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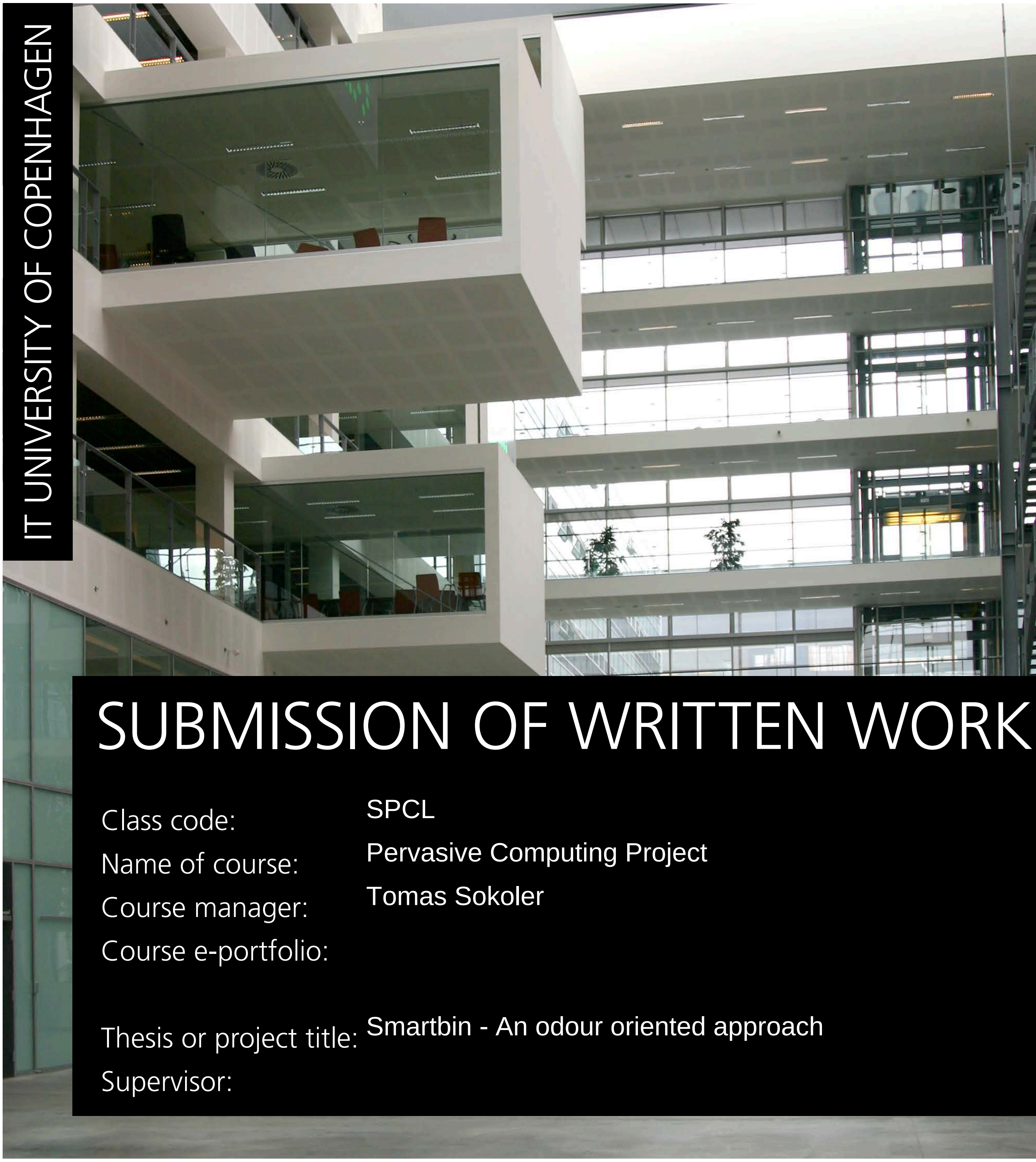

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Supervisor:

	Full Name:	Birthdate (dd/mm-yyyy):	E-mail:
1.	Ivan Naumovski	17-07-1989	inau@itu.dk
2.	Martino Secchi	04-08-1991	msec@itu.dk
3.			@itu.dk
4.			@itu.dk
5.			@itu.dk
6.			@itu.dk
7.			@itu.dk

Smart Bin - An Odor Oriented Approach to Waste Management

Ivan Naumovski
inau@itu.dk

Martino Secchi
msec@itu.dk

ABSTRACT
Technology enhanced trash cans have already been subject to a lot of research and have become available as market products. How the waste is handled has traditionally been a logistic issue, but it can also be approached differently.
This SmartBin perceives the trash as something more than a pile of waste - it is also something smelly!
We take a different angle on a known subject: waste management through smell detection.

The emphasis is on improving the indoor environment by monitoring air quality and smell levels emitting from the trash. We developed a prototype able to measure and transmit trash status over the cloud, where the information can be accessed by various client devices like situated displays around the house and smartphones. The system was evaluated by conducting user tests, the responses were both positive and negative

ACM Classification Keywords
H.5.m. Pervasive computing, smart measuring: Miscellaneous; C.2.4. Distributed systems: Client/Server; C.3. Special-Purpose and Application-Based Systems: Real-time and embedded systems

General Terms
Design; Measurement; Embedded devices; Internet of Things.

INTRODUCTION
Waste management is a constant issue, that is dealt with on the daily by different organisations. According to Eurostat, the countries in Europe have had a rather stable production of waste in the past decade. In 2014, over 200 million tonnes of waste have been generated just by households in european countries [3]. How waste is handled is a highly relevant issue in modern society, and the design of smart garbage systems for both houses and cities can help monitor the situation.

The traditional approach on waste management comes from a logistical point of view. However, imagine not the amounts nor the location of the bin being the driving force for interacting with it, but rather its smell.

Figure 1. The SmartBin system overview, the bin with ambient display

This is essentially the innovative take of our system - smell as an additional parameter. This additional information can be used in conjunction with existing systems or be used to produce an entirely new experience centered around the waste bin. Following this concept, a prototype of a simple system has been developed. With low cost and easily obtainable technology, the system measures both smell and garbage amount directly from the bin. This information is transmitted from the bin to the cloud and made readily available to a set of client devices. We use an android application to present the data to the user in two different modes, namely as an ambient display or as a smartphone app. Figure 1 shows an overview of the system.

The system is specifically designed for private use inside a household, but can be easily adjusted and extended for different usages.

In this paper we describe the system specifications and evaluation, and discuss its potential integration in other scenarios different from the one presented.

RELATED WORK
Smart Waste Management Systems (WMS) have been subject to extended research throughout the years. The usual approach for data collecting in this area is to explore the physical attributes of a bin, namely what is put in the bin. The common ways of obtaining such information are divided in two main categories: physical sensing and tagging.

Physical sensing is a great way to obtain generic information about the amount of garbage, and is usually measured in weight or height. In recent years though, the use of tagging has become fairly popular, and some research in WMS has been conducted through the use of RFID tags and other tagging technologies.

With different technologies, in general come also different purposes. While both approaches can handle well general monitoring and analysis of the processes revolving around waste management, some are better suited for specific uses.

Tagging technologies are excellent ways of tracking every object and associate meta information to them, therefore are often used in conjunction with recycling systems. On the other hand, amount information is often used for systems that focus on resource allocation, garbage collection or process planning.

Systems with mixed approaches have also been developed.

There are numerous examples of research in this area, we mention just few examples in the following paragraphs.

In a study conducted in Australia, a research group implemented an RFID and weight based system for real time automated WMS, with the main focus on bringing down management costs and facilitate automating waste identification [2]. In France, an RFID based system is instead focused in assisting in the recycling process by making sure that the waste is disposed correctly [7].

In another study performed in South Korea, the main approach was to analyse and identify food waste in a selected area of Seoul, and give citizens incentive to waste less food by fining them based on the amounts of waste they dispose [4]. The distinction of trash was done using RFID, and the amount was measured in weight.

In an italian study, a Smart-M3 Platform and sensor enhanced bins were used, this was done with the main focus on urban planning, smart collection and monitoring of urban solid waste [6].
In this case, the information that was collected was on the location of the trash can, level of fullness, and weight of the waste.

It's worth mentioning that all of the previous examples don't account for gas emission or smell, even though some steps in this direction have been taken. A research at MIT (Massachusetts Institute of Technology) enabled a trash can with a perfume dispenser, that would activate whenever gas emissions are detected from the trash [5].

SYSTEM DESIGN

Our approach includes the additional parameter of scent as a factor. The system we designed is able to detect smell levels emitting from the trash, in addition to trash amount measured in height, to ultimately improve air quality especially in indoor environments.

Odor detection in our system is performed by targeting specific gases that are well known for their bad smell. Most of these gases are produced as the result of decomposition of organic material, especially proteins, that are commonly present in waste. The other features of our system are the transmission and the presentation of the data.

To perform these tasks, the system is formed by four main components: a *sensory layer*, a *communication module*, a *data layer*, and a *data consumer*.

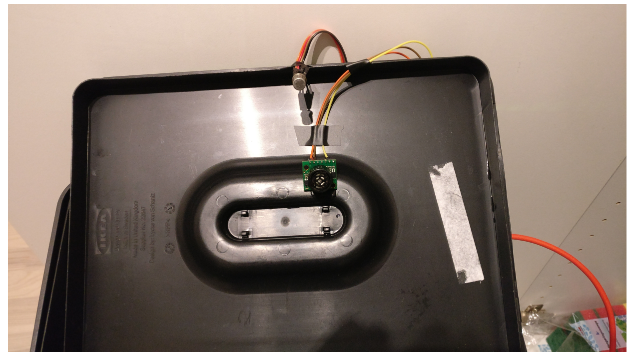

Figure 2. The sensors facing the inside of the bin.

Sensory layer and Communication module

The sensory layer is composed by two sensors (figure 2) and one communication device. The sensors detect the state of the bin. Our approach relies on two kinds of information related to the state of the bin: smell and fill level. For this reason, the sensory part of the system is of key importance, since it enables the information to be perceived and registered by the system. A gas sensor is able to capture volatile organic compounds (VOCs) and other gases, typical by products of food decomposition, commonly associated with bad smell. Some examples are Hydrogen Sulphide (H_2S), with the typical smell of rotten eggs, Ammonia(NH_3) and amines (its derivates), that are responsible for the "rotten fish" smell, and others like Methane(CH_4), Toluene (CH_3), short chain alcohols (ethanol, methanol) and more.

The other type of sensor is a ultrasonic distance measurement unit. This is used to get the distance to the bottom of the bin. This type of information is processed in the sensory layer to reflect the amount of trash filled in the bin.

The raw values are then processed and formatted into something understandable for our data layer. The last step is to send the values using the communication module. In this study, communication is performed over a WiFi network.

Data layer

The data layer is a simple RESTful web service for collecting the data and storing it in a database, thus making it accessible to potential consumers.

The service supports two types of entities, the SmartBins and the contexts.
Every SmartBin has a unique identifier and some information about its recent state information.
Every context is information about a state tied to a bin.
The REST api supports filtering of contexts by bin and lookups of all bins.

Data Consumer

The consumer in our case is an android client, but could just as easily have been any other platform able to connect to the internet and present content.

Our client can work in two separate modes: either as an android application or simply as an ambient display (single bin

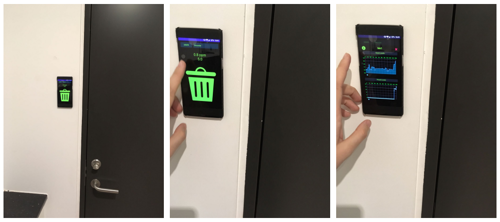

Figure 3. Interaction with ambient display

mode).

On the android application it is possible to manage multiple bins and get an overview of the last values measured by the system.

The ambient display is much more simple, it just displays a color of a shade from blue to red depending on the scent level, and the latest values measured for such bin.

In our system we use an android phone to run in both modes, so pressing on the screen even in ambient display mode will give the user the extra functionality of getting the overview for every bin that is registered to the user and of viewing the complete set of data measured from the bins.

Ideally the ambient display can be placed in a strategic location inside the house, for example by the door or on the fridge, where people can be reminded of the trash status and act accordingly.

Figure 3 shows an example of interaction with the ambient display.

HARDWARE

The Smartbin hardware platform is a simple construction consisting of two sensors, a microprocessor and a wifi communication module. It is embedded into a trash bin with a lid which is used as a base for both the distance sensor and the gas sensor.

We built the prototype using an Arduino Uno board (figure 4).

As for the sensors we used a Figaro TGS2602 as our gas sensor and a MaxSonar MB1013 ultrasonic rangefinder as our distance sensor.
The gas sensor is a generic air quality sensor that detects variations of most of the gases listed above as "of interest" in regards to bad smell emissions. It also detects other substances, like CO_2 that, although odorless, are still an indicator of decomposition.
Even though in the course of this project we have not been able to recognise specific gases from concentrations registered by the sensor, we make the assumption that the presence of any of the gases targeted by the sensor are valid indicators of decomposition and hence bad smell.

We use a WiFi shield on the Arduino board for wireless communication.

The presentation layer works on Android 4.0 or later.

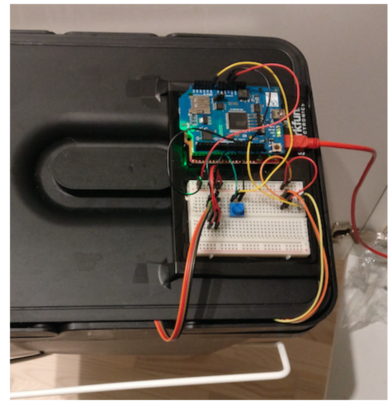

Figure 4. The controller board with communication shield

Figure 5. Cloud-based architecture

SOFTWARE

The software system consists of three components. The module on the bin, one cloud service and one android client. The components interact using the client-server model over the web, in a cloud-based architecture (figure 5).

On the bin, the gas sensor first needs to go through a warm-up period of about 15-20 minutes, during which the sensor is energised. The resistance registered by the sensor drops sharply for the first minutes after energising, regardless of the presence of gases. This behaviour is commonly known as *Initial Action*, and could cause a system to mistakenly report presence of gases during the first minutes of activity [1].

After the warm-up period, the system will go through a period of *calibration* (5 minutes), during which the value Ro (resistance measured by the gas sensor in clean air) is computed as an average of 300 samples. During this period the sensor has to be kept in "clean air", or in an environment considered to be in a base condition, because later measurements will rely on this value.

After warm up and calibration, the gas concentration sent by the module will be in the form of a ratio *Rs/Ro*, where Rs is the resistance measured by the sensor at a given time and Ro is the constant value detected in clean air. This means that if the gas concentrations registered by the sensor are very similar as the ones in clean air, the ratio will be close to 1. The more the values Rs and Ro differ, the more far from 1 the

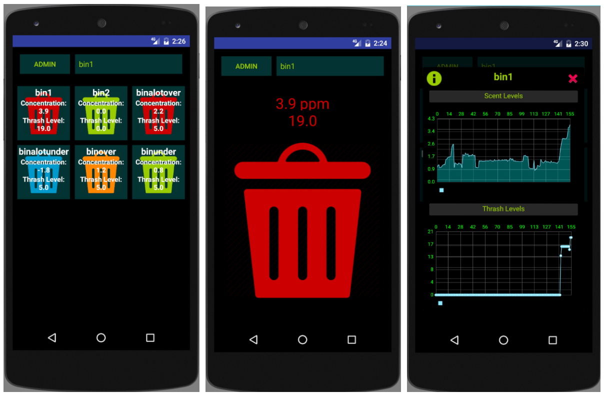

Figure 6. Image of the three main views in the android client

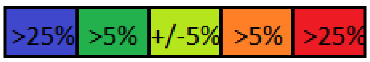

Figure 7. Image of the color codes ranging from deviation under the norm to deviation over the norm

ratio will be.

The cloud service is hosted using Google App Engine, it is a simple website that can present the state of SmartBins in the system. It also exposes a REST style API - which can provide SmartBins and Contexts.

A SmartBin represents the hardware instance of a smartbin, this includes information such as location expressed as coordinates, unique identifier, 'calibration' which is the intial air quality level (in "clean" air, a value to which compare later measurements) and meta information about the last associated context. This ensures that status of every bin is readily available without having to traverse the contexts.

The contexts model a snapshot of a bin's state at a given time, this is thus timestamps, associated bin, fill level and concentration. This data is the backbone for being able to provide graphs about the bins.

The service uses technologies such as HTML, JavaScript, Java Servlets and schemeless persistent storage.

The android client can provide statistics about different smartbins - it only supports presentation of data in its current form.

It uses third part libraries to simplify the REST api access and the graphing of data. We used Ion[1] to easily access our REST resources and MPAndroidChart[2] for presenting the graphs.

It supports two modes: *Admin mode* and *Single Bin mode*. *Admin mode* includes an overview of every single bin and graphs for each one. The graphs are only available as long as enough context information is present see figure 6.
Single bin mode provides a view of the current bin state.

The bin state is divided into five different categories, this is represented visually as colors.

[1]Android Asynchronous Networking and Image Loading: https://github.com/koush/ion
[2]MPAndroidChart: https://github.com/PhilJay/MPAndroidChart

The order is, *blue*, *dark green*, *green*, *orange*, and *red*, as seen on figure 7. The middle one, *green*, is when the concentration is deviating with at most 5%, next tier *dark green* and *orange* is a deviation of at most 25%, and the last ones *blue* and *red* are deviations above 25%.

EVALUATION

We interviewed a restricted poll of people in regards to usability of our system in a private scenario, in two different occasions.

We used two distinct focus groups, and we will refer to them as group A and group B in this paper.

Group A was a homogenous group of people, all males and all ranging between the age of 24-30, all with IT-related background. Group B was instead a more diverse poll of people, mostly females of age between 24-30, and non IT-related background.

Group A

Group A has been presented with the android app and some pictures of the bin and its setup. During the follow-up discussion, the general reaction from the group was that the system felt unnecessary and was not welcomed. The purpose of the system to serve as a reminder and state monitoring device was easily achieved "manually" by the participants, who regularly took the trash out and checked its status in person.

Group B

Group B was introduced to the system in loco and in its totality, with bin, situated display and android app, all embedded in the house environment. The reactions from this focus group were much more positive, especially towards the situated display placed on the wall. The general sentiment was of marvel and appreciation of the achievements of technology even in the ordinary life scale. Regardless of the actual purpose of the system, the prototype was mostly welcomed as an instance of what a larger system could become in the future of smart houses. That said, the fact that bad smell could actually be measured by machines was a surprise to most, and the visual reminder of the trash status right by the door was most appreciated by the ones that regularly forget to take out the trash.

DISCUSSION

The SmartBin system which has been constructed utilises gas sensors to open up an additional dimension when measuring the status of the trash present in bins. This extra dimension is the main focus of our system, as an innovative angle on an existing problem.

In this section we want to discuss some of the openings that this approach allows.

While we have tested this approach in small scale in a home environment, it is not limited to this setting.
What if we could use this data to expand our take on waste management systems?

Logistic for garbage collection is usually driven by amounts, but what if bad smell was also one of the leading parameters to act upon?

Large levels of bad smell emitting from the trash result in unsanitary conditions, insalubrity and even worse bad air quality, which can attract insects and other wild animals. While it remains true that trash handling is first and foremost a logistical issue, most waste management systems don't take bad smell into account at all.

By prioritising the collection of "smelly" garbage, alongside with the collection of full trash cans, insalubrity conditions might be reduced significantly. This would ultimately improve air quality and the quality of life around public spaces and all this can be achieved with relative ease.
Other smartbin systems already have means of communication integrated, so adding an additional sensor should not be highly problematic.

The components we have used for our prototype might not be the optimal components for systems in public spaces. The biggest weakness is the power consumption that WiFi modules have. Alternatives could be technologies like LoRa that are designed for lower power consumption.

CONCLUSION

The system described in this paper is a simple implementation of what waste management system can look like with the use of odor detection. It is designed for private usage inside the household, as one of the many different features that can turn a normal home into a smart home.

With the right IoT components, trash status can be easily monitored and transmitted, all with *off-the-shelf* and relatively cheap components.

The main purpose of the system is to provide the means for monitoring trash conditions inside the house, and to act as a reminder to the users so that they can dispose of their waste before such conditions become problematic.

It's been discussed how taking smell into account for waste management could lead to better air and sanitary conditions around the trash.

Even existing systems could be adjusted to take into account the smell factor, all with relative ease and at a low price, just by adding a small sensor to their infrastructure.

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