner's attempt scores, the corresponding running average, and the computed derivative of the running average at that attempt. This performance data is plotted in real-time along with when the tool adapts to an easier or more difficult setting.

3 SYSTEM DEMONSTRATION AND EXAMPLES

In our demonstration, the audience will watch a video showing configuration of the adaptive tools using the Adapt2Learn toolkit, the visualization tool, and 7 different applications of adaptive tools.

During the demonstration, the audience will experience the following demo videos: (1) Overview of the adaptive training tools and the toolkit design. (2) Demonstration of **an adaptive basketball stand** that supports learners in scoring baskets while playing basketball. The stand has a piezo snesor to detect board hits and a switch sensor to detect basket scores. The stand has a stepper motor to adjust the hoop height and a servo motor to adjust the hoop width to incraese or decrease the task difficulty of throwing the basketball (Figure 1a). (3) Demonstration video of using **Adapt2Learn's user interface to configure the learning algorithm** for the adaptive basketball stand (Figure **??**). (4) Demonstration of the **visualization tool** that displays the learner's performance and the subsequent adaptation of the basketball stand. (5) Demonstration of **a bike with adaptive training wheels** that supports learners in learning to balance the bike. The bike has one hall-effect sensor mounted on each of the training wheels to detect if the training wheel is being used, and one stepper motor on each of the training wheels to lower or raise them to provide more or less support in balancing the bike (Figure 1b). (6) Demonstration of **an adaptive wobbleboard with inflatable cushion** that supports learners in learning to balance the board. The wobbleboard has two ultrasonic sensors mounted on diametrically opposite sides of the board to detect if it is stable or wobbling, and a pneumatic pump to deflate and inflate the support cushion that restricts wobbling (Figure 1c). (7) Demonstration of **an adaptive armband** that supports learners in keeping their elbow straight during a golf-swing. The armband has a flex sensor to detect if the learner's elbow is straight or bent, and a pneumatic pump to deflate and inflate the arm band to restrict bending of the elbow (Figure 1d). (8) Demonstration of **an adaptive skateboard** that supports learners in training to skateboard (Figure 2d). The prototype has an accelerometer mounted on the skateboard to measure the balancing skills and a stepper motor mounted to adjust the length of the skateboard. (9) Demonstration of **an adaptive piano board** that supports learners in pressing the right key of the note (Figure 2e). The prototype has servo motors per key that actuates the key to raise them based on the note that needs to be played. (10) Demonstration of **adaptive heels** that support learners in training to walk in high heels (Figure 2f). The prototype has two ultrasonic distance sensors mounted per shoe, one on each side of the heel to measure the balance of the learner while walking in the heels. One servo motor was mounted on each of the shoe to raise and lower the heel height while walking.

4 CONCLUSION

We demonstrate the design of adaptive physical training tools for motor-skills that automatically vary task difficulty based on a learner's performance. We show how Adapt2Learn can be used to generalize over several application examples. We believe our contributions will inspire the next generation of adaptive training tools in different areas, such as sports, music, rehabilitation, and accessibility, thus making adaptive and personalized learning accessible to a larger audience.

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