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# A smart system for cardiovascular healthcare at home

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## Abstract

Cardiovascular diseases (CVD), as reported by the World Health Organization is the major cause of death in the world, and one of the most commonly found diseases within the elderly population. As life expectancy increases, with skewed demographic changes, there is an increasing need for independent living for the older generation especially in developed countries. The role of healthcare is paramount for success and home-care solutions has key role in the future of healthcare. In this article, we propose a smart system for elderly people with chronic heart diseases, especially the heart failure patients, for managing and giving feedback on their drinking activities at home. We present the prototype system including both the hardware and software implementation for tangible interaction and visual feedback.

**Keywords:** Cardiovascular diseases, elderly patients, ambient assistive living, healthcare at home

## Introduction

Cardiovascular disease (CVD) is one of the most common diseases found in the elderly. CVD is often a “silent killer” without obvious symptoms until the heart attack, stroke or target organ damage happens, mostly outside hospitals. Therefore, people tend to overlook their cardiovascular health status under the current medical systems. The treatment and management costs of CVD impose a substantial financial burden for societal economies and resources. Re-hospitalizations are high amongst elderly people with CVD [1]. Meanwhile, ongoing growth of ageing population and increase of life expectancy require new models of empowering elderly people to live more independently and with higher quality of life [2]. Thus, comprehensive person and home centric care solutions for cardiovascular monitoring, as compared to the current hospital-centered approach, are in a pressing need and subsequently will have significant impact on the quality of life of the elderly people, their families and society. Home monitoring helps to detect transient and rare occurring anomalies with prognostic value. Moreover, senior residents often prefer living in their homes with smart sensing technologies rather than in hospitals [3].

There are a number of dependent/independent factors that characterizes cardiovascular health which ranges from blood pressure, heart-rate, respiration, to modifiable behaviors like smoking, dietary, activity etc [4]. Psychological and psychosocial factors like depression or social-isolation have also proven to show significant influence on cardiovascular health. Many design intervention studies aim to overcome technological challenges also for wearable medical devices to be used for continuous monitoring of body-signs and results are promising [5-10]. Common approach is built on a framework to monitor patients at home [11].

In this paper, we propose a smart system for elderly people with chronic heart diseases, especially the heart failure patients, for managing and giving feedback on their drinking activities at home. Heart-failure patients are prone to fluid retention in their body, as a result can lead to heart failure event. Fluid retention is traditionally managed by careful fluid and salt intake, and adherence to diuretic therapy including other mechanisms [12]. The amount of fluid taken is critical for the recovery of the patients. The current practice enables caregivers to give advice to patients via phone call or at hospital visit. This practice is discrete and not continuous to ensure an appropriate behavior. In addition to that, the current practice does not give advice in context at the time of action, which makes it less meaningful for the patients to change their behavior. Our smart system will help patients to register their everyday drinking activities at home by tangible interaction to give force feedback at the same time. A visualisation of the drinking activities is also available to keep track of progress. The feedback is designed based on the clinical advice for them to adjust their activities for better

recovery. We present the prototype system including both the hardware and software implementation. The system is designed and developed based on the information gathered from our clinical collaborators at Catharina Hospital in the Netherlands and the inputs and feedback from heart failure patients who had treatments at Catharina Hospital. The paper is organized as follows. In the next section, we will present our vision on designing home-care solutions. After that, the concept and implementation of the smart system will be described. At last, conclusions will be drawn.

## **Designing Home-care Solutions**

Most homes are equipped with smart devices, ranging from television sets to mobile phones, alarm clocks, etc, they are an integral part of our living environment. Emerging technologies make it possible to connect these devices together and share useful information, i.e, weighing-scale or wearable devices can connect to a mobile phone wirelessly. Healthcare solutions can thus be developed upon this platform to ensure proper monitoring, appropriate behavioral changes and a connected experience. Connectivity with the outside world, including, care-centers, family members, or friends, will also come into play to enable timely clinical interventions, social cohesion, etc. However, the vision to integrate enabling technologies at home may also pose new challenges like user-identification, data segregation or privacy issues especially in homes with multiple occupants.

Recent studies in [13, 14] show that tele-medical monitoring may not yield expected outcomes in reducing re-hospitalization or mortality. This may be due to the quality of monitoring techniques adopted or the type of intervention facility used. For most tele-medical setups, only physiological parameters or symptoms are collected and intervention/advice is received on behavior or medications, usually through a phone call. This shows an insufficient monitoring mechanism that is currently in place as it is valuable to also monitor the actual behavior of patients as a means to performance measure and a more directed intervention. A clinical support system as being developed for clinical use, [15], can be further developed to avoid information overload, to help clinicians make appropriate intervention and adhere to protocol. The abstract framework, Fig. 1, shows the connectivity between tiers and the coupling between physiological and behavioral changes. Some interventions may be seen as actionable feedback (see Frogger framework and interactive materiality in [16, 17]) and could be provided in context of action as meaning cannot be separated from action. This is hoped to enable a seemingly continuous and unobtrusive communication between care-givers and patients at home. By following a human-centered-design approach, attention should be placed on ways to encourage the role of partners living together, family or friends, as well as contact with the care-provider. Such a framework may improve self management, the quality of care provided and increase the connected experience with loved ones. Additionally, it may reduce the time and effort (cost) needed for clinical experts to give intervention by changing simple parameters remotely, which otherwise will be unserviceable. One challenge is to design the smart-home-care-system through physiological and behavioral monitoring and to translate intervention protocols into an actionable feedback. The other is to create opportunities for social involvement with partners, family or friends in a meaningful way.

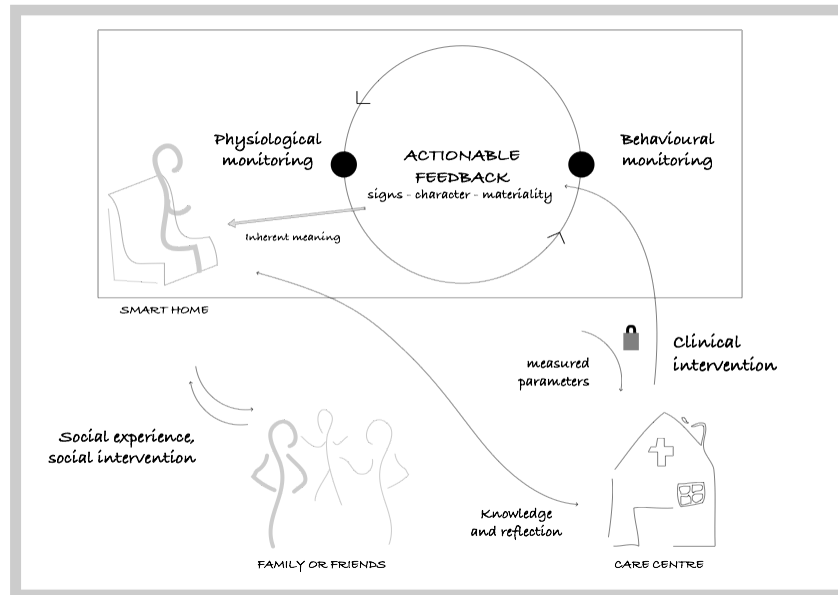


Fig. 1. Patient centered - Smart Home Care System.

## Smart System Design

A cyclic system for fluid management can thus be developed as in figure 2 based on the smart home care system described earlier. In addition to that, a focus-group discussion was organized with three heart-failure patients and a partner at the Catherina Hospital in Eindhoven, the Netherlands. The discussion centered on self-management, clinical support and social values. The goal was to learn from their experience and use the information gathered in designing.

The model on figure 2 is an abstraction from figure 1 for fluid management. It allows intervention to be provided considering physiological and behavioral risk factors. Fluid is monitored at point of intake, accumulation and discharge for a complete cycle.

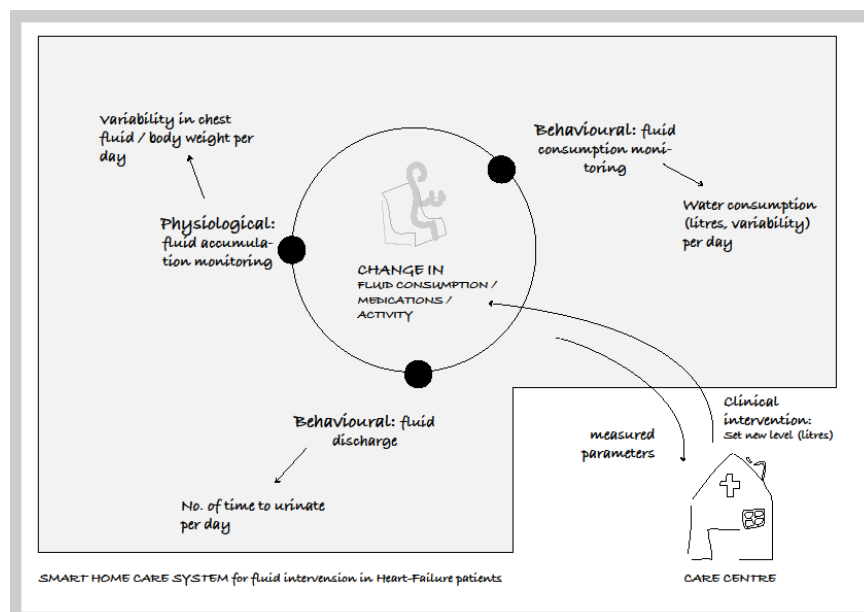


Figure. 2. Smart system for fluid management.

The prototype described in this paper covers only the aspect of fluid intake. It helps patients to register their everyday drinking activities at home through tangible interaction and a force feedback is provided while interacting with the object. The mockup called “Chrystal” is designed as a smart cup system. Interaction with Chrystal is illustrated on Figure 3. A ring is placed on the lower side of the cup in which the patient can rotate to specify the amount of fluid consumed or about to be consumed. In action of rotating the ring, a recommended amount is calculated for that point in time considering previous activities. The ring then pushes or pulls against the motion towards the recommended amount. As a result, the patient can reflect on his action and becomes more conscious of his final behavior. Chrystal then logs the amount specified online which can later be visualized on a mobile device by the patient or by the care-giver. A quick overview or advice is obtainable through the mobile platform. The care-giver can also intervene in a seamless and unobtrusive way by remotely entering values online which otherwise would be unserviceable.

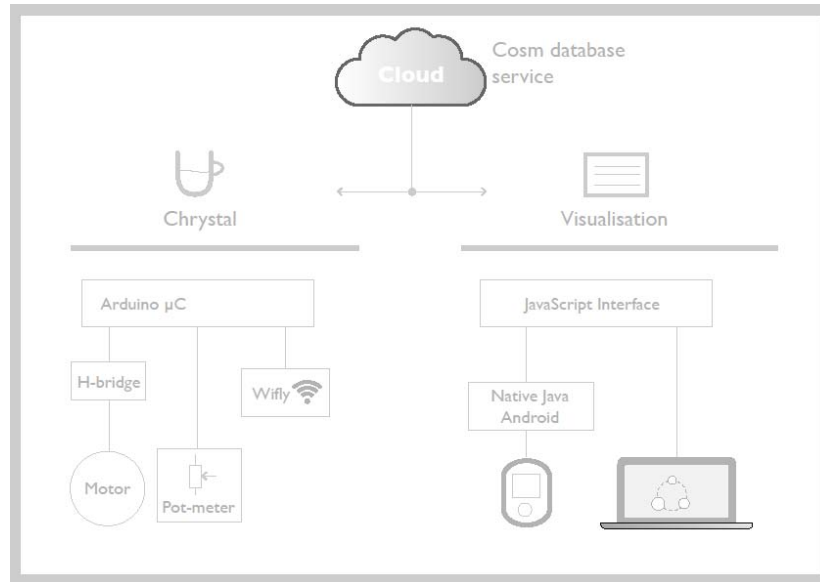


**Figure 3. Chrystal - Smart cup system.**

## Prototype Implementation

To demonstrate the design concept and enable patients to experience with the smart system and provide evaluation on the system, a prototype was built. The prototype consists of hardware with software implementation for a user to register their drinking activities in a tangible way as described earlier, and a web application to visualize the drinking activities.

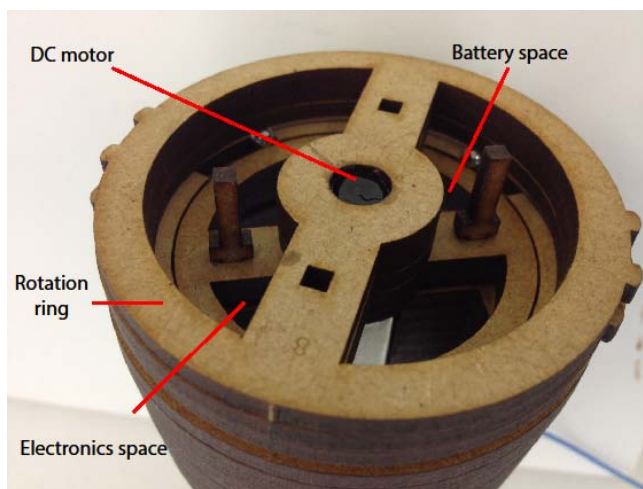
Figure 4 illustrates the system. The mockup consists of an Arduino microcontroller, a dc motor, an H-bridge driver, a Wifly module and a battery pack. The Arduino functions as the central processing unit in which other components connect to. It connects to the internet through the portable Wifly module to log and retrieve data from the online database. The current position of the ring is read through the potentiometer. Depending on the position, the motor is controlled to provide force feedback to the user as he or she turns the ring. The H-bridge makes it possible to control the motor bi-directionally. Data is stored using Cosm service ([www.cosm.com](http://www.cosm.com)), an online database, which is accessible by a distributed system through HTTP request and web sockets. A HTML5 with JavaScript+d3 application is built to visualize the data in a modern browser. A native android application renders and bridges with the HTML5 application using an Android Webview.



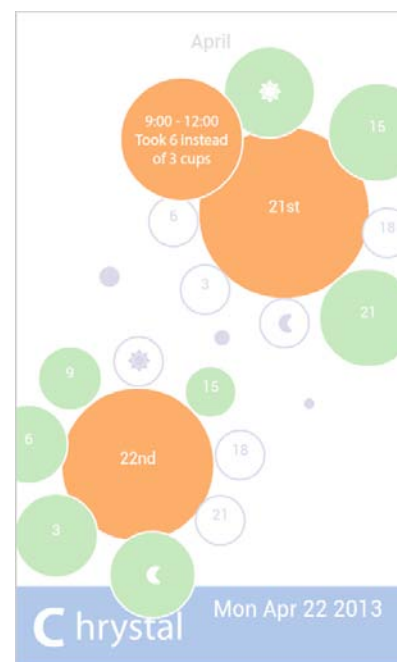
**Figure 4. Prototype implementation.**

Figure 5 presents the hardware and software prototype. The hardware is shown in Figure 5 (a).

The mobile view is restricted to a two days data visualization to maintain simplicity, see figure 5 (b). Each group of bubbles represents 24 hour visualization in style of a 24 hour clock. The inside bubble is the aggregate for the day and the outside bubble reflects consumption during the day. The size of the bubble shows the amount consumed and the color appears green or orange depending on how much the specified amount matches the recommended amount. Each bubble can expand when pressed to show specific details for the time range.



(a)



(b)

**Figure 5. (a) Hardware system of the smart cup (b) The visualization for a mobile device used to gain overview and to seek advice in an easy and natural way.**

## **Conclusions**

Independent living and the prevention of recurrent cardiovascular event is essential for elderly with chronic diseases living at home. Socially oriented designs and societal interventions are essential in managing chronic diseases; which encourages healthcare solutions to be built on lifestyle, and social/personal values. This will give rise to a smart environment, designed to facilitate appropriate behavioral choices as a means to improving healthcare and quality of life. In this paper, we focus on the design for patients with heart failure. The amount of fluid taken is critical for the recovery of these patients. A smart system is proposed to help patients to register their everyday drinking activities at home by tangible interaction and give both tangible and visual feedback based on the clinical advice for them to adjust their activities for better recovery. The prototype system is presented including both the hardware and software implementation. Evaluation of the system will be carried out with the use of the system at homes of some heart failure patients who had treatments at Catharina Hospital in the Netherlands.

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