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Bibo the dancing cup: Reminding people suffering from dementia to drink

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Abstract. We present the concept and technical realisation for a cup that moves and lights up so as to bring itself to the attention of a person with dementia, to trigger taking a sip as a response. The concept is aimed at people with dementia in home or resident care who still have the ability to act, but tend to mentally drift away and thus require external impulses and triggers. The cup moves and lights up in regular intervals if it has not been picked up recently. Once it is emptied, it alerts a caregiver to refill. Moreover, the degree or level of movement and light can be configured, depending on the person's needs and reactions. This paper describes the core idea and focuses on the technical aspects of building a prototype on Technology Readiness Level (TRL) 3.

Keywords: dementia · dehydration · elderly care

1 Introduction

In elderly care, a general concern is to prevent dehydration of elderly residents [7, 21]. The elderly often do not perceive being thirsty and therefore do not drink enough. For people with dementia at severe stages, this becomes even more problematic. In the authors' previous fieldwork in an elderly care home, where staff was shadowed and assisted in their daily work by project members, it was observed that a resident would take a sip, put down the cup, and then stare into space again, until a staff member would move the cup towards their hand. The resident then smiled, looked at and took the cup up again to drink. This procedure was repeated until the cup was emptied, posing a significant workload to staff. The resident appeared to need an external trigger that brought the cup to their awareness again, while still being able to associate the act of drinking with the cup and to drink without assistance.

This observation motivated the concept of the 'dancing cup' which brings itself to attention (as illustrated in fig. 1). The concept goes beyond existing products that integrate blinking lights as a reminder to drink [6, 4, 3, 1]. It is based on the hypothesis that the movement of the cup itself (fig. 1b), along with

(a) The caregiver activates the cup

(b) The cup moves and blinks to attract the individual's attention

(c) The cup prototype rendering

(d) First prototype

Fig. 1: Envisioned use of cup, prototype design and current working prototype

slight sound produced by the cup's vibration, provides a stronger trigger than simply integrated lights . Moreover, it does not interfere with the habituated appearance of a cup or glass, and thus may be more appropriate for people with dementia, where it is important that objects look familiar and can be recognised [10, 14].

The use of familiar objects can support daily practice, since patients will still be able to spontaneously relate to and use familiar-looking objects, even if dementia prevents them from understanding the function of new unfamiliar objects [10, 11]. The cup aims to support the person's remaining ability for action, a principle in elderly care where it is aimed to keep residents active and involved as this can delay the (inevitable) decline [22, 12] (see [9, 14]). Staff at the facility where the research team did observations and interviews had described this as an important strategy, e.g. preferring to accompany slow walking residents to the dining area instead of pushing them in a wheelchair, even if the latter would be faster.

Feedback from care staff as well as from geriatrics experts confirmed that they find the concept promising, and would like to see it tested. Therefore it was decided to create a working prototype that would both serve to better illustrate the concept and to enable user tests. In the current paper, the focus is on the technical realisation, including initial expert feedback that influenced the design. fig. 3 shows our current prototype in action.

In the following sections, the effect of dehydration on elderly people is discussed as well as investigated solutions for the issue (section 2); the prototype and its intended use is described in section 3; the cup functionalities, their implementations and reasoning behind them are specified in section 4; the achieved results are discussed in section 5 and finally conclusions and future work are considered.

2 State of the Art

Dehydration affects 20-30% of older adults and increases reported health issues [23]. Dehydration is even more perilous for people with dementia, as it poses one of the main, often less thought of, causes of death. More people with dementia, once they reach a late stage in the disease, die from cachexia or dehydration rather than of any other cause of death [19]. Dehydration has been found to be more severe in people with advanced cognitive impairments [20]. According to [24], on average 5.5 billion dollars are spent in the USA annually to treat hospitalisations caused by dehydration.

Dehydration in the elderly happens for multiple reasons. Fluid reserve is decreased compared to their younger selves, liquid loss is more frequent and the sense of thirst is not as intensive [18]. A combination of these reasons, among others, can co-exist in a person causing severe dehydration.

Most of the solutions that encourage people to drink have taken the form of augmented bottles or cups (e.g. [5, 4, 3, 8, 2, 16, 15]), while others take the form of add-ons to be combined with existing objects (e.g. [6, 25, 1]). The most common method seems to consist of grabbing the attention with a visual trigger through light effects (e.g. [4, 3, 6, 1]), via an audio signal (e.g. [8]), or through a combination of both (e.g. [2, 16, 15]).

The option of using vibrations to attract attention has been utilised in Ozmo [5], a bottle that reminds you to drink by vibrating (which might constitute rather an audio or haptic signal). Visible movement as an attention trigger has been explored more explicitly with the Bionic water drinking reminder [25], an additional attachment to a cup, shaped as a butterfly, which uses a vibration motor to flap its wings when triggered, to attract attention. However, the cup itself does not move.

Several of these products offer additional functions, such as monitoring water consumption (e.g. [5, 4, 3, 16, 15]), the frequency of drinking (e.g. [2]), or keeping the temperature (e.g. [4, 3]). Some products are paired with applications that allow to monitor daily fluid consumption, record hydration history and calculate personal hydration goals (e.g. [5, 4, 3]). Most existing products are general consumer products, and very few are aimed for elderly and persons affected by illnesses and offer specific functions for care, such as Drink Smart [16, 15], a cup connected to a digital care documentation, or Droplet [2], a dementia-friendly mug that alerts caregivers with flashes.

3 Product Description and Envisioned Use

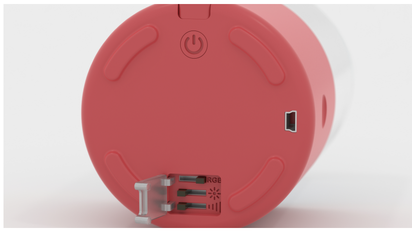
Through a few iterations and feedback from experts in geriatrics and elderly care, a prototype was designed (figs. 1b and 1c) as a proof of concept as well as demonstrator for planned user tests (fig. 1d). As a general design constraint, the shape and look needed to be recognisable as a cup and look familiar, so that it can evoke spontaneous use as response from elderly residents with dementia. The cup is small enough in diameter and light enough to be handled easily. The possibility of adding a supplementary handle for residents with limited hand functionality was added as an option (fig. 1c), based on recommendations from elderly care experts.

The cup consists of two parts. The lower part will be made of coloured polyamid and houses all electronic components and sensors. A coloured cup is considered easier to perceive, as intense colours aid visual perception in people with dementia. At the moment, the cup is made from a photopolymer (VeroWhite) for a Stratasys Objet30 Prime 3D printer to enable iterations within tests and development. Detailed consideration was given to the upper part, which holds the beverage. A food-safe and transparent material is used to facilitate diffusing of the coloured light (figs. 4b and 7) as well as to keep the appearance of a regular cup or glass.

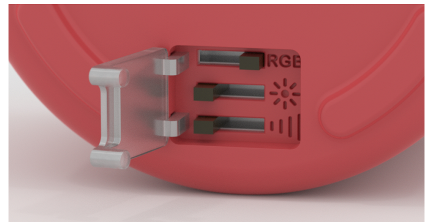
The envisioned scenario of use is that care staff places the cup in the field of view of its user (usually on a table) and activates it via a switch. If the cup is not picked up for a (predetermined) time, it will start to move and blink, thereby alerting to its presence. This would then attract the attention of the resident, who perceives and recognises the cup, thereby prompting them to drink. The activation (movement and light) is executed in spaced-out intervals, to enable the intermittent drinking and avoid overly disturbing the resident. If the cup is not picked up, the activation will be repeated after a predetermined time has passed. If a pickup is detected, the cup stops moving and will restart the countdown for a subsequent activation at a later time.

The device can be configured and personalised according to the individual's needs via physical sliders (fig. 2). Geriatric experts recommended providing the ability for configuration, because of the differences in each stage and form of the disease, where each individual might react differently, impacting on how strong the visual and/or movement signal needs to be (or what would be too much). They also stressed that such controls need to be simple and physical-tangible (not via a mobile app), since any caregiver (or temporary help) should be able to do this, and care staff often have little affinity with technology. The configurable parameters are the intensity of movement, intensity of blinking and light colour.

If the resident picks up the cup, this is detected by an accelerometer. The cup then ceases to move, so that they can drink. When the cup is empty, the



(a) Configuration and power on/off switches on the bottom



(b) Zoom in on configuration switches

Fig. 2: Activation and configuration switches

cup will repeatedly flash on and off in a predetermined colour to alert the stuff for refill as well as aid in liquid intake monitoring.

4 Detailed Overview of Functionalities

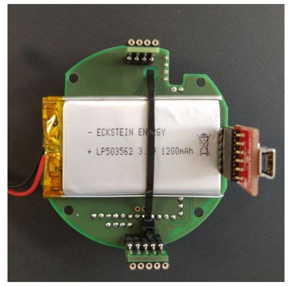
We now describe the cup functionalities and details of the mechanical and electronic realisation. This is structured along the core functionalities of our prototype: Grabbing attention (section 4.1); Water Level Detection (section 4.2); Activation, De-Activation (section 4.3); Pick up Detection (section 4.4); Configurability (section 4.5).

4.1 Grabbing attention

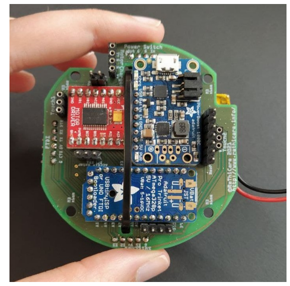
Two actions are implemented to attract the attention of the residents; movement (and the implicit sound from its production), and coloured light impulses that create visual stimulation. These occur in bursts, to enable drinking in between those phases and to avoid over-stimulation. Ideas for sound output as an explicit signal were discarded and we aim for fairly subtle motor sounds. This is because care experts advised that if the cup is used e.g. in the social setting of a care home's dining area or sitting/common room, this could overstimulate and annoy people (including the staff), in particular if several such cups are in use.

The movement (dancing) of the cup is generated using a small 3V DC motor mounted in the bottom of the cup (fig. 4a). A plastic lever is attached to the motor shaft. The end of the shaft holds a small steel puck which acts as an unbalanced Eccentric Rotating Mass (ERM) which generates instability resulting in a centripetal force, forcing the cup to rotate, and a centrifugal force away from the centre of the motor shaft. The motor rotates the lever arm at a variable speed, depending on the measured water contents of the cup (see section 4.2), generating the needed forces/vibrations to correctly rotate the cup, without spillage. With the eccentric rotation of the motor and of the cup itself, the cup moves on the table, changing its position and thus visually stimulating the resident. To avoid moving too far from the resident and prevent the cup falling off the table, the

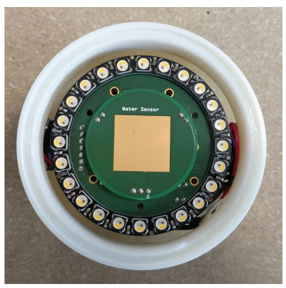
(a) Placement of PCB 1 in cup



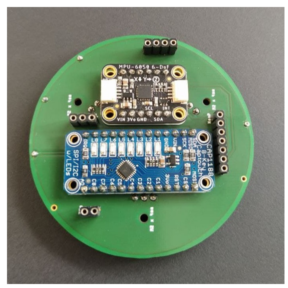
(b) PCB 1, side A. Battery, interface with switches, USB port



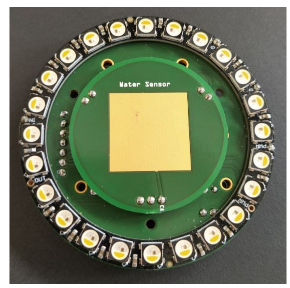
(c) PCB 1, side B. Microcontroller, motor driver, battery driver



(d) Placement of PCB 2 in cup



(e) PCB 2, side A. Accelerometer, touch sensor interface



(f) PCB 1, side A. LED ring, capacitive sensor

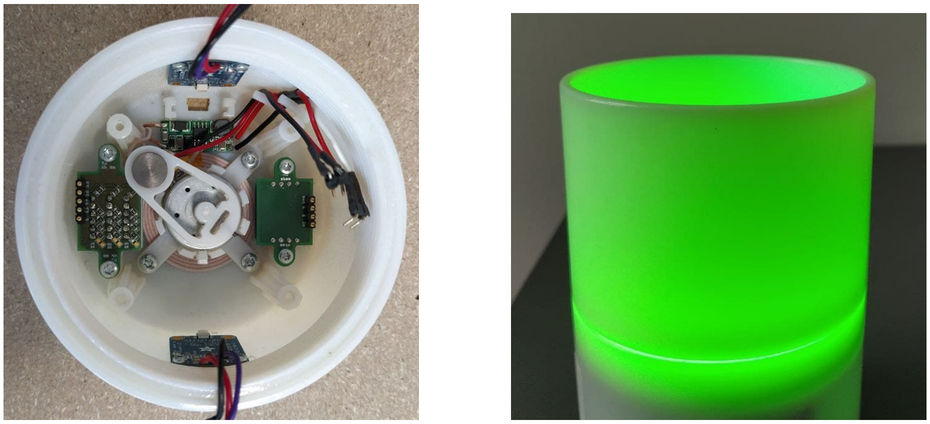
Fig. 3: Prototype components

motor changes direction of rotation between activations, thus moving in opposite directions in consecutive bursts. The specific speed of the motor at the respective water levels was determined based on lab-tests (see section 4.2).

As a complementary way of attracting attention, the cup subtly blinks (fig. 4b when activated, using an Adafruit Neopixel ring (fig. 3f). The colour and intensity of the light can be configured according to individual's needs as explained in section 4.5, see (fig. 2a). As a default, the colour red was chosen, as studies show that red or similarly intense hues increase liquid intake in people with dementia by ca. 80% [13].

4.2 Water Level Detection

Two approaches for water detection methods were explored, a capacitive sensor, that roughly detects the presence (not quantity) of water and a strain gauge bridge, which is also able to measure quantities. As it works contact-less, a capacitive sensor can be embedded in the plastic shell, (fig. 5a), and thus does



(a) The bottom of the cup containing the ERM mechanism for the cup movement

(b) Cup blinking with a green light, diffused in water and visible through the material

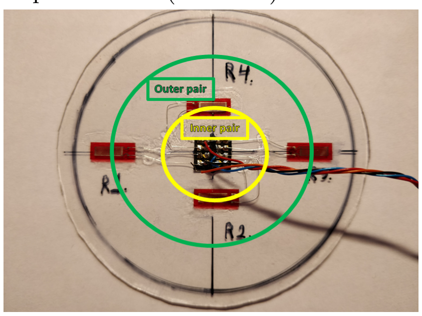
Fig. 4: Cup attention grabbing functions (dancing and blinking)

not require waterproofing. The current version of the prototype works with a capacitive sensor.

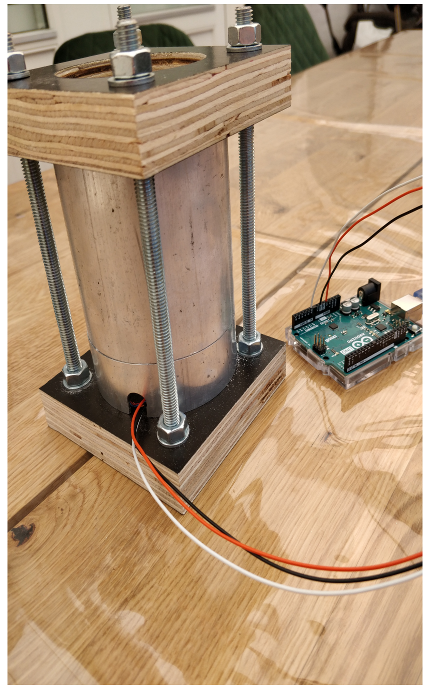
An additional method for detection is currently in the final stages of development. The strain gauge method measures the weight of the water content in the cup. This information can be used to adjust the RPM of the motor making the cup dance/rotate. The more water the cup contains, the faster the motor will spin (the more RPM the motor has), enabling movement even with the added weight.

The cup is comprised of a top and a bottom half, where the bottom contains the electronics. The top half, which contains the water, is fitted with a flexible bottom made of food-approved plastic, and has four strain gauges glued to it (fig. 5b). The strain gauges circuit is set up as a full Wheatstone bridge. [17], Physically this appears as strain gauges in pairs in two circles (see fig. 5b). A pair of strain gauges in this case, is two strain gauges placed with an equal distance from the center of the flexible bottom mirroring each other, which makes up the full Wheatstone bridge. A full Wheatstone bridge is needed to neutralise the effects of temperature changes which the strain gauges are sensitive to. The strain gauges deform due to the increased weight of water in the cup, thus changing resistance, making it possible to algorithmically correlate changes in strain gauge resistance to change in weight. To determine the weight of the cup content, the voltage output from the strain gauge Wheatstone bridge is correlated to a unit of weight. To do this, a steel cylinder (fig. 5c) is fitted with a 1mm thick PETG plastic bottom (fig. 5b), with the four strain gauges mounted on it. The Wheatstone bridge is connected to a micro controller which collects the data.

(a) Square capacitive sensor embedded in plastic shell (in center)



(b) Flexible bottom with physical wheat-stone bridge, outer strain gauge pair (green) inner strain gauge pair (yellow)



(c) Strain gauge water content measuring test setup

Fig. 5: Water level detection methods

4.3 Activation and De-Activation, Charging

The activation of the cup is done in two steps. First, a button is pushed on the cup's bottom (fig. 2a). Once switched on, the LED ring blinks briefly, its colour indicating the battery status. After the cup flashes with a green light, indicating sufficient battery power, the cup can be placed in front of the user, and is then activated by touching the two opposite finger recesses simultaneously (fig. 6a), thus preventing unintentional activation.

The main process then starts and will continue only if the cup contains fluid and is not grabbed. Once the battery is low, this stops and the LED ring starts to blink red. The cup must then be switched off by pressing the ON/OFF button at the bottom of the cup and placed on its induction charging base (fig. 6b). Although less effective than USB-charging, induction was chosen for its practicality and ease of use.

(a) Cup touch activation (b) Charging Platform

Fig. 6: Cup secondary activation method and inductive charging platform

4.4 Pick up Detection

The "dancing" of the cup should not continue when taken in hand. The accelerometer (fig. 3e) enables monitoring any movement in elevation and change in inclination; two parameters innate to handling a drinking cup, first lifting the cup from the table and then inclining it to drink. Together, these parameters make it possible to detect if the cup is picked up, and then to stop the motor and the LED signal. If the cup is taken up before the movement even starts, the whole cycle is reset once the accelerometer does no longer detect any movement.

4.5 Configurability

Geriatric experts and care staff, who provided feedback on our concept, recommended that it should be quick and easy for the care staff to reconfigure the three key parameters - LED colour, LED brightness and motor speed - according to the resident's needs. As care staff tend to not be very familiar with technological applications and since there are usually different staff members involved, including temporary helpers, we discarded the idea for a mobile app, prioritising work-efficiency and user-friendliness, and opted for on-product analogue/physical configuration modalities. To save space, we chose three slide switches (fig. 2a), with four positions for configuring LED colour (Red, Yellow, Green, Blue), LED brightness and motor speed. After each colour change, the LED ring blinks in the selected colour as feedback (figs. 7a and 7b); after an LED brightness change, the LED will blink with the currently selected colour in the chosen intensity (figs. 7c and 7d); and a change in motor speed is shown with a blink in white colour with different intensities, to indicate the intensity of the movement (a decision to refrain from movement in the configuration process was taken). Following recommendations by care staff, we plan to conceal these switches with a safety strip (fig. 2b) to avoid inadvertent changes of the configuration by the elderly residents.

5 Results

At its current state, the prototype was tested for functionality in the lab. The previously described capabilities have been implemented. The achieved results for the three main functionalities (visual signals, movement and water level detection are discussed in the following sections.

5.1 Visual Signals

As shown in fig. 7, the different hues and light intensities diffused through the cup are clearly visible. The light bursts are not intense, but fade in and out, as advised by care experts. This is because intense and rapid blinking is feared to startle and overstimulate patients.

(a) Yellow (b) Blue (c) Red, high intensity (d) Red, medium intensity

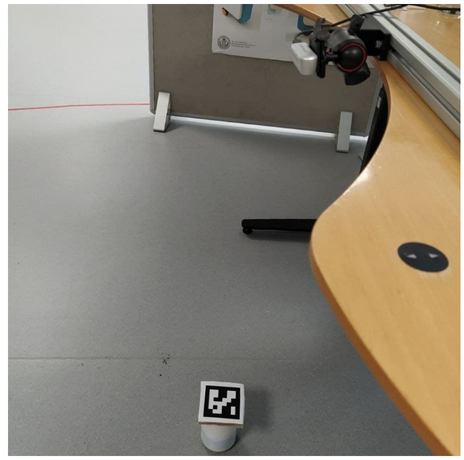
Fig. 7: Light colours and intensities

5.2 Movement

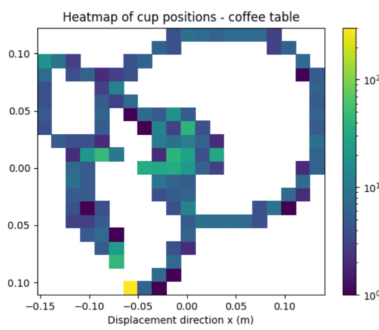
The cup rotates in opposite directions in subsequent turns. This leads to displacement in a constrained area and ensures that the cup does not fall off the table, given that it is placed within a minimum predefined distance from the edge before activation.

To quantify the movement, structured experiments were executed. The cup containing 150ml of water, fitted with an ArUco marker, was activated and left to translate freely, as it would in a normal activation. A stationary camera placed above the area was used to record the movement (figs. 8a and 8b). The Aruco marker was detected and used to extract the exact position of the cup relative to the camera. This process was repeated 10 times to acquire sufficient measurements. The translation of the cup depends, as expected, on the intensity of the motor rotation set by the configuration switches (section 4.5). The movement was tested in two different surfaces, a wooden coffee table and linoleum flooring (figs. 8c and 8d). The heatmap illustrates the positions of the cup on the surface and the frequency of the occupation of the specific position. The translation on the surfaces was found to be confined to an area of $0.08m^2$ for the highest intensity of movement set on the coffee table and much lower on linoleum flooring ($0.01m^2$).

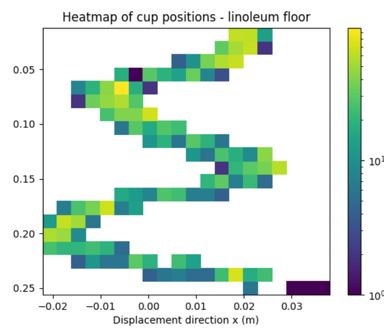
(a) Experimental Setup - top



(b) Experimental Setup - side



(c) Cup positions and their frequency - coffee table



(d) Cup positions and their frequency - linoleum flooring

Fig. 8: Movement quantification experiments

5.3 Water Level Detection

The current prototype includes a capacitive sensor for water detection. The strain gauge method is however developed and planned to be included in a future second prototype, to test both possibilities. In laboratory tests, the strain gauges have proven to enable inferring the volume of water in the cup, with relative accuracy. Some instability is observed when less than ca. 50ml is in the cup. To obtain a reliable reading of the cup contents, 1000 readings from the gauges are taken (which lasts ca. 2.5min). This poses no issue as it is performed before and during the intermittent break from ’dancing’. Spikes and noise are removed using interpolation, as mentioned in section 4.2, and a mean value is calculated. The linear regression coefficients are then used to infer the cup content and the

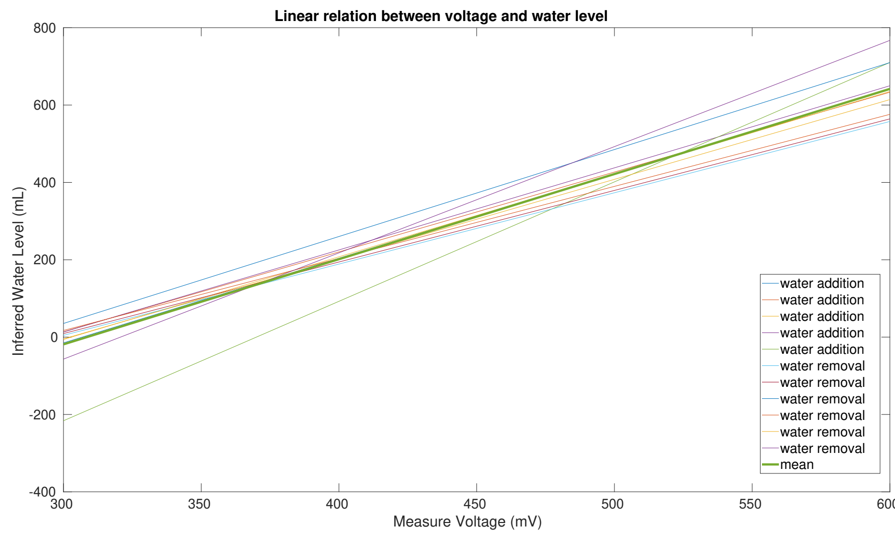


Fig. 9: Linear regressions of voltage-water level measurements (5 repetitions) and calculated mean

appropriate motor speed. Less samples could also suffice if needed; as a minimum, 700 samples have proven adequate.

The relation between voltage and water level was determined as follows: two test procedures were performed as preparation for water level detection. In the first, approximately 40ml of water was added in the test setup, then the cup took 1000 measurements/samples with a frequency of 4Hz, this took approximately 2.5 minutes. Then another 40ml was added, and the procedure was repeated until the cup was full (i.e. six times). The next procedure was the reverse, where 40ml was removed with a sample interval of 1000 samples. The data for each test was then linearly interpolated to eliminate spikes and outliers caused by contact with the cup, sudden shaking of the surface, etc. The process was repeated multiple times in different days and times of the day, for thorough data collection and to ensure that climatic changes were not of effect.

A mean measurement value is calculated for each sample set of each water level, and a linear regression model is fitted to the readings. Each procedure is fitted separately to obtain linear model coefficients. The mean coefficients are then calculated. It was observed that a stable linear function can describe the relation between voltage and water level, with a small instability when the water is below 50ml. The coefficients are plotted, along with the calculated mean coefficients (fig. 9). The mean coefficients can then be used real-time in the cup to output the water level depending on the measured voltage. This calculation is used to adjust the rpm of the motor (section 4.1).

6 Conclusion and Outlook

So far, our work has focused on creating a working prototype. The movement as well as the light stimulation have been implemented and initial tests in lab conditions for the movement and the water level detection have been carried out.

We are now at the stage were it is possible to test our idea, that such a 'dancing' movement of a cup can trigger the attention of people with dementia and activate them to drink. Initial discussions with domain experts indicate this to be a promising idea. In such tests, we will need to determine the range of motion and visual stimuli that are acceptable for people with dementia (which stirs them out of their stupor but does not frighten them) and the need for personalisation or adaptivity.

In the future, investigations of different rotational bursts leading to different movement patterns as well as a variety of materials for the bottom of the cup (used for noise dampening and movement control), will be carried out. The water level detection functionality will be included and finally the behaviour of the cup will be tested on different surfaces to determine the adadptability of the cup on different tabletops.

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