Towards Context-Aware Assistance for Smart Self-Management of Knowledge Workers

Fabienne Lambusch[1] and Michael Fellmann[1]

[1] Business Information Systems, University of Rostock, Germany
{fabienne.lambusch, michael.fellmann}@uni-rostock.de

Abstract. The development of the knowledge-based society and ubiquitous information technology offer individuals a variety of personal and professional possibilities. At the same time, increasing flexibility in modern everyday life can lead to high working pressure and blurring boundaries between life domains. Thus, self-management skills steadily grow in importance. These skills are not only important for productivity, but also for health and wellbeing. The availability of various small sensors and their easy integration into everyday life enables new kinds of data collection. Data ranging from heart rate to location can be analysed and combined with data about tasks and time schedule to provide guidance in self-management. However, up to now it is unclear how such a guidance based on sensor information could be designed and how it can positively contribute to self-management. In our research, we hence provide a first contribution towards context-aware assistance for self-management of knowledge workers. To do so, we first devise a scenario to show how such a system could positively contribute to self-management via a set of interventions based on sensor data. We then present an architecture that conceptualises a context-aware system integrating several data sources along with descriptions of implementation options of such a system. With this, we intend to provide an overview on the design space relevant for the construction of such systems. This overview is meant to inform and inspire the future design of concrete systems that assist knowledge workers in the enhancement of their self-management skills.

Keywords: Self-Management, Sensor-based Monitoring, Context-aware Assistance, Work Organisation, Stress Prevention.

1 Introduction

Work intensification and blurring boundaries between personal and work life pose major challenges in today's society. Many workers are often pressed for time. Frequent interruptions and multitasking constitute additional difficulties for the planning and completion of tasks. According to results of the Sixth European Working Conditions Survey, 45% of workers carried out work in their free time in order to meet work demands [8]. More than every fifth worker did this several times a month or even on a daily basis. The overall findings of the survey indicate that many of today's workers face very high work demands. Stress resulting from high work intensity can have negative effects on work performance and is furthermore a risk factor for personal health and wellbeing [17]. Long-term exposure to stress can lead to serious health problems like back pain, depression, and burnout [2]. Possibly causing poor productivity and absenteeism, consequences of work-related stress not only pose a major problem for workers, but also for the organisation they work for [17].

While the organisation is responsible to support workers by paying attention to good working conditions, it is often not feasible for supervisors to adjust the amount of work on a daily basis to meet the current capacity of each employee. This is even more true in the context of work that is characterised by a high degree of freedom, i.e. the worker often can decide on what to do next, what methods of work are used, or what could be accomplished on a daily basis [7]. However, the improvement of self-management competencies can help the individual to cope with high demands in everyday life. We follow here the definition that self-management competence comprises the willingness and ability to manage the own life responsibly and to shape it in such a way that productivity (e.g. in terms of knowledge, skills, health), motivation, well-being, and balance in life are promoted and maintained over the long term [10]. This means that self-management is also about becoming more efficient and effective, but should always be linked to handling the own resources carefully. Graf [11] points out two key abilities for effective self-management: *self-reflection* and *self-development*. Self-reflection corresponds to determining necessary changes and development steps whereas self-development denotes the operationalisation of these steps. The author figured out that many people, even if they know what they should change, find it particularly challenging to take action in order to accomplish the latter, i.e. reach self-development. As a lack of success in achieving goals weakens self-esteem and well-being, it is important to promote taking action.

Therefore, we propose to assist workers in self-management at both stages, self-reflection and self-development, by utilising the opportunities provided by modern information technology. Existing tools, such as to-do lists or digital calendars, offer only rudimentary support for self-management. The latter, for example, support creating appointments and may warn when these temporally overlap, but they do not plan for the workload accompanying certain appointments. Furthermore, most of the existing tools are static and require continuous manual adjustment. In regard to this problem, sensor technology that has become ubiquitous in recent years might serve as a remedy. Mobile and wearable devices, such as smartphones and smartwatches, have various built-in sensors, for example, an accelerometer or gyroscope [14,23]. Thus, a wide range of contextual information can be made accessible to assist users. The devices not only offer the chance to collect data, but are also capable to unobtrusively provide guidance at any place [19] and remind the user of taking necessary actions.

Up to now, no integrated architecture has been proposed that incorporates various sensor data to provide users analysis and recommendations specifically for supporting their self-management. In this research in progress article, we present an architecture of a personalised and situation-aware assistance system for smart self-management. Regarding self-management at work, we focus on knowledge work. According to [5], "knowledge workers have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the creation, distribution, or application of knowledge". Therefore, working conditions for knowledge work differ from that of other work. For example, knowledge workers are often not bound to fixed working hours and locations [16]. An assistance system for smart self-management may be of particular relevance for the group of these workers as managing themselves is a substantial factor determining their productivity [7].

In the next section, our vision of smart self-management is explained in more detail. Section 3 presents the proposed architecture for the assistance system. Finally, we conclude with a discussion and outlook.

2 Smart Self-Management – The Vision

Before we introduce the constituents and architecture of our smart self-management system, we describe a vision towards smart self-management in this section. The purpose of presenting such a vision is to illustrate the envisioned integration of a smart self-management system in personal life and the possible effects of system usage independent from technology choices and constraints. In addition, the demand for assistance in self-management may be very individual. Besides the aforementioned changes in the working world, there can be a variety of other reasons motivating interest in support for enhancing self-management skills. Hence, we describe our vision in the following by adapting the notion of personas [4] in order to provide concrete descriptions. The notion of personas stems from user-centred design and is intended to explore potential preferences and expectations regarding a product by creating vivid fictional characters representing user groups. In general, multiple personas are at first described independently from interacting with the system and the focus is on making up their personal details and exploring their goals. However, in this article we use a persona mainly as an instrument to illustrate how the assistance system for self-management is envisioned to be integrated in one's daily routine and which interventions may be important. In this sense, a single fictional character directly in action with the system is described below:

Karl (48) is an independent business consultant and father. Karl has built up a satisfied customer base and has accompanied some of the customers for many years. Unfortunately, his workload is difficult to predict, because his customers spontaneously contact him with smaller jobs. Hence, it is particularly important for Karl to make the most of his time.

This Friday, his smartwatch running the smart self-management assistance system wakes him at 6 am, an hour earlier than normal. This is because the assistance system of his watch, which he uses consistently since the first signs of burnout and a sick leave last year, has recognised that Karl has enjoyed an excellent sleep quality over the last few nights, so getting up early is no problem. At the same time, the system knows that there will be a lot of traffic on the streets on Friday afternoon, so Karl should start working at 8 am to be able to return in time before the traffic jams start. He has scheduled several interviews with clients on this day. During this working day, the system rarely interrupts with notifications because it learnt that disturbances are undesirable for entries of the type *customer contact* in the appointment calendar. Against a warning from the system, Karl has scheduled four interview appointments seamlessly and even over the lunch break. As the system recognises an increased stress level and a decreased cognitive performance, it announces itself after the last appointment unremarkably with a vibration and suggests taking a break. Because the system has learned from the answers of the short weekly questionnaires that Karl can relax well during movement, it furthermore recommends going for a walk. Thereupon, Karl takes a walk through the nearby city park and eats a snack in his favourite café near the lake in the park.

After this break, Karl decides to do some desk work. So he drives home, relaxed and as planned by the system without traffic jams. Subsequently, the system recognises that Karl enters his home office and reminds him to perform an outstanding evaluation of a client's files. While Karl is still fully absorbed in his work, after 1.5 hours his assistance system makes him aware that his planned time budget for this client will soon be exhausted. He decides to write an e-mail to the client and ask him to send some missing data. On the basis of these data he will finish his already sophisticated evaluation in a short time on Monday.

Now, the system suggests Karl to play with the children or to cook for his family. Alternatively, he could now get a birthday present for his mother, who has her birthday next Wednesday, because Monday and Tuesday are already scheduled with appointments all day, as the system points out. Karl decides to prepare dinner together with his children and set the table. He plans to get the gift during Saturday shopping.

Karl's wife does not return from work until 6 pm today. With great pleasure she sees that dinner has already been prepared. Moreover, she surprises Karl with a theatre visit that evening. The grandparents will take care of the children. For the way to the theatre, the assistance system suggests going a station by tram and the rest on foot. Both enjoy the warm summer evening and Karl can now relax very well, because he has achieved his professional and private goals, also thanks to the coaching provided by his assistance system.

3 Architecture for Smart Self-Management

In order to realise the vision of a context-aware assistance system for smart self-management, the system has to be composed of various hardware components (computing devices, sensors) and software components (e.g. for data analytics and user feedback). Designing such a system is a complex and complicated task since numerous components have to be selected and composed to an integrated system. We intend to ease this design task by presenting a conceptual architecture that contains a set of elements and their relations relevant for the creation of smart self-management systems. This architecture is shown in Fig. 1. Fundamentally, the architecture has been developed by following the core idea that information systems essentially acquire or receive information, process it, and deliver relevant results to the user. Therefore, the architecture consists of three main parts: *Devices and Sensors*, *Data and Analytics* and *Feedback*. Instruments and mechanisms to collect data are shown on the left side of the architecture, while the centre shows relevant data that can be retrieved and information resulting from further analysing these data. The right part of the architecture contains the different components of system feedback generated to inform and assist the user. In the following sections, we describe the parts and components of our architecture in more detail.

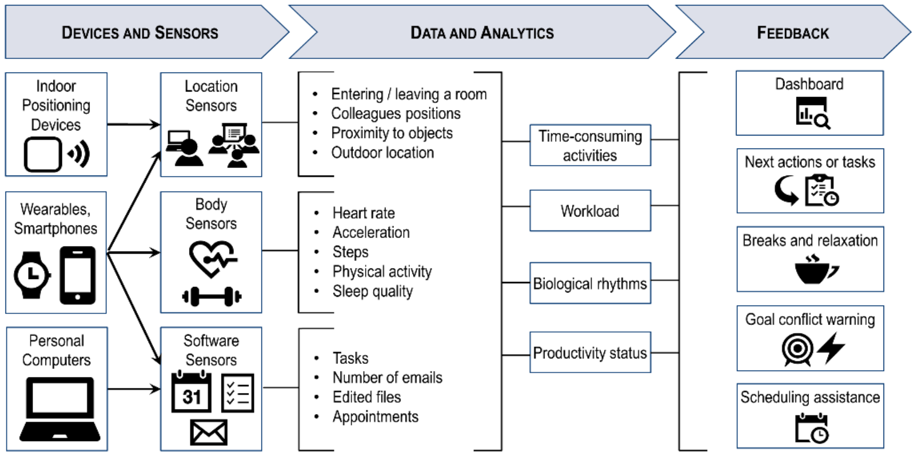

Fig. 1. Architecture for smart self-management

3.1 Devices and Sensors

To create an assistance system that can automatically adapt its interventions to individual circumstances, contextual information is required [1]. An established definition of context is provided by Dey [6], who states that "context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." As the assistance system is envisioned for everyday usage, context data needs to be collected mainly without user intervention and in an unobtrusive way, i.e. via sensors. The term "sensors" here not only means physical sensors, but any kind of technology capable to automatically sense the context of the user. We distinguish roughly between three types of sensors according to the data they record. These are *Location Sensors*, *Body Sensors* and *Software Sensors* (cf. Fig. 1, the right column of rectangles subordinated to *Devices and Sensors*). Location sensors identify the user's current position indoors (e.g. being in a specific room) or outdoors (e.g. longitude and latitude). This information is relevant since it can help to detect the current context of the user, e.g. working in the office or relaxing in a public park. Body sensors monitor a user's activity (e.g. walking) and physiological data (e.g. heart rate), which are especially important for considering wellbeing and health aspects of self-management. Software sensors are used to identify software-based work and to monitor contents related to the used application. By using these kind of information, it becomes possible to retrieve the working context, e.g. if the user currently is in a meeting, works on a document, browses for information on the web or is engaged in organising and communication.

Regardless of the sensor type, data can be collected by utilising modern off-the-shelf technology that can fulfil the sensing tasks thus helping to implement an unobtrusive as well as cost-effective sensor. In this regard, devices for collecting data are shown on the leftmost part of Fig. 1. They are grouped in *Indoor Positioning Devices*, mobile devices such as *Smartphones or Wearables* and *Personal Computers*. These devices can be used to implement various sensor types, i.e. there is an 1:n relation between devices and sensor types.

Research regarding *Indoor Positioning Devices* is still ongoing and diverse. These systems utilise, for example, Wi-Fi, Bluetooth, or ultrasonic [18]. Most technology in the field of location-awareness is focused on more or less exact position data. For assisting knowledge workers in self-management indoors we consider a user's proximity to rooms, persons, or objects as main issue rather than exact positioning. Therefore, Bluetooth Low Energy (BLE) beacons may be valuable. These hardware transmitters periodically send a signal that can be received by Bluetooth compatible devices, such as smartphones or smartwatches. The transmitted data then lead to proximity or position information. Although, extra hardware in terms of transmitters is necessary, it is possible to attach beacons to every entity relevant for self-management and to easily deploy them by using an app that recognises proximity to certain beacons. It is, for example, possible to attach one beacon to an office desk and one to a wall in a meeting room to make smart devices aware of the difference between being in one of these rooms. Thus, beacons may suit well for retrieving indoor location context for smart self-management.

Smartphones and *Wearables* such as smartwatches are devices that in particular can be integrated easily in daily life. While smartphones are already widespread, smartwatches are an emerging wearable technology with numerous features and embedded sensors [14,19]. Furthermore, as these watches are wristband-type devices, they are unobtrusive, light-weight, and do not interfere the user in daily processes. In contrast to smartphones, smartwatches deliver regular and more accurate data in respect of body sensors, because they are worn directly on the skin [23]. Since both, smartphones and smartwatches, can give feedback even in a mobile context, we propose to use them as core devices of the context-sensitive assistance system. As smartwatches typically can be coupled with a smartphone, function and load can be distributed between both devices [13]. For example, due to limited battery capacity, some of the tasks such as outdoor positioning using GPS may be delegated preferably to another mobile device such as a smartphone.

Personal Computers finally can be used to identify software-based work and to monitor contents related to used applications via an additional software running in the background that records all types of events. By using these kind of sensors it becomes possible to retrieve, for example, information from digital calendars, mailing programs, writing tools, or web browsers. At a desk-based office workplace, data can be collected from personal computers (PCs), which can be stationary or portable. In more mobile settings, information about used applications can also be recorded via a background app on the smartphone.

All the aforementioned devices are envisioned to be connected and to share information to form a large data basis. A database can be implemented using dedicated database technology, most notably time series databases (e.g. influx as on open source database). Time series data then can be analysed in an efficient way in order to provide the user feedback and assistance.

3.2 Data Analytics

In order to process the collected sensor values, data analytics capabilities are required. These capabilities are necessary to aggregate data, detect patterns, and analyse developments over time. For example, to detect the work-related stress level which is relevant for activity suggestions or even breaks, a variety of sensor data originating from different devices has to be aggregated and combined. Among these data could be heart rate, the amount of processed mails, the number of meetings per day etc. Another example would be to detect the amount of time a user dedicates to one topic. Here, various data concerning the processing of documents, related e-mails as well as visited websites have to be aggregated. Such data aggregation, combination and interpretation can be executed on different levels of abstraction. Fundamentally, we differentiate between *lower-level data analytics* and *higher-level data analytics* according to the self-management context.

In the lower-level analytics, basic pieces of information are retrieved via an Application Programming Interface (API) from raw sensor values. It should be noted here that retrieving values via APIs already implies some sort of pre-processing of the raw sensor values. This is implemented in the device as the lowest level of data processing that for our purposes of improved self-management is out of scope (in addition, it is also vendor-specific and the industry competes on how well this is implemented, making the lowest level of data processing rather non-transparent). In the process of lower-level analytics, various data spanning all sensors is retrieved, stored in a database and some simple calculations are performed such as e.g. calculating average values or min/max values for a given time span. Regarding location sensors, information on outdoor or indoor location is processed, such as the user's proximity to places, buildings, rooms, objects, or colleagues. Also, information from body sensors can be processed such as the user's heart rate, physical activity, or sleep quality. Moreover, data from software sensors can comprise contents from various used software tools ranging from writing tools through digital calendars and mailing programs to web browsers. The analysis of these contents can lead to information about, for example, assigned tasks, created appointments, number of e-mails (received or sent), or time spent on editing specific files.

In the higher-level analytics, several results of the lower-level analytics are aggregated to even more complex information associated with the self-management factors productivity, motivation, wellbeing, and health. We identified four important components of higher-level analytics. The first component is called *time-consuming activities*. It is used in order to analyse time spent on certain activities and subsequently, to identify exhausted time budgets or activities on which time may be wasted. Existing time tracking software, even leading tools like RescueTime[1], analyse time spent on used tools and websites only. They largely lack to automatically associate time-consumption to more than basic activity categories such as "creating" or "organizing" without an extensive manual configuration. Using additional sensor data such as location and time may help to improve this situation. Second and even more important, they lack to automatically monitor activities where no operations on a device are performed. By utilising the proposed lower-level information, it will become possible to even capture such activities. For example, entering a rest area or meeting room can be recognised by location sensors. Similarly, appointments in a digital calendar or physical activity can be used to identify the user's situation.

The second higher-level component is called *workload*. As a high workload in the long-term can lead to decrements in performance, motivation, wellbeing and health [12], it is important for smart self-management to observe the workload over time. A generalised workload measure could be inferred from the amount of tasks, appointments, emails, opened files, and physical activity. Furthermore, a user's cognitive workload can be estimated to regard individual reactions to demands. Current research considers, for example, how heart rate variability can be used to recognise or even predict changes in cognitive performance that are caused by mental workload [15,24].

Biological rhythms as the third analytics component considers the human's circadian rhythms that drive the patterns of cognitive, behavioural, and physiological processes. As the biological clocks influence, among others, activity, sleep, and mood, rhythm disruption can lead to consequences like reduced motivation, performance, and health [9]. In order to determine biological rhythms or their disruption, especially body sensor information like sleep and activity timings and also heart rate variability may be relevant. Furthermore, as biological rhythms could already be associated with patterns of smartphone app use [20], software sensor information from several devices on a timeline could be analysed in combination with physiological information.

The fourth higher-level component will analyse the *productivity status*. The time tracking software RescueTime presents a productivity value according to time spent on certain tools or websites. As the quality of outcome is at least as important for knowledge work as the quantity [7], considering only time spent on activities may not be sufficient to characterise knowledge workers' productivity. For example, if decreased cognitive performance is recognised, taking a break for recovery may be productive, but randomly surfing the internet when near an alertness peak may be not. Therefore, we propose to combine information from time-consuming activities, workload, and biological rhythms, to create more comprehensive measures regarding also aspects related to motivation, wellbeing, and health.

3.3 Feedback

In order to assist the user in self-management, the system has to provide transparent feedback. Different mechanisms can be used in order to support self-reflection or self-development (for an introduction to these two concepts, cf. Section 1). For the first,

[1] https://www.rescuetime.com/

we propose to present the user information delivered from data analytics in a so called *dashboard*. The information should be visualised in a way that also shows changes over time. The system is envisioned to further provide the user the opportunity to define goals related to the information presented, e.g. to work on high-leverage tasks at alertness peaks.

In order to support self-development, we propose encouraging the user to take action by providing recommendations on carrying out or omitting activities. These recommendations are intended to have preventive effects on work-related stress. To ensure transparency, the system could show an additional hint of why the certain recommendation occurs. For example, for the component called *next actions or tasks*, a next task could be chosen according to an urgent deadline or alertness peaks. Similarly, the system could intervene distracting actions. Recommendations of *breaks and relaxation* are likely to depend on workload and biological rhythms. On the one hand, the system could recommend a break, e.g. if decreased cognitive performance is predicted. On the other hand, it could intervene, e.g. if the user only forgot about time seemingly. A *goal conflict warning* would occur, if carrying out or omitting certain activities contradicts a specified goal, e.g. the user carries out a certain work longer than the self-defined goal is. The *scheduling assistance* component could extend the existing mechanisms of digital calendars that warn the user when appointments overlap to also regard workload and biological rhythms. The system could then recommend a suitable date and time according to these factors, when the user is about to plan an appointment.

Finally, feedback could be delivered by personal computers in a stationary context and by smartphones or smartwatches in a mobile context.

4 Discussion and Future Work

In this article, we first motivate why self-management is increasingly important, given the continuously growing flexibility of knowledge workers made possible by modern IT systems. We also introduce the two concepts of self-reflection and self-development, whereby the former is required for the latter and self-development in turn is required for an effective self-management. Unfortunately, self-development is hard to achieve even if the individual is successful in self-reflection. This calls for an improved IT-support. To address this issue, our research effort aims at providing an improved IT-support for knowledge-workers' self-development. In more detail, we propose a conceptual architecture for a context-aware assistance of self-management for knowledge workers. With this, we intend to provide an overview on the design space as a first step towards the construction of systems that assist self-management. Therefore, it is meant to inform and inspire the future design of concrete assistance systems. We describe how such a system could positively contribute to self-management via a set of interventions made possible by lower-level and higher-level processing of sensor data. In addition to this, theoretical implementation options of such a system are described.

It is planned to extend the proposed components for data collection in the future by integrating questionnaires that could periodically or situationally be presented to the user on a smartphone or PC. Answers from psychology questionnaires can, for example, reflect a person's experiences of positive or negative moods [21], [25]. Considering not only measured data, but also subjective appraisal will have an impact on the quality of system interventions to enhance individual self-management skills.

A prototypical implementation and subsequent evaluation of the system components is a main issue for our future work. On this basis, the implementation options could then be adjusted or extended. As a next step, the accuracy of sensor data from different sources will be observed. Physiological data from current smartwatches, for example, may be more accurate in workload monitoring for user activities with little movement than in motion [3]. If higher accuracy will be required, e.g. approaches to filter misleading data could be used [22]. Furthermore, the interplay between different devices has to be arranged and tested. In this regard, also technological questions have to be solved such as dealing with data transmission between devices and buffering data if connectivity is lost.

It may be important for users that the system can be configured according to personal preferences in order to influence system feedback. There could then be options to choose between recommendation modes ranging from reactive feedback, i.e. the system presents recommendations only on request, to proactive feedback, i.e. the system intervenes automatically. It is conceivable that the user could also specify times, where proactive recommendations are undesired, or that a vacation mode can be chosen. Furthermore, machine learning algorithms could be utilised to let the system learn from user reactions to certain recommendations. As a result, the system could adjust, for example, the frequency of recommendations. User preferences and opinions are, however, subject to separate further research efforts that we are actively pursuing.

From the above future research options and plans, it should become evident that developing such as system is not a one-shot short-term research activity. It is rather a process of research spanning multiple years that we want to share and discuss with the research community. With the proposed architecture, we provide the first contribution on this new avenue of research. It is envisioned to lead to self-management assistance systems that encourage people to work smarter and to excel in self-development. Among the most important merits that we envision with such a system is that time shall be gained by systematically organising and shaping life in order to maintain and promote balance in life.

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