# A Case Study on Using the Windows Sensing Evaluation Platform (WSEP) for Monitoring Rehabilitation in Sarcoma Patients

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*Abstract*— **Patient self-rehabilitation efforts after sarcoma surgery, a rare variation of cancer, currently relies on the patient's ability to self-motivate and self-report the level of rehabilitation correctly. Thus, rehabilitation-efforts cannot be verified by healthcare staff. The aim of this study was to evaluate the feasibility of using WSEP to register and verify patient self-rehabilitation efforts. This includes whether the patients are adhering to the guidelines given by the clinicians. The application WSEP is used to detect activity level and distance travelled using the built-in accelerometer and GPS. The results demonstrated that it was possible to accurately classify a patient's activity level and distance travelled. However, the duration of monitoring was limited to six hours, rendering the WSEP infeasible for clinical use. A power optimized version needs to be developed before moving on.**

## I. Introduction

Soft-tissue sarcomas are a rare variation of cancer, where the preferred treatment is surgery (1). There are roughly 200 new cases of soft-tissue sarcomas per year in Denmark out of a population of 5.5 million people (2,3). In order to secure a higher function and quality of life, these patients are offered rehabilitation, including self-rehabilitation-based exercises. Not all patients who receive rehabilitation perform it as intended; this may lead to reduced function and, in time, quality of life.

Some rehabilitation is given in the form of instructions the patient have to follow alone at home. This can increase the likelihood of the patients training either insufficiently or excessively. This may be caused by the lack of feedback on the current training effort of the patient. This can lead to further impairment and loss of function and quality of life.

The aim of this study was to evaluate the feasibility of WSEP, as a tool for creating a device that will allow the patients rehabilitation training efforts to be quantified in real time using 24-hour "motion monitoring" based on accelerometer and global positioning system (GPS) data.

## II. Methods and Materials

### A. Methods

A workshop with technical researchers, healthcare researchers and staff from Aarhus University Hospital, Department of Orthopaedic Surgery, Sarcoma Section, including physiotherapists, doctors, and clinical researchers , was held to determine the specific elements of the study and the evaluation prototype. For the evaluation case study the Adherence Strategy Engineering Framework (ASEF) was used. This framework defines a set of phases, steps and guidelines for designing and building self-care solutions using adherences strategies.

### B. Hardware and sensors

The system is designed for use on the Windows Phone 8 platform. This platform was chosen as it is a fairly easy platform to develop for, the application will be relatively simple to edit and it offers some freedom in terms of development.

### C. Evaluation Prototype

We constructed the WSEP as an activity sensing prototype for the Windows Phone 8 platform. The intended use of the prototype is for the pervasive healthcare domain. The application provides a relatively easy way of securing and monitoring appropriate training efforts of the patient, by using a standard smartphone.

### D. Evaluation

The prototype was evaluated in two phases. First, by testing it in a laboratory setting where several tests were performed. The purpose of the first laboratory test was to evaluate battery lifetime. The second test was to determine GPS accuracy. The third test was to evaluate the accelerometer accuracy with two test users.

### E. Clinical Evaluation Approach

When a patient submits to rehabilitation, the patient will be fitted with a smartphone attached to the arm. The application requires the physiotherapist to enter the patient id, e.g. social security id or another id of choice, and an email address. The physiotherapist will then activate the application and the patient can now leave the clinic. During the measurements, the application automatically uploads data to a web-service. Where the physiotherapists can evaluate on the data and ensure the accurate rehabilitation for the patient.

### F. *System overview*

For every five minutes the GPS is activated, the application sends the data from the accelerometer and GPS to a cloud. The patient will have the smartphone for a week, and when the week has passed, the application stops the recording of data. The smartphone can now be returned to the clinic.

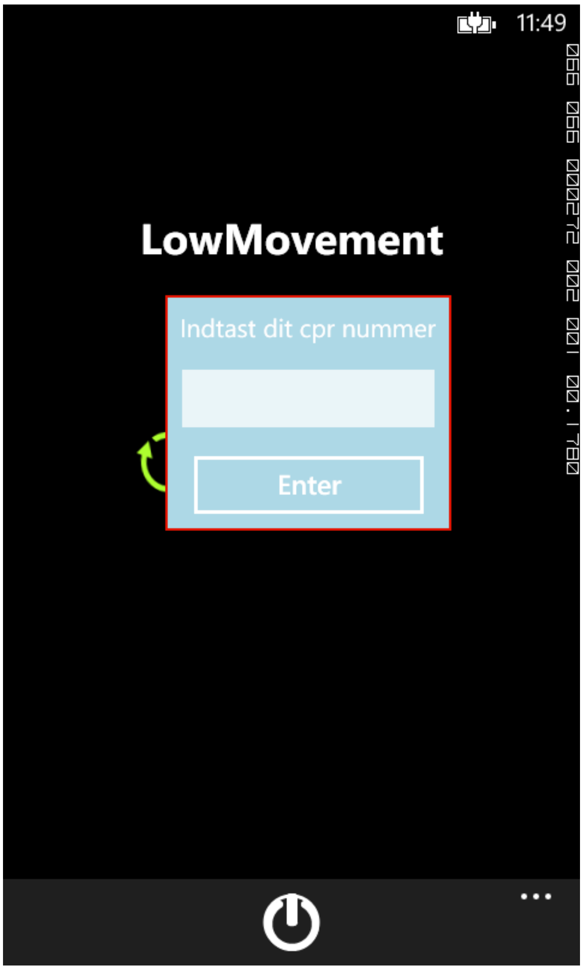


**Figure 1: User interface for the application**

The case study application uses the accelerometer and GPS sensors. The GPS sensors provide information as to how far the patient moves. An algorithm was developed, for processing the readings from the accelerometer based on the x, y, z axes and determining whether the patient is moving. These accelerometer readings were divided into seven categories, low movement (includes standing and lying), walking, running, high movement, transport, unknown and unset (the first 10 samples). These classification categories are an indication of the patient's level of activity. The smartphone used for the measurements is a dedicated device, and not the patient's own smartphone. This is to ensure, that the patient does not drain the battery during ordinary smartphone usage.

### G. *Algorithm description*

One of the main purposes of the lightweight application is to implement an accelerometer algorithm that can determine the patient's activity level.

The algorithm is able to process the data from the accelerometer and classify these into categories of motion.

| | |
|---|---|
| Low movement | Acceleration below 0.2 |
| Walking | Acceleration below 0.4 |
| Running | Acceleration below 1.0 |
| High movement | Acceleration below 3.0 |
| Cycling | Not implemented |
| Transport | Not implemented |
| Unknown | All above 3.0 |
| Unset | The first 10 samples |

### H. *Algorithm definition*

The following describes the algorithm, and how the different parameters were defined. 1 sample per second was used, resulting in 1*60 = 60 samples per minute. Each second the standard deviation is found for the last 30 samples:

$$Acc. = \sqrt{Sum\ of\ deviation\ avg. - (Avg. *\ Avg.)}$$

### I. *Evaluation*

The accelerometer algorithm was tested under a series of different conditions, to verify that calculated result matched the actual level of activity.

The evaluation focused on the following three levels of activity:

1. LowMovement
2. Walking
3. Running

The test subject performed each test 25 times, where test 1 and 2 where performed for 15 minutes and test 3 for 5 minutes.

## III. RESULTS

25 tests, where the data was collected for approximately 15 minutes, were performed. The purpose of the tests was to determine whether the application perceived the activity levels correct or not.

TABLE 1:
DEFINITIONS OF MOVEMENT CATEGORIES, AND THEIR SUCCESS RATE

| Description | Number of test x duration | Results |
|---|---|---|
| Standing/Lying | 25 x 15 | 100 % low movement |
| Walking | 25 x 15 | 80 % walking, 20 % running |
| Running | 25 x 5 | 90 % running, 10 % high movement |

A power consumptions test was performed, to give an indication of how long the device can be used at a time. 15 tests were performed, where the application was started and used as intended.

TABLE 2:
RESULTS OF THE POWER CONSUMPTION TEST

| Activity levels | Number of tests | Average operation time |
|---|---|---|
| Low | 5 | 6 hours |
| Medium | 5 | 3.5 hours |
| High | 5 | <2 hours |

The power consumption test showed that the prototype, as it is now, can hold power for an average of 6 hours. The primary cause is, that the screen is active at all times and consumes the battery. The secondary cause is the GPS, which is activated, whenever the patient's movement is in one of the following categories: Walking, Running and HighMovement.

## IV. DISCUSSION

Previous work has investigated motion detection, particularly detecting falls, as well as context-related motion in connection with ambulatory blood pressure self-measurement. In this study hypertensive patients would be tracked for a 24-hour period, context tagging the data with GPS coordinates and level of activity as in the present study (4).

The results presented in Table 1 displayed 100 % accuracy in the category "LowMovement". While the second category resulted in an accuracy of 80%, with a false negative level of 20%, shown as category "running". For running, the accuracy was 90%. Thus, there is some insecurity in detecting the activity levels.

The power consumption evaluation showed that the battery of this particular smartphone will not last the required 16-20 hour period if the screen is always on, and the GPS activated.

Thus, the results indicate that remote monitoring of rehabilitation patients can be achieved using a smartphone's built-in sensors, such as the accelerometer and GPS. The overall test results appear promising, but more work is needed to optimize operational range.

Only two test subjects were involved. In order to further substantiate the tests results, future work should involve test on actual rehabilitation patients in a clinical environment.

## V. CONCLUSIONS

The WSEP application was able to determine a patient's activity levels and classify the movements into one of four categories. The work resulted in a lightweight application that is capable of determining activity levels in rehabilitation patients.

## REFERENCES

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