

# Remote Drawing on Vertical Surfaces with a Self-Actuated Display

Patrick Bader<sup>1,2</sup>, Norman Pohl<sup>1,2</sup>, Valentin Schwind<sup>1,2</sup>, Niels Henze<sup>1</sup>, Katrin Wolf<sup>1</sup>, Stefan Schneegass<sup>1</sup>, Albrecht Schmidt<sup>1</sup>

VIS, University of Stuttgart, Stuttgart, Germany<sup>1</sup>  
Stuttgart Media University, Stuttgart, Germany<sup>2</sup>

## Abstract

Today, most digital devices are either stationary, often placed on horizontal surfaces like tables, or so-called mobile devices which are carried around by the user. In this demonstration we showcase our ongoing work on a novel type of self-actuated display. It can be placed on walls, or whiteboards and other arbitrarily oriented surfaces like ceilings. It is equipped with a whiteboard marker which allows the device to draw on surfaces it is attached to. In this work, we demonstrate the device's capabilities using an interactive scenario in which users are able to remotely control the self-actuated display to draw lines on a whiteboard. They control the device either by using their own smart phone or a provided tablet computer.

## 1 Introduction

Most current computing devices can be separated into two groups: Stationary devices like desktop computers, and mobile devices such as smart watches or mobile phones which are usually carried around or worn while in use. While the drawback of mobile devices is that they need to be carried around, the great advantage is that they can always be accessed. Interactive self-actuated displays tackle the drawback of mobile devices while keeping their advantage. However, previous work on self-actuated devices focused on horizontal surfaces such as interactive tables, e.g. *TouchBugs* (Nowacka et al. 2013). With the exception of *WallBots* (Kuznetsov et al. 2010) vertical surfaces were left mainly unexplored.

In the context of tangible user interfaces some previous work focused on vertical surfaces, like *Vertibles* (Hennecke et al. 2012) however without self-actuation. In our previous work we explored the application space of self-actuated displays for vertical surfaces (Bader et al. 2015) by conducting focus groups and then implemented and evaluated four example scenarios using video prototypes (see Figure 1):



Figure 1: Pictures taken from video prototypes which were implemented in Reference X. 1. kitchen scenario 2. class room scenario 3. museum scenario 4. office scenario (Bader et al. 2015).

1. A kitchen scenario where the self-actuated device helps a user finding ingredients for preparing coffee.
2. A class room where the device helps a teacher with drawing graphs on a whiteboard.
3. A museum scenario where the device follows the user and explains exhibits.
4. An office scenario with multiple devices joining to form a larger display space during a video conference when a user joins.

As part of implementing these scenarios a functional prototype was built. In this demonstration we showcase our ongoing work on self-actuated displays for vertical surfaces. We implemented an interactive scenario that further extends the class room scenario. Using the prototype users can remotely draw lines on a whiteboard. In the following sections we shortly describe the prototype and the drawing scenario in more detail.

## 2 System Description

The self-actuated device is based on the commercially available 3pi robot platform, produced by Pololu. The robot has a differential drive with two gear motors and a ball caster (see Figure 2). We added the "3pi expansion kit without cutouts" and attached a Bluetooth Low-Energy enabled microcontroller to enable wireless communication. To allow movement on arbitrarily oriented surfaces a 3D printed frame which holds 15 neodymium magnets was attached to the bottom. The magnets generate enough force to prevent the robot from falling off ferromagnetic surfaces like whiteboards. The default gear motors were not able to gener-

ate enough torque to move the robot upwards on vertical surfaces. Thus we replaced the motors by more powerful 298:1 gear motors.

On top of the robot a 3d printed frame was added which holds a Google Nexus 7 tablet. The tablet computer is used both as a display for the self-actuated device and also for its various sensors so no additional hardware is required to obtain the orientation. Adding a tablet computer furthermore adds many more sensors and actuators such as cameras, speakers and Wi-Fi.

As an additional output method in combination with device movement we extended the frame for the tablet with a pen and an eraser holder. With a whiteboard marker attached the device is able to draw on ordinary whiteboards. The pen and eraser holders are actuated with servos which are driven by the Bluetooth microcontroller.

As mentioned above device orientation is tracked with the tablet computer's inertial sensors. Unlike orientation we track the absolute position with an external ASUS Xtion depth camera connected to a laptop computer. To track the device, background is subtracted from each depth image and segmented with a constant threshold. Although other tracking methods are possible, e.g. using the camera of the tablet to implement localization based on feature tracking we chose the depth camera for its simplicity and robustness.

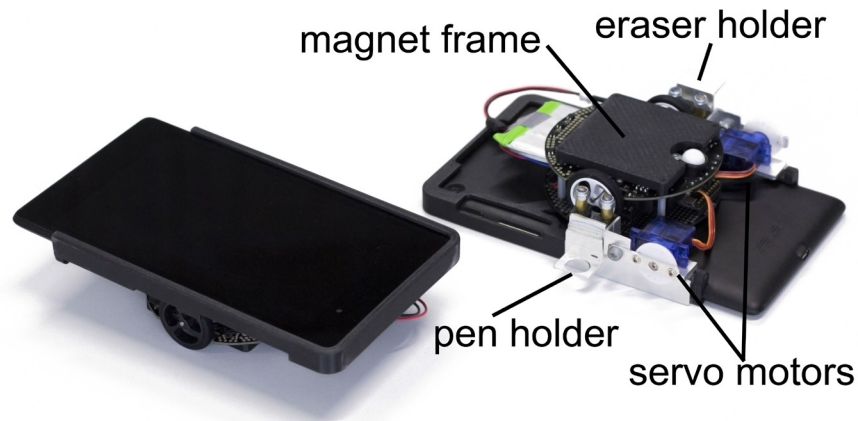


Figure 2: Self-actuated device shown from the top with the tablet attached (left) and from the bottom showing the 3pi robot platform and the extensions (right). (Bader et al. 2015)

Control of the robot is also handled by program running on the laptop computer, which receives sensor inputs from the tablet wirelessly via UDP and sends motor speeds to the 3pi robot according to the current control scheme. During the whole movement process both position and orientation are continuously tracked. A PID (proportional-integral-derivative) controller compensates for gravity and wheel slippage and thus reduces movement errors. The whole system is covered in more detail in (Bader et al. 2015).

### 3 Demonstration

During the demonstration, users will be able to remotely draw lines on a whiteboard using the self-actuated display that is equipped with a pen. The pen can remotely be placed on the board or released. Hence, the motion paths of the self-actuated display can be used to draw and to write on the board. To draw on the whiteboard, users draw lines on an additional mobile touch-enabled device. Then the self-actuated display shows the drawing on its display and then starts drawing it on the whiteboard using the attached whiteboard marker.

Alternatively users may take the self-actuated display from the whiteboard and directly draw lines on its Nexus 7 tablet which is the touch screen component of our self-actuated display. After returning the device to the whiteboard it will be localized by the depth sensor and then starts drawing.

In the demonstration described here, we show how a self-actuated display could be used in a class room scenario to support analysis teaching by letting pupils and teachers accurately draw arbitrary graphs on the whiteboard. The self-actuating display automatically generates the correct movement path for each graph.

#### Acknowledgements

This work was supported by the graduate program Digital Media of the Universities of Stuttgart and Tübingen, and the Stuttgart Media University.

#### Contact

E-Mail contact for all authors: {firstname.lastname}@vis.uni-stuttgart.de

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