Hydrostream: A Platform for Collecting, Annotating and Analyzing Water Pressure for Health Applications

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Abstract
We are developing Hydrostream, a server-based platform for the collection, visualization, annotation and analysis of water pressure in a home setting. While designed with health applications in mind, Hydrostream can be easily applied towards more general-purpose personal informatics applications. In this paper we describe the system in detail, present motivating design goals and discuss challenges and opportunities.

Keywords
sensing, activity inference, online learning, ubiquitous computing, personal informatics, ui design, health

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Motivated by the vision that a sustainable healthcare system hinges on prevention rather than post-diagnosis treatment, we have been developing tools to help individuals and their caregivers keep track of Activities of Daily Living (ADLs) in a home setting. Examples of ADLs include cooking, eating, bathing, using the toilet and doing laundry. Our hypothesis is that it is possible to correlate deviations in behavior at home with the

onset of disease, taking into account that the earlier a condition is diagnosed, the higher the likelihood that treatment will lead to a positive outcome. This view is corroborated by medical professionals and backed by cases where home monitoring behavior analysis has been successfully applied to diagnose diseases such as depression [4] and urinary tract infection [10].

Recognizing ADLs in a home setting has been an area of intense research work over the last decade. Several approaches that sense humans in the physical world have been demonstrated. Some of these rely on mobile and accelerometer-based sensors [1,3] while others are based on environmental sensing [7,11].

A promising method for observing human activity in a home environment is called Infrastructure-Mediated Sensing (IMS). The core concept behind IMS is to choose a specific form of home infrastructure (i.e. power lines [6,9], water lines [5], gas lines [2], HVAC [8]) and create a device that attaches and monitors the chosen infrastructure with a high degree of fidelity. By sensing some physical phenomenon that is linked to the chosen infrastructure, it is possible to try to infer what actions are being performed on that infrastructure.

Design Requirements

A number of prototypes have been built with the purpose of validating the IMS approach, some of which have been deployed and tested in multiple homes. One of these prototypes is Hydrosense [5], a water-based IMS system which has shown that a single pressure sensor can localize human activity in a home.

Encouraged by these promising early results, we are developing a water-based IMS system for medical and health-modeling applications that extends Hydrosense. A pilot installation at an assisted living facility revealed many of the challenges of working with an IMS solution in residential environments. Motivated by this experience, we have implemented a platform called Hydrostream around a new set of design goals.

Data Collection Automation

Collecting data from geographically dispersed homes on a regular basis poses a logistical challenge. Ideally, data collection should be a completely automated process. Hydrostream uploads sensor data to a web server in real-time through an Internet connection, thus greatly minimizing the need for home visits.

Failure Detection

There are situations when data collection might be permanently or temporarily interrupted (e.g. system failure). Issues that emerge should be quickly identified. Because of Hydrostream's server-based architecture, any interruption in the sensor data flow can be more easily noticed, and corrective action can be taken.

Medical Alerting

When used as a platform for medical applications around human behavior monitoring, it should be possible to react to the data in real-time, as it might indicate a medical emergency. With Hydrostream, the collected sensor data lives on a database, and can be continuously analyzed for medical abnormalities

Interactive Activity Labeling

When used in the context of activity recognition, we believe a promising technique for obtaining ground truth for activities of daily living involves getting

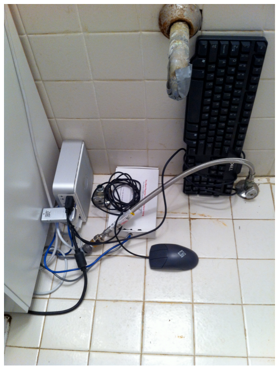

Figure 1. Hydrobeacon collects water-pressure data and uploads it to a server in real-time using an Internet communication interface.

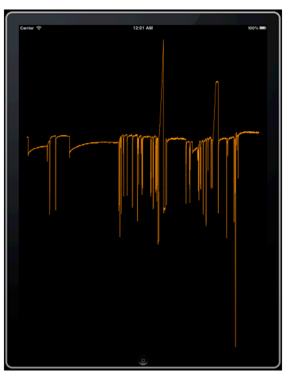

Figure 2. Hydropad displays the raw sensor data stream. The application will let users visualize and annotate activities of daily living.

residents to contribute to activity labeling in an interactive fashion. Hydrostream makes this possible through the combination of server-side data analysis and an iPad application for data visualization and annotation that residents interact with in their homes.

Consistent Data Aggregation
Ultimately, our goal is to deploy our system in a large number of homes. To facilitate analysis and comparison, aggregating data from multiple homes should be accomplished through a consistent process. The Hydrostream sensor data pipeline ensures that only one data path exists from data acquisition to analysis.

Hydrostream

The Hydrostream system is made up of 3 components, *Hydrobeacon*, *Hydroserver*, and *Hydropad*. Hydrobeacon forms a hardware-client combine that probes the water system for pressure readings. Hydroserver is a cloud-based server backend for data analysis and storage. Hydropad is an iPad-compatible application built to give home residents immediate feedback about their water usage activities and collect the context surrounding those activities.

Like the original Hydrosense prototype, Hydrobeacon (figure 1) relies on a water pressure-sensing device. The pressure sensor used can measure up to 100psi and outputs a ratiometric voltage between 0.5v and 4.5v.

The analog signal from the sensor is converted to a digital representation through an Arduino Uno board, sampled at 200Hz. All digital pressure readings are forwarded to a computer through the USB interface. The data is validated and sent over to a web server in bursts of 10Kb.

This approach was successful with two types of communication interfaces, Wifi and 3G. At the server level, a script written in PHP saves the data onto a database. A moving average is calculated as a way to save a smaller, down-sampled representation of the pressure readings.

Discussion

So far, we have tested Hydrostream in one home for 25 days with success. Initially, we chose to evaluate the system with the 3G communication interface. From our experiments, we were able to verify that the performance of the communication interface was adequate. Unfortunately, the 3G interface proved to be unreliable. We are currently exploring approaches that mitigate this issue, which involve buffering the data until a connection can be re-established.

A key component of Hydrostream in the context of personal informatics and health-centered applications is Hydropad (figure 2). The iPad application, used for data visualization and annotation, is the face of Hydrostream as far as individuals are concerned. At the moment, Hydropad can only display the raw, down-sampled water pressure data stream. As previously discussed, we are particularly interested in understanding how we can turn residents into active participants in the process of acquiring activity ground truth at home. This step is crucial to train classifiers that recognize activities of daily living automatically. We are currently exploring online learning algorithms and interfaces to make this a reality.

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