

SUPPORTING NURSING CARE ASSESSMENT PROTOCOLS WITH SMARTPHONES

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Abstract: Technological advances in mobile phones make them appealing to support nursing care at the point of treatment, especially by combining the easy-of-use, mobility and wireless communications. Novel capabilities, such as picture capturing, enlarge the applications scope. In this work, we present the HOPE system to facilitate nursing care documentation, by leveraging on standard off-the-shelf mobile phones. The proposed system moves a substantial part of the work usually deferred and performed at desktop computers to the moment and place of care. In addition, health professionals can document the clinical cases with photos, using the mobile phone built-in camera, which is being applied in diabetic foot consultation. Basic support for wound measurement is available. The information acquired is integrated in the patient's Electronic Health Record and can be shared using the mobile devices or the workstations. The proposed system is in pilot use at two Portuguese hospitals targeting inpatient care and diabetic foot consulting.

1 INTRODUCTION

Care provision includes a significant amount of effort on effective documentation of patient conditions and performed actions. In nursing care, documentation time is estimated to surpass half of the nurse's activities (Kossman and Scheidenhelm, 2008). The introduction of Electronic Health Records (EHR) (Häyrinen et al., 2008) including the nursing domain, led professionals, in many cases, to defer the documentation activities, since the available information systems are not well adjusted to be used at the bed side (Stevenson et al., 2010); (Andersen et al., 2009).

An emergent paradigm is the use of handheld computers to support nursing care planning and recording (Garrett and Klein, 2008); (Lu et al., 2005). These devices meet the mobility requirements of the practice and their integration with organization wide information systems can raise the efficiency of nursing care documentation (Lu et al., 2005).

The convergence of handheld computers (or Personal Digital Assistants) and mobile phone features in the same devices originated the nowadays popular *smartphone* concept. As a consequence,

there's a mass expansion of the familiarity with *smartphones* operation and significant decrease on devices cost. This trend extends the opportunities to use modern *smartphones* in nursing care and telemedicine (Istepanian et al., 2006); (Ebner et al., 2008). The combination of intrinsic support for mobility, rich and intuitive user interfaces, and wireless communications provide sound arguments for their introduction in care settings, if articulated with the existent "ecosystem" of health information systems.

Mobile devices are being used to take pictures of wounds and skin lesion to document clinical cases. Such approaches can be found in teledermatology projects (Ebner et al., 2008); (Pirris et al., 2010). Nurses are also aware of its potential (Berglund et al., 2007) but implementations are still lacking.

In this work, we present the HOPE system, which uses *smartphones* to help nursing care recording at the point of care. The *smartphones* are not expected to replace the existing desktop-based solutions, but act as a practical first line or recording that can be performed at patient side. In addition, the *smartphone's* built-in camera is also used to capture images of lesions, allowing for skin integrity monitoring of inpatients and to monitor diabetic foot

lesions.

The motivating context for this work arose from the nursing practice at Hospital São Sebastião (HSS), located in Feira, Portugal. Presently, the system has been also in pilot used at a second Hospital (Hospital Infante Dom Pedro, Aveiro, Portugal).

2 METHODS

2.1 Workflow 1: Patient Assessment Protocol

The HSS hospital uses a comprehensive EHR, which includes the nursing record too. The system provides support for hundreds of data fields to follow inpatient nursing care. The patient assessment protocol, in particular, includes over 120 data fields, from more subjective information, like social context and habits, to more objective details, such as biosignals, pain scales and wounds characteristics. The assessment stage is performed each day (not necessarily altogether) in the presence of the patient, but the nursing staff opts to defer recording activities to a later stage, and use paper notes as a memory helper. This is justified by the absence of mobile interfaces and the complexity of the desktop system.

In this context, the Health-On-Palm Environment (HOPE) system has been proposed to facilitate patients' assessment routines by nurses. The objective of HOPE is not to replace the existing and comprehensive desktop system, but to move a subset of those recording needs to the nurses' *smartphone*.

The careful selection of which segments of the nursing evaluation protocol were to be supported in the mobile device became a critical success factor. This definition has been achieved over multiple interactions with domain experts, to avoid system rejection due to insufficient involvement of domain users (Stevenson et al., 2010).

Using the HOPE system, the nurse starts by authenticate himself on the mobile device (Fig. 1).

Patient details can then be easily retrieved from the Hospital-wide EHR by entering the record number on the device or by reading it from a bar code (often available in stickers and bracelets) using the built-in camera. The previous assessment context is retrieved and can be accessed in the *smartphone*. The nurse will then complete the assessment protocol, going through a wizard-like interaction (Fig. 2). Errors in data entry (e.g.: inconsistent values) are immediately revealed by changing field colours. At any point, the data collected can be

uploaded to the central servers using the device wireless networking capabilities.

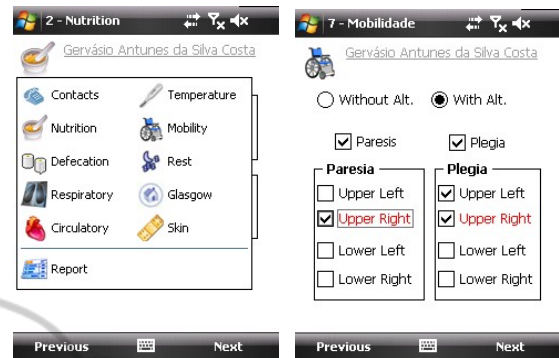


Figure 1: Views on the step-by-step assessment protocol. Left: steps to be completed. Right: signaling error with color feedback.

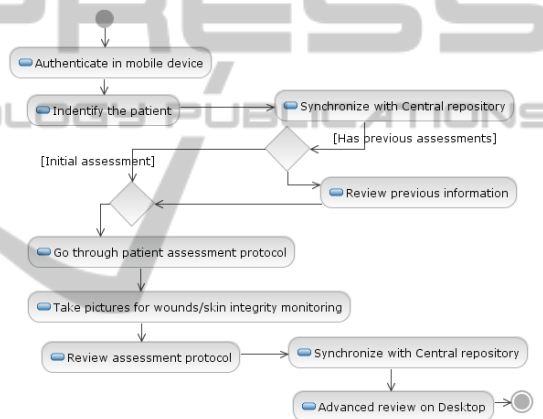


Figure 2: Nursing assessment protocol executed in the HOPE mobile system.

2.2 Workflow 2: Diabetic Foot Protocol

The HOPE application enables the use of the built-in camera in the diabetic foot consultation. The patient will initially receive treatment at a primary care facility but, if suffering from severe conditions, s/he will be referred to secondary care provider (Hospital). After the patient acute conditions have been stabilized, s/he will be followed at the primary care again (Fig. 3).

Wounds related to the diabetic foot condition take a long time to heal, usually spanning for several months. During this time, the wound evolution can be hard to monitor without a visual record, due to the time span and the number of care professionals involved (different teams and service points). Note that wound assessment is being conducted at each care organization, but little information is usually shared, especially with respect to multimedia types.

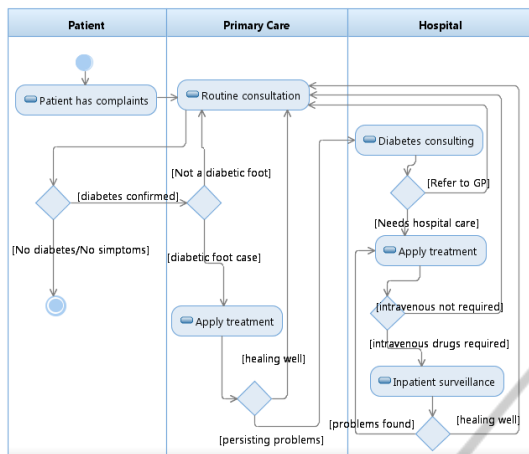


Figure 3: Diabetic foot distributed care workflow.

This clinical case brings a complying need for visual evidence that can be supported by *smartphones*. In addition, it requires a distributed, collaborative workflow, which gave us the opportunity to integrate the mobile application in the more comprehensive Regional Health Network (Oliveira et al., 2011).

2.3 Mobile Usability Requirements

The acceptance of mobile devices in care practice is heavily connected to the practicability and user-friendliness of the solutions (Stevenson et al., 2010); (Andersen et al., 2009). Factors such as the small screens size, tolerance to wireless network availability and energy-aware applications become essential requirements in software conception. In this sense, the following design options have shown to play a significant role on HOPE acceptance:

- Elimination of free text fields. Data entry is based on values selected from close lists (Fig. 2). When and if a note taking approach is necessary then the nurse has the ability to record an audio note (and later transcribe it to the desktop system).
- Prompt visual field validation. Extensible field validation is implemented to ensure robust data entry. Inconsistencies in fields (e.g.: values out of range) are visual marked by changed the field background colour, a much less intrusive alarm than popping message boxes (Fig. 2).
- Automatic persistence and recovery. The nurse's work is being continuously persisted and can be recalled at any point, especially in case of battery failure.
- Full support for on-line and off-line operation. Although some features can only be completed in

the presence of network connectivity (e.g.: submit the patient assessment), the overall operation is available in off-line mode. Besides being battery-savvy, this approach is required to tolerate the intermittence of wireless coverage along the Hospital.

- Touch-based interactions. User interfaces were optimized for stylus-less operations, allowing the use of a finger as the main pointing and data entry "device".
- Non-blocking operations. Potential lengthy operations, such as data synchronization with the central node, use non-blocking calls (multi-threaded) avoiding the nurse to wait for the device to continue the work.

2.4 System Architecture

The HOPE mobile application is implemented in Windows Mobile and Android *smartphones* for data recording and image acquisition. These are native applications, programmed from the scratch for each target platform with the standard SDK. The mobile device is also used for local visualization (to access previously entered information).

Besides the mobile application module, the HOPE system relies on a Central node for collecting the uploaded information and acting as a proxy to the several Hospital Information systems. The Central node includes the following modules: the HOPE repository, Integration Services and the Web application.

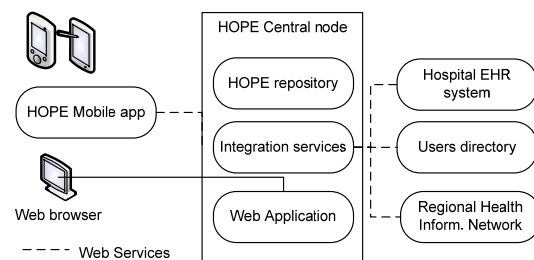


Figure 4: Modular system architecture.

The Repository holds the database specific to support the HOPE workflows, like persisting the wounds images. The Integration Services dialog with the surrounding enterprise systems, namely to authenticate nurses against the organization reference Directory system and to retrieval patient demographics. Integration services also handle the interaction with the Regional Health Information Network for the diabetic foot distributed workflow, acting as a provider for the wounds information, and

a consumer, for patient and professionals identification.

The Web Application module extends the mobile device capabilities, providing helper tools to analyze the captured images and a friendly environment to explore wounds information in the diabetic consulting (Fig. 4).

The interaction between the *smartphone* and the central module is based in standard Web Services which allows several *smartphone* operating systems to be used. The interaction between the Central node and the Hospital Information Systems and the Regional Information Network is also based on the Web Services stack.

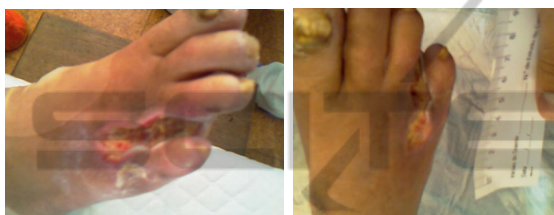


Figure 5: Diabetic foot wounds images captured with the *smartphone* (for the same patient) in two different consultations.

2.5 Pictures Use in Skin Integrity Monitoring

HOPE support to carry skin integrity and wounds monitoring is included in two stages:

1) At the point of care, the nurse can take several pictures of the region of interest which will be associated with a particular patient and assessment event. The nurse can do a basic review, for example, to reject unsatisfactory photos. The body area being considered is marked on the full body map, facilitating an overview of the existence of photos, if any (Fig. 6). Pictures from several assessment moments (e.g.: several days) will be available for visualization in the *smartphone* as in the desktop (web module).

2) Additional features are available outside the *smartphone*, once the data has been synchronized with the Central node. A web-based application (HOPEweb) will allow the nurse to do basic measurements and picture annotation (Fig. 7).

The measuring method in use does not require any special hardware nor imposes picture acquisition constraints. In fact, it is meant to work with of the shelf mobile phones and tolerate variability in picture quality standards. The nurse will place a reference object in the same plan of the wound and

take a picture of these two elements with the smart phone camera orthogonally aligned. Afterwards, in the web module, the nurse or other professional will identify the reference object and the system will calculate measurements and areas of wounds based on its size. The goal is not to supply a full wound measurement solution, like in (Bowling et al., 2009), but basic support for nursing care, in which the user has to delimitate the areas of interest interactively.

2.6 Security Issues

The storage of EHR in mobile devices raises concerns on patient data security and privacy (Lu et al., 2005). In this context, the HOPE system is not used for storing clinical data, except for the period while the data has been recorded but not yet uploaded.

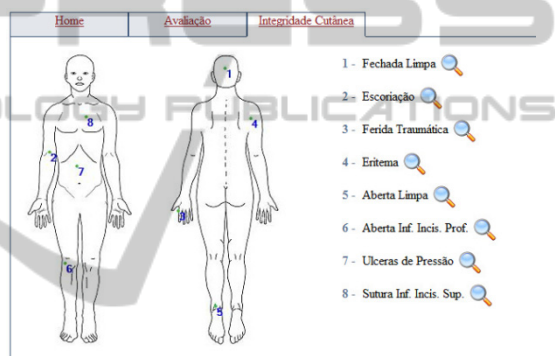


Figure 6: Overview of the body locations documented with photos (text labels indicate the type of wound being signaled). Similar maps are used in the mobile device and web application (the later being displayed).

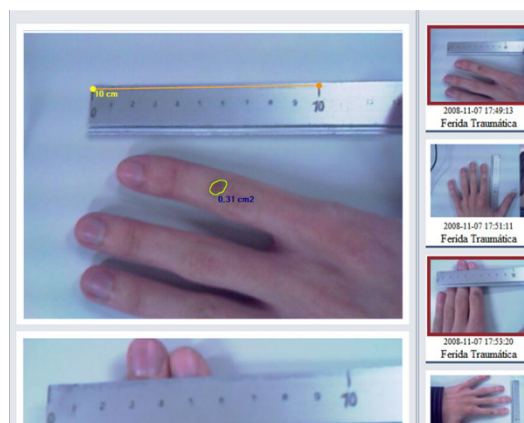


Figure 7: Wound measurement support using a reference object and interactive user delimitation of areas. Pictures can be organized in series for easy comparison.

HOPE uses the device memory card as the

primary storage device (although it can operate without it). This may support scenarios towards the individual assignment of storage tokens (memory cards) to staff members. The physical association between professionals and storage tokens may help on raising users' confidence, especially for settings in which the smart phone itself can be shared among professionals. Note, however, that separation of user contexts is already implemented by Access Control Lists associated to nurses' logins.

3 RESULTS

The HOPE system has been deployed in two Hospitals, in Portugal. In each Hospital, a pilot users group was formed, with volunteer nurses. Although at an early stage of introduction, it was possible to validate the entire workflow, including the integration with the external Hospital-wide information systems (different at each organization). For this validation, a group of twelve nurses from medical awards is being involved in pilot used. The nurses are asked to use the mobile application to search for a patient, collect the answers to a short clinical interview and document skin lesions with photos. In the present stage, nurses' feedback is being collected by a key domain user, which is a nurse which received extensive train on the application; he supports his peers and informally collects usage feedback. A more formal and extensive assessment is required, and structured questionnaires will follow.

Preliminary observation of execution times doesn't reveal relevant speed-ups in care documentation activities using HOPE. Other benefits, however, have been perceived and reported by the pilot users. The ability to browse previous information and to record the nursing protocols at the point of care (by the patient) is referred as the main benefit of the system. The HOPE solution was found to provide a more practical user interaction and bears the potential to reduce documentation omissions induced by deferring data entry.

The pilot use of the skin integrity monitoring in HOPE has raised the awareness of this kind of tool for clinical applications in both Hospitals. The specific case of diabetic foot monitoring with a regional scope is being piloted. (Fig. 5).

Work in progress includes collecting further evidence that HOPE can provide a safer and more productive environment for nursing care, besides the existing pilot users group.

4 CONCLUSIONS

The HOPE system has successfully introduced off-the shelf *smartphones* in nursing practice. A key issue towards system acceptance was the careful selection of the subset of the information to be supported in the device, along the synchronization with Hospital central systems, including the patient EHR. The novel use of the built-in camera allows for skin integrity monitoring along several days for inpatients, establishing basic tools for wounds evolution assessment.

Besides the use of the HOPE system for inpatient nursing care, the system is being used also in multi-institution nursing protocols, such as the diabetic foot, for longitudinal documentation of wounds assessment.

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