# Wearable Technology as a Booster of Clinical Care

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## ABSTRACT

Wearable technology defines a new class of smart devices that are accessories or clothing equipped with computational power and sensors, like Google Glass. In this work, we propose a novel concept for supporting everyday clinical pathways with wearable technology. In contrast to most prior work, we are not focusing on the omnipresent screen to display patient information or images, but are trying to maintain existing workflows. To achieve this, our system supports clinical staff as a documenting observer, only intervening adequately if problems are detected. Using the example of medication preparation and administration, a task known to be prone to errors, we demonstrate the full potential of the new devices. Patient and medication identifier are captured with the built-in camera, and the information is send to a transaction server. The server communicates with the hospital information system to obtain patient records and medication information. The system then analyses the new medication for possible side-effects and interactions with already administered drugs. The result is sent to the device while encapsulating all sensitive information respecting data security and privacy. The user only sees a traffic light style encoded feedback to avoid distraction. The server can reduce documentation efforts and reports in real-time on possible problems during medication preparation or administration. In conclusion, we designed a secure system around three basic principles with many applications in everyday clinical work: (i) interaction and distraction is kept as low as possible; (ii) no patient data is displayed; and (iii) device is pure observer, not part of the workflow. By reducing errors and documentation burden, our approach has the capability to boost clinical care.

**Keywords:** Clinical pathway, Wearable technology, Goggle Glass, Medication documentation, Medical care

## 1. INTRODUCTION

In recent years, medical advances have made the impossible possible and we are nowadays able to diagnose and cure diseases with tools ranging from specially designed molecules to lasers. Nonetheless, many aspects in everyday clinical care still lack improvement and are prone to many errors[2]. With upcoming tools like Google Glass, which have the potential to shift current technology from a stationary or handheld device to wearable technology, medicine is anticipating another revolution in devices and procedures. This new technology will allow users to constantly interact with medical software to make more informed choices, ease documentation hassle and get instantaneous feedback. Overall, this will be a major boost to clinical care. New bodywear information technologies are increasingly available. Industry has already identified the healthcare sector as an important field of application. For example, Qualcomm and Palomar Health recently launched a glassware medical incubator named Glassomics to explore potential usages of wearable technology in the medical environment[2].

However, most concepts are mere adaptations of existing applications and ideas to the new format. Concepts making full use of the potential of the new information technology have not yet been reported, and such devices have not yet been integrated, neither in picture archiving and communication systems (PACS) nor in any other information system like the radiological information system (RIS). Most current work is focused on wearable technology in the context of improvement of rehabilitation and remote health monitoring[3,4].

In clinical care, the highest potential is seen in the omnipresent screen that can be used to access patient or general medical information everywhere (e.g., vital sign monitor, medical lexica, clinical education)[5]. However, no scientific work exists so far, that has actually made use of the next generation of wearable technology, like Google Glass. Only one medical app for Google Glass has been made publicly available. This app is made for home-use and supports the user during the reanimation procedure[6].

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Medical Imaging 2014: PACS and Imaging Informatics: Next Generation and Innovations,
edited by Maria Y. Law, Tessa S. Cook, Proc. of SPIE Vol. 9039, 90390F · © 2014 SPIE
CCC code: 1605-7422/14/$18 · doi: 10.1117/12.2042986

A key task in the medical sector is medication prescription, preparation and administration. Studies have shown that errors occurred in up to almost 50% of intravenous medication preparations and administrations[1] with one of the biggest problems being the preparation of drugs that require multiple steps. Additionally, dosage is often a problem and life threatening overdoses have been observed in 0.5 % of the cases. Medication preparation and administration is therefore a good example of a clinical workflow and well worth improving. Furthermore, computer based decision support for medication has matured in the last decade especially in the context of computerized provider order entry (CPOE)[12].

Here, we propose a novel approach to use wearable technology for the improvement of medication administration. One challenging aspect of the proposed integration of wearable technology into existing workflows is the reliable detection of the current task performed by the wearer. Research results focus on that problem for more than a decade and present promising approaches for sensor-based activity recognition[7,8]. Early adoptions of wearable technology in the clinic already detect specific activities of all-day work and, thus, provide positive indications for feasibility[9,10,11].

## 2. METHODS

We propose a concept to improve clinical workflows like medication preparation and administration by using wearable technology. Our software will be integrated with existing IT-infrastructure like hospital information systems and drug databases.

### 2.1 Clinical workflow example: medication preparation and administration

This work will focus on medication preparation and administration as a use-case of our proposed method of clinical workflow support. For simplicity reasons, medication preparation and administration will be reduced to three steps, but an extension to a multistep process is evidently possible. The three steps are:

1. Patient identification and prescription lookup. In this step, the nurse normally uses the patient record to look up prescribed medication.
2. Medication preparation. In this step, the prescribed drug is prepared, for example, by loading the drug into a syringe, diluting it or by counting tablets.
3. Medication administration. In this step, the nurse is either handing the mediation to the patient or administering it directly.

### 2.2 Wearable technology

This work is focused on the use of camera-based wearable technology such as Google Glass (Fig. 1.A) and Samsung Galaxy Gear (Fig. 1.B). These novel devices provide all basic features needed to be seamlessly integrated into everyday workflows in a clinical environment. Google Glass and Galaxy Gear are microcomputers that have features similar to those of modern smartphone. Google Glass provides a build-in front-facing camera and the head-up display. The Galaxy Gear has both camera and display located on the watch. Both feature connectivity (usually through a bluetooth-tethered smartphone) and moderate processing power. Our application enables the device to identify the patient, medication and dose rate. The device reports this data to a central server and receives and displays feedback concerning the agreement with the patient prescription and possible interactions with other administered or prescribed drugs.

### 2.3 Workflow integration and support

The interfaces mirror the current workflow. Additionally, our software operates within existing environments hiding the hospital information system (HIS) behind a workflow transaction server (e.g., rule engine or workflow engine). The server is responsible for collecting information from the user and the HIS to provide the user with feedback on his current action.

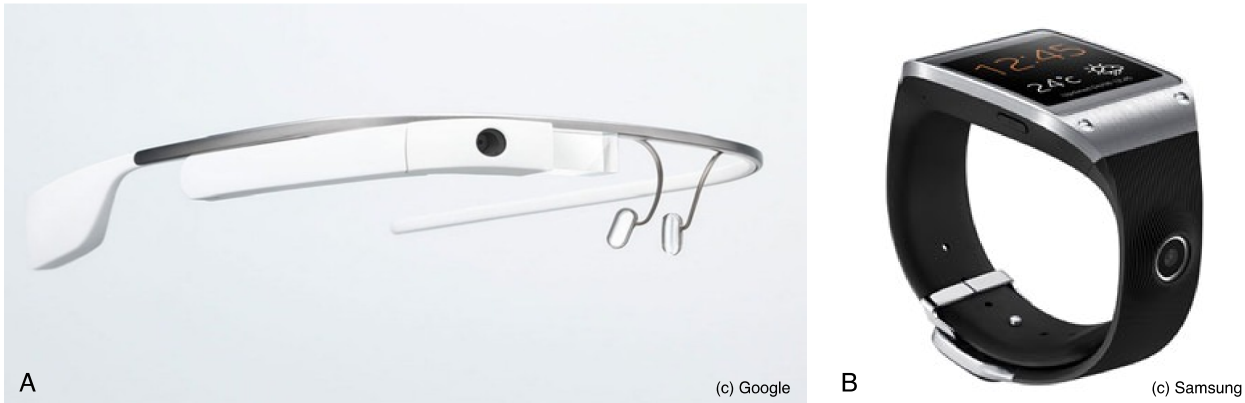


Figure 1. Examples for new types of wearable technology: Google Glass (A) and Samsung Galaxy Gear (B).

### 2.4 Prototype development

A prototype was developed based on the previously described properties (Fig. 2). The prototype client software uses the built-in camera to automatically detect barcodes in the current field of view. QR-codes are used in the prototype application, as they are easy to create and process. However, almost any kind of barcode can be adopted. The barcodes encode identifiers of the patient and the medication, respectively. The identifiers consist of a leading letter (P for patient and M for medication), and a trailing unique number. As soon as both a patient and medication number have been detected, a request is send to the transaction server. The transaction server uses lookup tables to load patient and medication information. As a complete reasoning of medication interactions has not been implemented for the prototype, blacklists and whitelists of medication have been created for each patient. The server uses the identified patient and medication information to check for violations or prescriptions on the patient-specific lists. A feedback in traffic light style is send back to the user:

- Red: A violation or contraindication has been detected. Medication is not permitted.
- Yellow: Neither prescription nor contraindication was found. Medication should be reassured with a medical doctor.
- Green: Drug is marked as prescribed in the system and no contraindication exists. Medication is allowed.

The procedure can readily be extended to support more complex states, for example, overdose or contraindications based on patient data. In this prototype, the server-workflow is visualized along with patient and medication name. These parameters are only shown for visualization reasons and will be omitted in production systems.

### 2.5 Automated documentation

An additional part of the proposed system is automated documentation of detected tasks. Since the proposed system does not accept direct interaction between the user and the system is rather an observer, actions have to be documented in two steps. In the first step, the wearable device detects the ongoing action and submits a request to the server. The server analyses and evaluates the ongoing action. At this point, the detected action along with the server's conclusion on validity is stored in a documentation database as a detected event. However, detection does not imply completion of the action. Therefore, in a second phase, the user has to go through all detected actions and confirm those completed versus those aborted. This makes the system more robust and adds an additional verification step. While this takes up some time, it is still faster than having to enter dosage, date and patient individually.

## 3. RESULTS

For each of the steps of the medical workflow, device interaction is needed (Fig. 3). Two of these interactions consist of looking at barcodes that already exist today. First, the patient identification is performed by reading the patient ID from a barcode on the printed patient record. Second, the medication itself including dose information is retrieved by reading the barcode printed on the medication package during the preparation step. Both interactions do not intervene with the

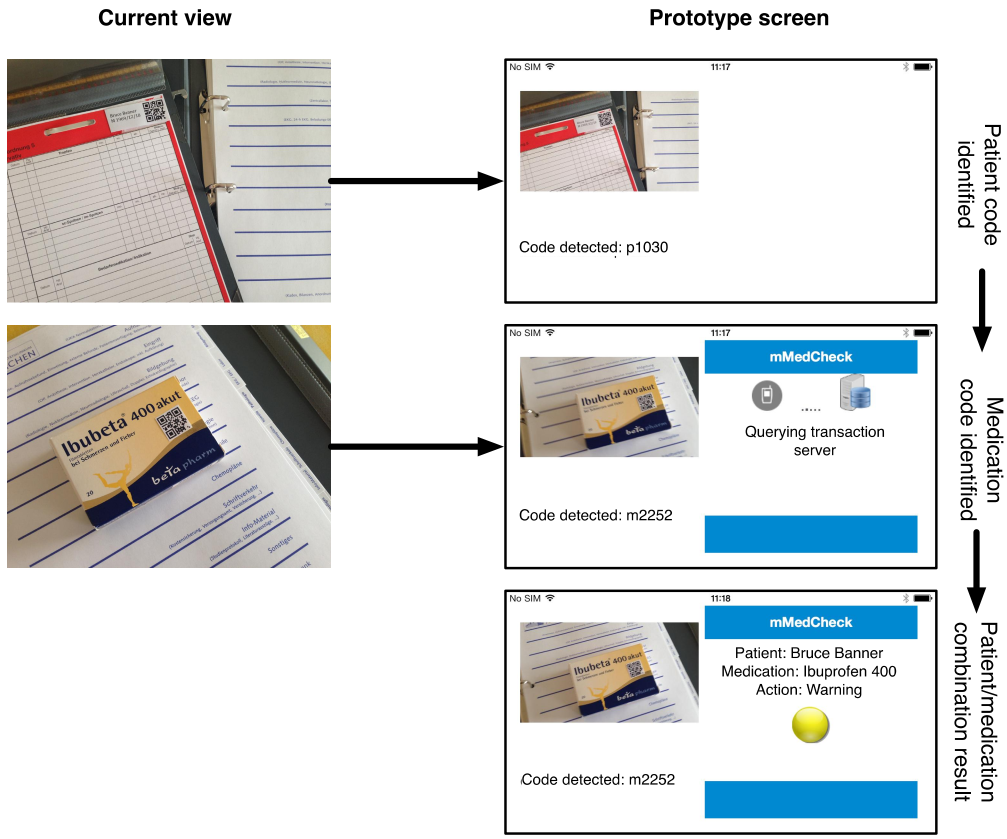


Figure 2. Sample workflow of medication performed with current prototype. On detection of both a patient and medication code, a query is submitted to the transaction server and a color-coded result is returned.

regular lookup of patient information and prescribed medication. Audiovisual feedback is presented upon successful scanning of a barcode. Immediately after having received both patient and medication information, the workflow transaction server checks the medication knowledge base for violations. If any violations are found, an alarm signal represented in traffic light style is displayed to the user: green means no violation; yellow means mild violation (e.g., possible overdosage); and red means critical violation (e.g., life-threatening overdose or inadvertent interactions with other medication). Detailed warning information can either be displayed directly on the Google Glass, or on a computer in the nursing station.

In a last step, a documentation of the action is submitted to the HIS in real time for further review, creating a record of possible medication administration. The documentation has to be verified by the clinical staff at a later point. The reapplication of the same medication leads to an adequate warning of the system.

## 4. DISCUSSION

In this paper, we propose seamless integration of cutting-edge technology into the clinical workflow. We aim at supporting existing workflows instead of creating new instances or trying to change them. By using wearable technology as a virtual "emergency brake" that is only intervening if errors occur but otherwise not challenging or interrupting existing and well-thought-of workflows, we aim to gain wide acceptance while making a contribution to everyday tasks.

Results of first investigations and requirement analysis show demand for improving decision quality and support of clinical routine work and its documentation. Reduction of errors in operational procedures like medication preparation and administration is needed as well as consistent documentation. Meanwhile, there is no need for a system that reorganizes all the operating processes of a hospital. Most hospital processes are already highly optimized and efficient.

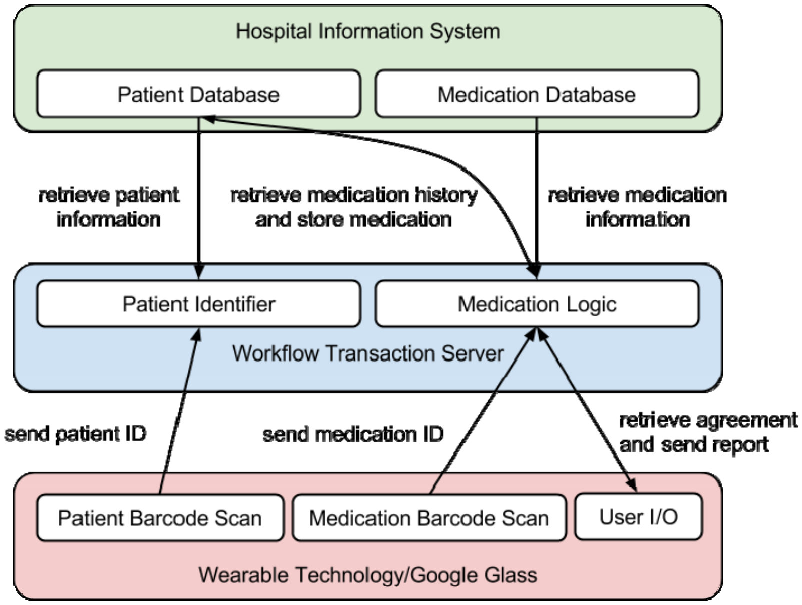


Figure 3. Workflow integration of wearable technology and transaction server into the current hospital information system. The arrows represent the data flow.

The approach proposed in this work qualifies as a possible way to improve existing workflows while not demanding a change of current procedures but supporting without interfering. It offers a hands-free form of communication by voice or gesture control, which has the advantage of reducing the risk of infection by touching keyboards or other electronic equipment while still being able to document medical processes.

The workflow integration including the user interface has been designed following the basic principle to be as simple as possible and avoid distractions of the user. Additionally, one important aspect in a clinical setting, especially when utilizing a device with a built-in and always active camera, is confidentiality and privacy. The workflow integration allows for a minimal exchange of patient information between the wearable device and the workflow transaction server. Thus, personal data is never transmitted through WiFi. No images or video data are send to the system and no patient information is exchanged with the device except for the patient ID.

An initial implementation of the proposed software design has shown feasibility of barcodes (here, QR-codes) for the detection of both patient and medication. However, position and orientation of the camera as well as resolution issues have to be further investigated.

In contrast to other methods, we did not aim for high-tech visualization of information or decision support, but to improve error-prone everyday tasks and automatically document procedures in real-time. We focused on three basic principles to achieve this goal: (i) interaction and distraction is kept as low as possible; (ii) no patient data is displayed; and (iii) the device acts as pure observer and is not part of the workflow. Therefore, the proposed method has the potential to change medicine from a document-driven environment back to patient-centered procedures.

Limitations of the given design are acceptance and compliance by both the hospital staff as well as patients due to possible privacy issues. However, if the patient is informed carefully about system's not storing any images and never receiving any patient information, these issues might be overcome. Additionally, a possible lack of acceptance may result from the fact that the patients are not able to verify the measures taken to protect privacy, while observing a running webcam pointed to them. This issue needs to be addressed by getting the patient's informed consent before using the device. Another limitation is the obligatory access to WiFi, which is not granted in all stations due to interference with medical equipment. In such areas, transmission by bluetooth protocol can provide a way out, which is known to not cause interference but has the drawback of limited range. Concerning the service provided by the system (medication alerts following a watch-dog metaphor) the issues of over-alerting and alert fatigue are known from the CPOE literature and have to be carefully addressed[13].

Further investigations will focus on the application of the proposed method to more complex procedures and workflows, improving security through hands-free login/-out techniques, and analysis of gesture recognition versus other means of hands-free user interactions suitable for medical applications. Socio-technical studies need to investigate the possible changes of behavior induced by the system: Getting used to the feedback of the device could for instance lead to overconfidence and a reduced vigilance of the medical staff, which could provoke serious complications in case of unnoticed system failures. Additionally, the issue of long-term system verification and validation in a realistic context needs to be solved.

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