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Evidence-Based Mobile Wound Application to Support Professionals in State-of-the-Art Chronic Wound Treatment

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Abstract. Background: One of the most important tasks within wound management and the basis of successful wound care is a clear and accurate nursing documentation which can be created in various ways. However, this documentation is only partially standardized mainly due to the interdisciplinarity of this task. Objectives: The goal is to overcome interdisciplinary boundaries in home care between health professionals, and to increase the patient's motivation to actively participate in wound healing by providing consistent structure and guidance. In this paper, the development of a mobile wound documentation application is described. Methods: Comprehensive literature reviews were conducted on state-of-the-art wound documentation as well as on machine learning frameworks, databases and mobile app development technologies. Results: As a result, a mobile wound application with Flutter, SQLite and Tensorflow Lite was developed. During the development process interoperability was considered to enable future extensibility. Conclusion: Further development in respect of backend and API is planned, involving user field tests.

Keywords. mHealth [L01.178.847.652], Mobile Applications [L01.224.900.685], Home Care Services [N02.421.143.524], Documentation [L01.453.245], Wounds and Injuries [C26]

1. Introduction

The management of chronic wounds is a challenge worldwide. Pressure ulcers, venous and arterial ulcers and diabetic ulcers, which constitute most common chronic wounds are a significant burden to patients as well as to health care providers [1]. The Wound Report 2015 shows that 250,000 Austrians are affected by chronic wounds, of which only 15% are adequately cared for [2]. One of the most important tasks within wound management and the basis of successful wound care is a clear and accurate nursing documentation. There are several essential factors that must be assessed, e.g., patient's medical history or size and localization of the wound. Nurses are accustomed to performing wound assessment with the help of various tools, which include different sets

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of information. As a matter of fact, this situation shows that the documentation process is only partially standardized. The process of gathering information includes several parameters, which can be collected in various ways. Pen and paper documentation comes up against ambitious methods for measuring wounds, including cameras that provide 3D images of the wound bed [3]. The combination of both, the bedside assessment of wound images and information gathered for wound history appears optimal [4]. Moreover, accurate documentation is time-consuming, so it would be a relief if wound care assessments would combine mentioned requirements. Documentation of wounds should assist with improved details about required parameters like the current condition of the wound. The possibility to provide guidance with wound care product selection, wound care services and standardized wound photo documentation is requested [4].

1.1. User Groups and Context

A big challenge in wound care is the involvement of many different kinds of medical professionals in the overall care process, ranging from home care nurses and physicians to physiotherapists and other medical specialists. The lack of unified services aimed at addressing the complex needs of patients with wounds is an ongoing issue, while at the same time interprofessional collaboration is crucial to providing the best patient care [5].

The main objective of this mobile wound application is to overcome interdisciplinary boundaries between health professionals, and to increase the patient's motivation to actively participate in wound healing by providing consistent structure and guidance.

The user group of the final product will mainly focus on medical professionals who are significantly involved in the care of chronical wounds such as nursing staff, especially in the field of home care, physicians, and physiotherapists. In addition, optional features intended for patients and their relatives will be evaluated.

Currently, there are already several apps on the market that are intended to support caregivers and nursing staff in the care of patients. Although existing apps provide many useful functionalities, they only fulfill parts of the needs requested by wound care professionals. Therefore, these existing solutions needed to be evaluated.

2. Methods

Firstly, a comprehensive literature review was carried out by scanning scientific databases (e.g., Medline/PubMed, CINAHL, Cochrane Library) with the keywords “wound documentation”, “wound assessment”, “standard”, “guideline” and “chronic wound” in German and English language. Due to scientific relevance, outdated papers published before 2010 or dealing with wound treatment of children were excluded within the scanning process. This scanning phase delivered 415 publications. These publications were screened, and 17 studies were selected for their relevance.

Additionally, a market analysis of existing wound applications was performed.

Moreover, literature research on state-of-the-art machine learning frameworks, mobile software development technologies as well as database types was carried out and a final selection was chosen according to the fulfillment of previously identified requirements. Finally, 3 qualitative interviews with experts in wound care management were carried out.

Data from the literature research and interviews were aggregated to identify requirements for a standardized method. This approach formed the basis for the mobile app development.

3. Results

The following chapter includes the results, where the market analysis, identified requirements, the architectural overview, interoperability aspects as well as database and data structure design are described in more detail.

3.1. State-of-the-art Wound Care Solutions

Currently, there are already several apps on the market that are intended to support caregivers and nursing staff in the care of patients. These are listed in **Table 1**. Although existing apps provide many useful functionalities, they only fulfill parts of the needs requested by wound care professionals.

Table 1. Overview of apps and tools. Currently available solutions to support wound treatment and documentation, including their functionalities and platform availability according to the market analysis.

Product (Platform)	Functionalities
WCaSol /PATIDOK [6]	Selection of affected **body areas**; **Documentation** of **wound photos**, wound **parameters** and **pain** scale; Wound **classification**; trigger **ToDo's for nursing**
Wunddokumentation WTM App (Windows) [7]	**Documentation of wounds** and their progression
eKare (iOS) [8]	Offers **3D wound measurement**, **tissue classification** and **automatic visualisation of wound edges**, documentation, reporting
WUND APP (Android, iOS) [9]	For patients to prepare themselves for medical appointments; reflect on and **record of wound data** and **quality of life**
Wound Desk (Android, iOS) [10]	Semi-automatic **wound measurement** and **recording of wound assessment**; **Analysis of wound area** and severity; **Recording of the treatment** method
iWundpflege (iOS) [11]	Specific **product suggestions** for cleaning, dressing and covering of wounds; **specific therapy recommendations**, background information on treatment methods
iDokument (Web Application, iPad) [12]	**Photographing and automatically measuring the wound** with the integrated iPad camera **Wound and pain localisation** on a virtual patient body; **Documentation** through selection menus, graphics and stored scales; also **offline** available
Wound care buddy App (Android, iOS) [13]	**Wound documentation** with product information and tips; with SilhouetteStar™ (separate camera) also 3D photo and measurement
Wound Central (Android, iOS) [14]	**Image library** for wound care; Step-by-step **instruction videos; Anatomical reference guides; Keyword search** function; information on any type of wound
Wound Smart (Android, iOS) [15]	**Documentation of wound** parameters; details for wound characteristics
Mobile Wound Care 2.0 (Android) [16]	**Automated wound measurements; Recording and documentation of photos;** Availability of **diagrams for analysis**
Wound Zoom (Windows, Android, iOS) [17]	**3D representation of the wound**; **tissue classification**; exact **measurement of the wound edges; Documentation**

3.2. Requirement analysis

To fulfill the interdisciplinary aspect and enhance benefit of the app, a comprehensive two-step-approach requirement analysis was performed before the app development started. As a first step, expert interviews were carried out with the main stakeholders involved in the wound treatment process in primary/ambulatory care. Fields of experts included nursing care, health care supplies industry (medical products for wound treatment) and physiotherapists. In a next step, requirements of medical experts were clustered according to IEEE software requirements [18] (see **Table 2**). All identified user requirements were translated to technical requirements (to prepare a technical setup) and research was conducted to identify suitable technologies for the app implementation, on-device-wound-segmentation and selection of a suitable database.

Table 2. Overview of user requirements. Requirements were identified during expert interviews and were clustered according to categories. The main identified requirements are listed within this table.

Requirement	MUST HAVE	SHALL	CAN
Functional Requirements	**surveys** (patient reported outcomes, quality of life aspects), **anamnesis** (medical history, case history, …), **wound assessment** (documentation, photography, automatic segmentation), **documentation** (according to international wound documentation standards), **trends** (healing process/treatment process)	**support for various profession groups** (nurses, physiotherapy, dietology,..), **treatment progress dashboards** (motivation, satisfaction, engagement for patient), **documentation of additional treatment**, **interfaces to existing medical applications** (e.g., ELGA), **treatment recommendations** (according to pathway), **additional material** (videos, encyclopedia for professionals, ...)	**additional app for patients** (motivational aspect, support for care givers/family members)
Non-functional Requirements	**Support for internationalization** (multi-language support), **adherence to data protection regulatory** (GDPR), **fulfilled legacy aspects**, **ability to run on commonly and widely used devices such as mobile phones**	Development as medical product (European Region), **smart periodic maintenance**, **traceability** of procedure/activities (needed for legal aspects), **remark of state-of-the-art user experience** and design recommendations, adherence to state-of-the-art software quality aspects	Technical integration of existing medical data

3.3. Architectural overview

The mobile application is built on the pre-evaluated specific user requirements described in section 3.2. During the initial evaluation phase of user requirements, it became apparent that network connection aspects will play an important role within the architecture design phase. It was strongly desired to use the app in an online as well as offline modus. Therefore, patient data collection as well as wound segmentation with machine learning is done on-device and can be applied and stored without network connectivity. Data input will be stored in a local database, which adheres to the constraints identified in the requirements phase. To enable collaborative work, data will be transferred to a central storage when network connectivity is available. As depicted

on **Figure 1**, the app architecture consists of various modules which include input activities (e.g., patient data input filled in by the professional), the local storage module (database and JSON files for surveys), the AI module for image segmentation, a module for user authentication and a module where pathways and state-of-the-art wound treatment guidelines will be stored locally. Future activities will include the setup of an application server to handle all the incoming and consumed data from the app.

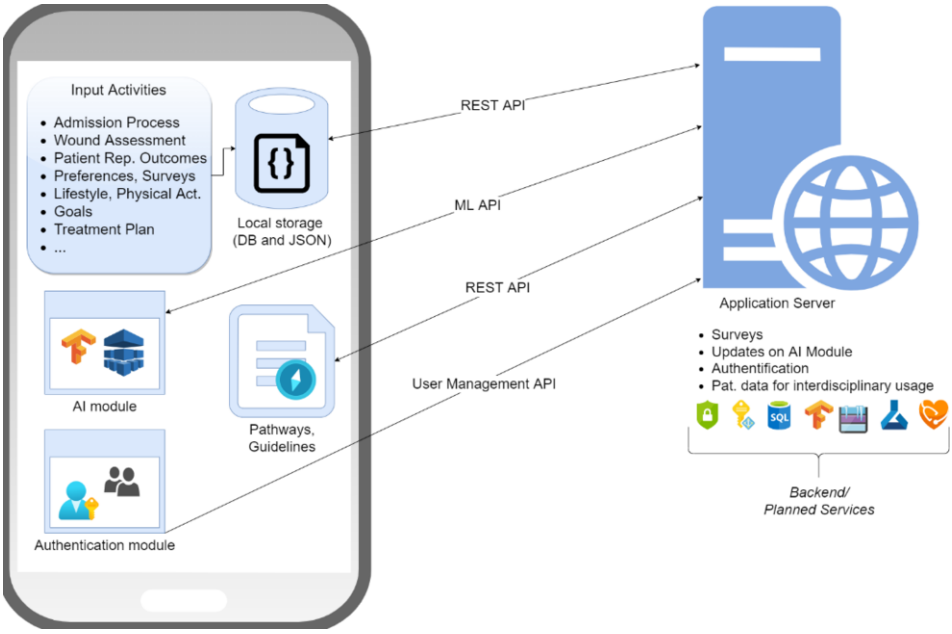

Figure 1. Overview of application concept. The app works online and offline with various tools for data input, data storage, user authentication, usage of current pathways as well as on-device machine learning.

Additionally, research on state-of-the-art machine learning platforms (Tensorflow [19], Torch7 [20], Rapids [21], pyTorch [22], Google ML Kit [23], Caffe2 [24]) and frameworks in respect of identified requirements was carried out and requirements were matched with framework services and compatibility. Finally, the following setup was selected:

- App Development with Flutter Framework [25]
- SQLite Database [26]
- TensorFlow Lite [19]

Cross-Platform-development was identified as a crucial requirement. It enables responsive app development for multiple operating systems such as Android and iOS in a one-step-development approach, speeds up support and maintenance for future feature implementation and speeds up the release process.

Due to offline-accessibility of data, the SQLite database has been chosen to optimize support for local storage as well as data integration from a server API as a planned feature. JSON files from a server backend can easily be converted to SQLite database structure.

TensorFlow Lite turns out to be the most appropriate choice to enable on-device machine learning and supports integration and usage of customized machine learning algorithms. It can easily be integrated into Flutter by simply adding a library.

The app development itself was carried out in an agile way, where experts were encouraged to give continuous feedback within the development process.

3.4. Pathways, Digital Documentation and Interoperability

Prior to the app development, the literature research was carried out where widely used wound anamnesis sheets and documentation sheets as well as wound assessment processes were collected and translated in a suitable way for data collection via mobile apps. All relevant aspects according to wound assessment processes (initial processes as well as follow-up processes) were evaluated and transformed into the resulting mobile application structure. The overall goal was to enable professionals to fill in data in an intuitive, easy, time-effective and structured way, according to their needs and widely-used wound assessment process. The app was developed in an agile way, where a small group of professionals evaluated the app design/concept continuously. The final selected design of wound assessment and documentation structure translated into a digital structure is displayed on **Figure 2**.

The interoperability aspect was considered right from the beginning of the project. Hence state-of-the-art standards in healthcare were used as a basis. Scenarios and interfaces were identified in which interoperability should be provided. Local database entries as well as used resources (e.g., surveys) include state-of-the-art code systems, value sets, ontologies, classification systems and standards. Additionally, FHIR [27] resources and associated code systems and value sets (e.g., for gender, educational level, FHIR observations) are planned for the backend/application server. Pathways and guidelines can currently be included locally and will be updated via API in the future.

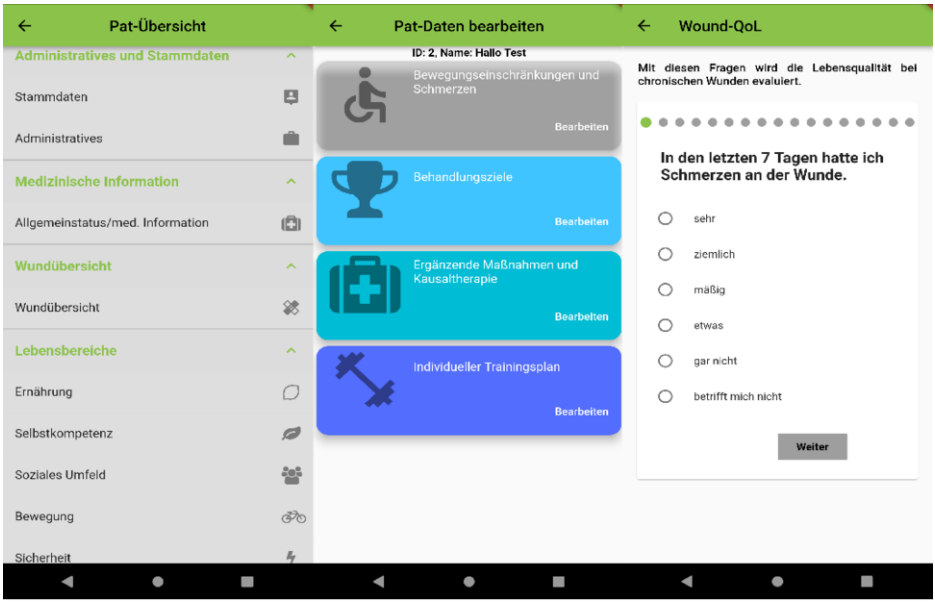

Figure 2. 3 selected screenshots of the mobile application. The user is able to fill in all relevant medical patient data, wound data, survey data as well as lifestyle data e.g., nutrition self-competences, social environment, training/exercise behaviors, and resilience.

3.5. Database Design (Tables and Structure)

In order to transfer the identified parameters into a logical and physical database model, a literature research was conducted. Common database types were examined to identify the most appropriate database technology. We examined hierarchical, relational, object-oriented, object-relational, No-SQL, document-oriented, in-memory, graph-based and multi-model databases, and mixed forms [28]. We chose an SQLite database which is a lightweight relational database system suitable for the presentation and management of data on mobile devices. Furthermore, it offers the benefit that it can be easily integrated into mobile applications and mapped for communication with backend/API.

An overview of the data structure and respective tables is given in **Table 3**.

Table 3. Overview of data structure of the app. The given table provides an overview of database tables and outlined features integrated in the app.

Data Structure (Table or Section)	Outlined description of included columns in tables
Patient Core Data	**Patient related data**
Responsibilities	**IDs of responsible professionals involved in the treatment process**
General Patient Status	**Diagnoses** (primary and further diagnoses), **medication**, presence of **allergy**, allergy types and qualitative description
Examinations	Type and date of **examination**, involved physicians
Lifestyle Factors	**Smoking** habits, **alcohol** consumption, **drug** usage/therapy and description
Diet	**Eating** and drinking habits, **height**, **weight** and **diet status**
Goals	Personal **goals** with description, start and planned end date, **satisfaction level**
Pain	**Pain** related to resting and movement, **itching**
Additional treatment	Notes on additional therapy, which are not collected in a standardized way
Coping Strategy	**Psychotherapy** needed, **anxiety**, **healing** beliefs, personal **resources**
Participation	**Orientation** data, **limitations** in communication, **visual** and **hearing** aids
Self-competence	**Risk** cautions, self-management, checkup **adherence** and **necessities**
Causal Therapy	**Physiotherapist** related **data** (compression, correct positioning, …)
Physical Impairment	**Pain** and related **limitations,** muscular atrophy, limitations in **mobility** and movement, **gait** analysis and **correctness**, constrained **ADLs**, and **risks** for **falling**
Training plan	**Physiotherapist** related **data** (endurance training, tissue techniques, manual therapy, coordination training, strength training and ADL education)
Questionnaires	Questionnaires with **description** and **scores**
Latest Wound Treatment	**Information** related to **wound treatment** - flush, antiseptica, debridement, phase (wet/dry), bandage and application time of wound treatment
Wound Material	**Material information** (product name, category, treatment phase, application time)
Wound Specific	**Detailed wound information** (type, classification localization, width, length, area, ground, smell, edge, surroundings, sensibility, …)

4. Discussion

The wound documentation app presented in this paper is intended to support the documentation and photography of chronic wounds. On the one hand, the app aims to reduce the time and resources required for documentation by caregivers and medical professionals; on the other hand, the app should improve the patient's quality of life by providing optimal care for the wound. The app combines the most important functionalities that were collected in the context of the competitive analysis and the requirements analysis and is to be expanded at a later stage with further functionalities, such as the automatic measurement of the wound and the automatic segmentation and

classification of the wound by using machine learning algorithms. Furthermore, treatment pathways will be included in the backend to enhance maintainability.

Field tests will be carried out to further test usability and intuitiveness of the app and final legal considerations will be examined in future work.

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