Puppet Cycler: A vibrotactile cycling navigation assistant

MICHAEL CHAMUNORWA, Carl Von Ossietzky Universität Oldenburg, Germany

Navigation systems for bicycles have found use in areas that have advanced cycling culture. However, many of these systems rely on the typical visual cues seen in commercially available GPS units. This approach has been shown to reduce the ability of cyclists to explore their surroundings more liberally. We present Puppet-Cycler, a navigation system that uses vibrotactile cues to guide cyclists to surprise destinations in a chosen area.

Additional Key Words and Phrases: Cycling, Navigation, Cycling Safety, Cycling exploration

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1 INTRODUCTION

When we play video games, participate in scavenger hunts and other such activities, part of the fun, stems from the feelings of suspense and uncertainty which these activities invoke. It is usually a journey to the unknown. A trail of clues or directions is followed while not having a complete picture of the final destination on the game quest or the nature of objects to be collected during the scavenger hunt. While it is accurate that one knows the mission specifics or objectives in many video games, it is also worth noting that the player is never sure what to expect and what type of artefacts and objects they will interact with. Therefore, we attempted to use some of these observations to enable urban cyclists to use their bicycles as objects that encourage exploration in a puzzle-like manner. Typically, when people explore cities on their bikes, they can go to familiar places without maps or navigating assistants. Alternatively, they use GPS units or paper maps. This enables them to pick a destination and follow the best/shortest route to this destination. While this works, there have been attempts to find alternative cycling and exploring with the route and not the destination in mind. Researchers have determined that cyclists will use a familiar route and therefore miss other points of interest if there are not along this familiar route [2]. The result assumes that one has explored all places of interest in their locale while they would have only explored those spaces either visible on maps or in proximity to their typical cycling routes. These systems do not only enable cyclists to interact with information while cycling. Most of them also aim towards making this interaction as safe as possible by directing the user's visual attention away from the mobile device.

2 SUPPORTING WORK

Researchers have explored multiple interventions to improve cycling safety and promote alternative navigation systems. This section summarizes three studies conducted to showcase the possibilities in cycling safety and navigation improvement.

Author's address: Michael Chamunorwa, Carl Von Ossietzky Universität Oldenburg, 1 Thørväld Circle, Oldenburg, Germany, michael.chamunorwa@uni-oldenburg.de.

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2.1 Supporting exploratory bicycle trips with visual and vibrotactile cues

Authors such as [2] [1] [3] have proposed conceptual prototypes for bicycle navigation systems that use vibrotactile feedback to guide cyclists. For example, in [2] et al., their Tacticycle system enables tourists unfamiliar with a locale to explore the area using a minimal set of navigation cues. Tacticycle helps cyclists to stay oriented while supporting intuitive navigation and exploration at the same time. Direction cues are provided through Vibro-feedback on the handlebars, where the corresponding side of the handles will vibrate on an impending turn. Lastly, points of interest are displayed on a map shown on a smartphone screen. In this manner, cyclists can make pit stops and explore any recorded points of interest along the route of their trek. An alternative prototype is the Vibrobelt [3], a belt fitted with vibrator motors and tied around the waist. The belt is connected to a mobile phone and provides waypoint and final destination information using vibration-based directional cues. Conversely, [1] et al. have proposed a wrist-worn prototype that relies on smartphone GPS to guide cyclists on unfamiliar and familiar routes using vibration-based cues during navigation.

The three platforms perform the same task, albeit with different influences and end goals. For example, Vibrobelt and Tacticycle prove that it is possible to guide cyclists in an unfamiliar area to a destination using vibration cues only OR vibration cues and visual cues, respectively. On the other hand, the wrist-worn vibration bands attempt to improve cyclist safety by using vibration cues and therefore ensure that the cyclist eyes remain on the road and not on a screen to follow visual GPS cues.

3 METHOD

Based on the navigation methods detailed in the Supporting work section, we resolved to design and test an enhancement to help us further explore unorthodox navigation methods that do not emphasise the traditional means of guidance systems for hiking, walking, and cycling. We started the development process by first establishing what we wanted to be changed on the existing systems. Then, we observed that the systems in question relied on a smartphone as the main brains of the prototypes. Therefore, we wanted to conceptualise a different setup in which smartphones are not the primary control mechanism of the navigation system. Instead, we propose a navigation system using commercially available sensors, actuators and electronic components and achieve similar results to those realised in works [1]. However, this alternative setup does not show the cyclist the destination name, nor does it give visual cues for navigation. Additionally, we want to promote safe cycling by avoiding visual cues, as documented in [1]. Lastly, we think that having visual cues and a name of the destination takes away the suspense factor because one can easily start searching for images of the destination online to get a feel of what it looks like. If the name of the destination and the turn by turn navigation points are not visually accessible, then the suspense factor will remain. We did not want to reinvent anything wholesale but instead picked one theme and ideated how it could be changed to suit what we had in mind. As detailed above, the screen and reliance on a mobile phone were the two effects we decided to depart from. We then used a storyboard to uncover the basic functionality we expected from the new navigation system, as shown in fig 1.

4 FUNCTIONAL REQUIREMENTS

Based on the story, the functional requirements were as follows:

- Power up the system
- Enter the preferred round distance, i.e. how far the cyclist intends to cycle to and from their current location.
- Fetch a list of locations within that distance
- Without showing the cyclist the destination compute the turn by turn navigation instructions and then prompt the cyclist to begin the journey
- Vibrate left to notify cyclist of impending left turn
- Vibrate right to notify cyclist of impending right turn

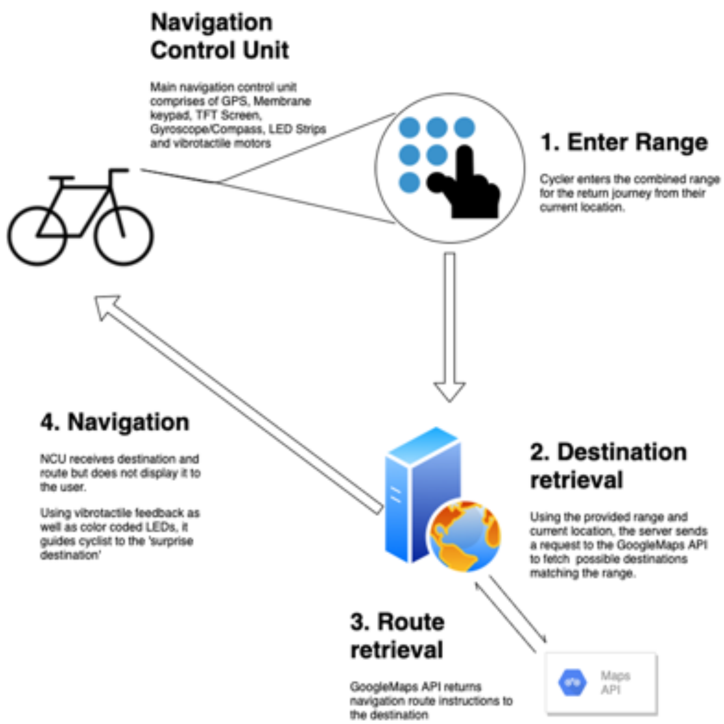

Fig. 1. System architecture

- Continuous vibrate on both sides when a turn is missed or wrong direction is being pursued.
- 3 long vibrates when the destination has been reached.

The system requirements were used to then formulate the system architecture depicted in figure 2.

5 EQUIPMENT

With the functional and non-functional requirements of the envisioned system in place, we set out to gather all components required for a prototype. First, we collected components based on those used in previously highlighted projects. The components were as follows:

- Arduino Nano IOT 33
- 4 vibromotors
- Ultimate GPS breakout board V3 (Adafruit)
- Triple axis accelerometer with magnetometer (Adafruit IMU9250)
- Mini TFT - 1.3" 240x240 Color TFT
- Number/Keypad

6 PROCESSING

A NodeJS service brokers communication between the Arduino and the Google Maps API. The NodeJS service receives a maximum range value manually entered by the cyclist before the journey, and the current longitude

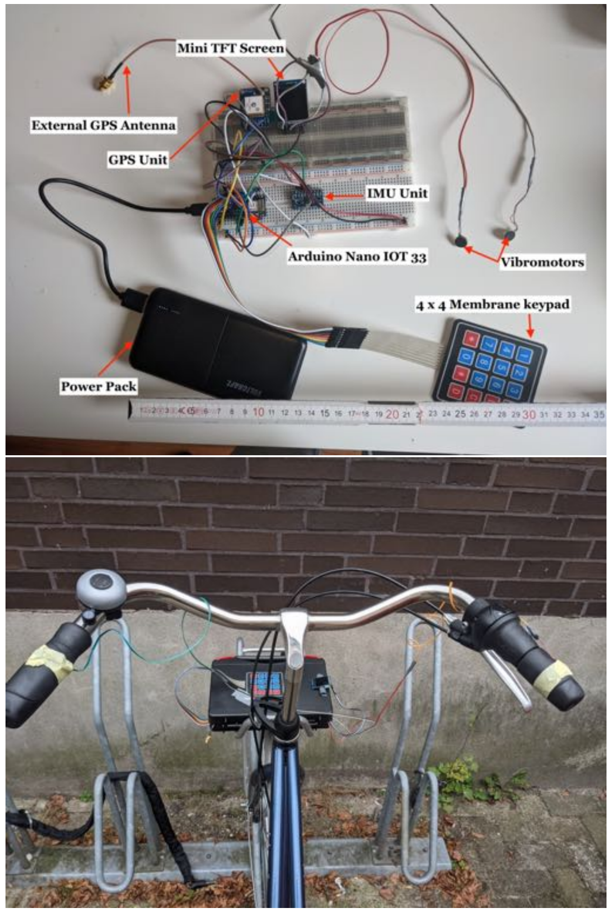

Fig. 2. (a) Hardware assembly on breadboard. (b)Hardware assembly on Bike.

and latitude values automatically retrieved from the GPS module. The NodeJS service requests destinations within the specified radius of the current location. An array of destinations is returned to the NodeJS service by the Google Maps API. After that, a function in the NodeJS service fetches a single location at a random index in the array. With the destination retrieved, the NodeJS service makes a second call to the Google Maps API to fetch the turn by turn navigation instructions for that destination. The GPS unit and the Accelerometer continuously send their current readings to the NodeJS service. These readings are used to calculate the next step and angle, which are needed for accurate turn by turn navigation.

7 TESTING

We conducted a single Wizard of OZ test on the system. An acquaintance of the researcher used the NodeJS service to retrieve a destination within a 2km radius of the starting point. Furthermore, the researcher was only furnished with the Longitude and Latitude coordinates but not told of the name. Keeping the name of the destination unknown to the researcher was done to ensure that there would be no anticipation of the destination by reading its name in the Google MapsAPI result. The destination coordinates were then noted down and

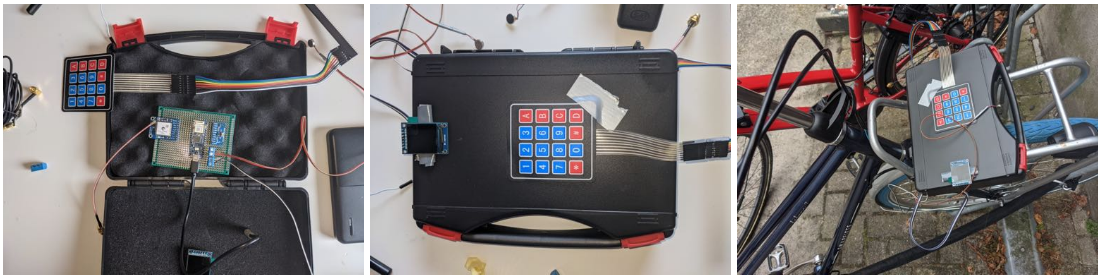

Fig. 3. Hardware assembly on PCB

hardcoded in the NodeJS service. A smartphone was used as an internet hotspot to provide wireless internet access between the server and prototype. The bicycle was first ridden in along a 50meter street four times in either direction for acclimatization. We observed problems with the right-hand vibromotors, which tended to issue slightly weaker impulses than the left-hand Vibro motors. However, despite this, the prototype issued the correct instructions during the acclimatization phase. Thereafter, the vibration cues were followed while cycling slowly to ensure no turns were missed and to also compensate for the possible lag in communication between the prototype and the server.

8 RESULTS

Cues to make a turn were issued timeously, but the absence of voice or screen prompts indicating when to make a turn somewhat confused the journey's first moments. Despite this, only three wrong turns were made before reaching the destination. The prototype issued the three long vibrations to indicate the journey's end on arrival at the destination. Then, we used the smartphone to confirm whether this location was the same one retrieved from GoogleMaps API and logged. We observed that it was in the general Latitude/Longitude position. The navigation feedback was easy to feel even on uneven road surfaces. However, the tested route also did not have 'slight turns', so we did not test how this would work in situ.

9 REFLECTIONS

A single test for such a system, is definitely insufficient to make any conclusions about the feasibility and reliability of a vibrotactile only navigation system. However, some lessons can be drawn from this.

- Consultations with cyclists on what the acceptable /easy to understand cues are
- There can be no one solution to satisfy all cyclists - some platforms have already been tested each with merits and successes but we will always want to make new interventions.
- For this to work, the safety factors must be well understood and considered.

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