An Information and Communication Platform Supporting Analytics for Elderly Care

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Abstract: Germany faces an increase of its elderly population and along with it the number of people reliant on nursing care is also rising. In this context, access to reliable information is key for all actors involved, be they family members or political decision makers. Currently, the country lacks a centralized platform on which such actors can access and exchange relevant information, e.g. as concerns finding a suitable facility or identifying trends on the demand for care spots. Existing solutions are based on regional data silos, which render information exchange time-consuming and error-prone. As a result, nursing care actors lack access to timely, reliable information to support strategic decision-making. In this paper, we introduce a software platform built upon an In-Memory database that meets the information and communication needs of the different user groups involved. The platform establishes the necessary framework for real-time data collection and information exchange, laying the foundation for deriving key performance indicators and enabling data exploration and prognoses.

1 INTRODUCTION

The increase in life expectancy in Germany has coincided with a sharp rise in the number of elderly people who are dependent on specialized care. In fact, the average amount of pensioners with substantial care needs has increased threefold between 1995 and 2017 (Bundesministerium für Gesundheit, 2018). This phenomenon is not restricted to Germany. The worldwide number of the elderly – those aged 60 years or over – is expected to more than double by 2050 and triple by 2100 (United Nations, 2017). Aging leads to a gradual decrease in physical and mental capacity, a growing risk of disease, and further dependence on nursing care (World Health Organization, 2018).

Today, acquiring information on nursing care services in Germany is a laborious undertaking. Patients looking for a nursing care facility can communicate directly with it or consult with a nursing care support center to obtain information on available care spots. Both alternatives are associated with a significant time expenditure as important information such as availability must be explicitly requested, often by phone. At the policy level, social planners aim to improve a district's nursing care offering through demand forecasting and capacity planning. This requires comprehensive up-to-date datasets coming from different sources. Currently, these sources are either scattered throughout different silos, thereby presenting high heterogeneity, or are simply not available outside the respective institutions.

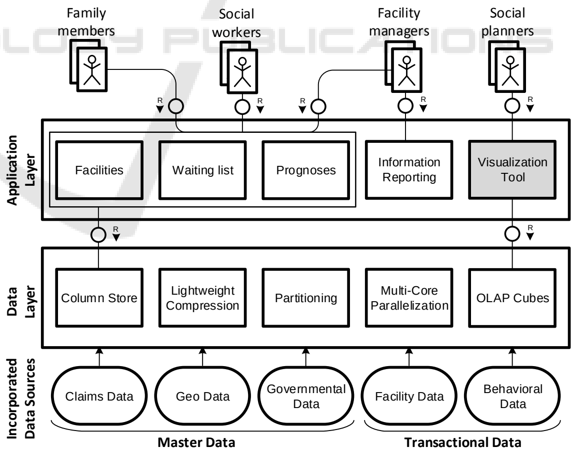

Figure 1: Software system architecture of the elderly care information and communication platform depicted as a FMC block diagram.

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A centralized software platform with reliable information on offer and demand for nursing care services can help to close the gaps between silos. Such an integrated platform can also be of interest for related actors, such as social workers and facility managers. Fig. 1 shows the architecture of our software solution in a Fundamental Modeling Concepts (FMC) block diagram. The foundation is formed by data coming from different sources, which are either predefined (master data) or continuously updated (transactional data). The master data is only updated periodically, consisting of governmental data, geographical data, and insurance claims data. In contrast, transactional data is continuously updated, originating from nursing care facilities and users' search behavior. The different sources are integrated and harmonized in an In-Memory Database (IMDB), which has been demonstrated to support flexible and fast analysis of extensive amounts of data (Plattner and Schapranow, 2014). The application offers a wide range of services such as a personalized waiting list, recommendations for nursing services matching given search criteria, fine-grained data exploration, and prognosis on different key performance indicators (KPIs). The requirements of our software were elicited following principles from design thinking, a user-centric approach. The platform standardizes information exchange across the nursing care spectrum, making it possible for the first time to tap into existing data silos. It therefore establishes the basis upon which to perform advanced analytics, ultimately enabling users to derive recommendations that inform policy and to reduce the time needed to find appropriate care services.

The remainder of this work is structured as follows: Sect. 2 places the work in the context of already existing initiatives in the field. In Sect. 3 the software architecture and the technical infrastructure are discussed. Our specific contributions are described in Sect. 4, while they are critically analyzed in Sect. 5. The paper concludes with an outlook on the next steps in Sect. 6.

2 RELATED WORK

Decentralization of care delivery is currently gaining more importance (Real et al., 2018). Information and communication technologies in nursing care thus shift towards decentralized networking. *Honor* (Honor, 2018) and *careship* (Careship, 2018) are two examples of this development. The idea is to bring together people in need of care with suitable caregivers from the neighborhood. This strengthens local care. Nevertheless, compared to our platform, it does not cover people who can no longer stay in their own home and are dependent on a care facility.

Other platforms, such as *AOK Pflege-Navigator* (AOK, 2018), *Wohnen im Alter* (Wohnen im Alter, 2018) and *Seniorplace* (Seniorplace, 2018) offer a complete overview of care facilities in the search region and also provide additional information on the facilities. Unfortunately, these platforms lack information about capacity utilization. In contrast to our solution, this information has to be requested.

The focus on a specific user group is another disadvantage of these approaches. In order to improve the entire process of care, there is no holistic approach. All approaches concentrate only on one specific user group or the interaction of two user groups, e.g. carers and people in need of care. On our platform, on the other hand, the four actors care recipient, nursing facility, social planner and social worker are linked.

Linking the actors further leads to a homogenization of data. This data collection and process standardization of information exchange in association with the IMDB technology facilitates individual real-time analysis, consistency, scalability and leads to more transparency (Knawy, 2017). Current solutions in this area, as in the case of *Recom* (RECOM, 2018), only take place within a closed facility, such as a hospital or a care facility.

The federal ministry of education and research in Germany is promoting aging in place through the primacy of outpatient rather than inpatient care (Bundesministerium für Bildung und Forschung, 2017). Ambient assisted living and e-health are current methods that intend to promote this (Cedillo et al., 2018). Still, people reliant on care facility is increasing (Destatis, 2015). In order to meet increased demand, social planning derives prognosis based on static and aggregated data at a district or state level. Short-term changes due to new technologies and population migration are not absorbed by this approach and thus make it cumbersome for changes. In comparison, our centralized approach provides analysis of real-time data even at a municipality level.

3 METHODS

In the following, we share details about the utilized research methodology. To get an overall picture of the existing challenges in the field of nursing care we used the design thinking approach. Based on its guidelines, we elicited the software requirements via subject-matter interviews with the identified stakeholders. To implement these requirements we made use of selected IMDB building-blocks and web development technologies.

3.1 Requirements Engineering

In order to understand the whole process of decision-making in the nursing care field, we followed the problem-solving method design thinking (Lockwood and Papke, 2017). In interviews with subject-matter experts, we were able to pinpoint problems and challenges, e.g. concerning how they are connected to each other and how they communicate. This enabled us to derive a concise representation of the stakeholders in terms of personas and user stories. Personas are a generic entity that represents a typical user of the solution. In particular, four personas have been identified. The first is the family member who is looking for an appropriate nursing care facility as soon and as easily as possible. The second is the social planner, responsible to carry out data analyses and draw up the elderly care plan, which contains a number of recommendations for policy making. The third is the social worker in a nursing care support center, in charge of counseling people on several topics related to nursing care. Finally, we identified the facility manager, who needs to inform prospective patients on available spots, submit key indicators to district administration and ultimately optimize occupancy rates. A user story helps to create a simplified description of a requirement (Cohn, 2004). A user story template often uses the following format: 'As a *Persona*, I want *feature* so that *reason*'. This led to a collection of user stories that have guided the implementation of the platform. They laid out the foundation for a set of functional and non-functional requirements, which can be examined as Supplementary Material [1] as per the ISO/IEC/IEEE 24765:2017 (International Organization for Standardization, 2017).

3.2 IMDB Technology

Following the users' non-functional requirements for our software platform such as fast response times and scalability, we decided to utilize the IMDB technology. It uses the main memory for storage and enables real-time data processing and analysis of the stored data (Prassol, 2015). Increasing computing power and recent advances in hardware allows real-time analysis of massive amounts of data (Plattner and Schapranow, 2014). Our platform makes use of selected building-blocks of the IMDB technology, which are described in the following.

Column-oriented Data Layout. In classical relational databases data is stored in a row-oriented format (Halpin and Morgan, 2008). This characteristic makes this approach particularly suitable for online transactional processing (OLTP) systems. Row-oriented data storage allows fast writing of data, while retrieval takes longer. In contrast, column-oriented databases are less able to cope with this frequent writing (Ordonez et al., 2018). However, the columnar structure is often used in online analytical processing (OLAP) systems. Since user queries are limited to only a subset of the available attributes, for example when a given district wants to access its KPIs, our platform uses only columnar tables. Another advantage of columnar format is that the data can be stored in highly compressed form.

Lightweight Compression. Compression is targeted at retaining the information content of a data structure with a concomitant reduction of disk space needed to represent it (Plattner, 2014). Column-wise storage eases lightweight compression given that certain patterns in the data are often repeated (Svensson, 2008). As our platform shall cater to a wide user base, acceptable performance must be ensured. Performance gains can be enabled either by cache-conscious algorithms (Rao and Ross, 1999) or by reducing the amount of data transferred from and to main memory, which can be achieved by data compression approaches (Westmann et al., 2000).

Partitioning. Partitioning can be either vertical or horizontal (Lightstone et al., 2007). Vertical partitioning splits columns of database tables into multiple column-wise subsets, which then can be distributed on individual databases servers (Hellerstein et al., 2007). In contrast, horizontal partitioning handles large database tables by dividing them into smaller pieces of row-wise data. This approach has the advantage that it enables parallel search operations and improves scalability (Plattner, 2014).

Multi-Core Parallelization. Trends in multi-core processing with multiple cores in each case can be exploited by reducing the amount of sequential work and developing parallized applications in order to achieve highest processing speed. The IMDB system used for our platform enables inter and intra operator parallelism (Plattner, 2014). The IMDB handles parallelization autonomously so that we do not have to explicitly manage it (Plattner and Leukert, 2015).

[1] `https://tinyurl.com/y4vt8b86`

3.3 Web Technologies

For the development, we utilized the Model-View-Controller (MVC) architecture. It is an architectural pattern used to efficiently link the user interface to the underlying data models (Goodrich and Lenz, 2016). It separates the application into the components models, controllers and views. Separating our software platform into these components leads to improved scalability, ease of maintenance and reusability. In particular, we used the Ruby on Rails framework v3.2 along with the JQuery user interface library. The geographical exploration of care services and the overview of care utilization was developed with the open-source JavaScript library Leaflet.js (Vladimir Agafonkin, 2018).

3.4 User Experience Evaluation

For a first assessment of this platform, we conducted a survey for users in the role of a family member. A survey was carried out among people with different socio-demographic characteristics. In order to evaluate how well family members are supported by the platform, they were asked to find a nursing care facility matching pre-defined criteria. Subsequently, they answered a survey on the usability of the platform. A total of 42 subjects took part in the survey, out of which 36 gave an answer. Questions were answered using a Likert scale with grades from ”not applicable” (1) to ”fully applicable” (5).

4 CONTRIBUTIONS

In the following, we detail the contributions we made concerning software requirements, software architecture, incorporated data sources, and process standardization.

4.1 Software Requirements

As per Sect. 3.1, the interviews conducted with the different stakeholders formed the basis for a set of user stories, from which we derived functional and non-functional requirements.

4.1.1 Functional Requirements

Our platform provides the needed foundation for different stakeholders to exchange information, with each user group having different sets of needs, which might overlap. In the following, we briefly outline the identified functional requirements for each user group.

Family Members. This user group is primarily concerned with finding a suitable care spot which meets specific criteria. Among others, geographical proximity is a key factor in the decision-making process. Therefore, the platform shall enable family members to define advanced search criteria and explore the results with a geographical visualization front-end. Since the desired facility is not always available, family members shall be able to define search agents which can trigger e-mail notifications upon available spots matching the criteria defined. Furthermore, the platform shall provide centralized waiting lists across all facilities.

Social Planners. Tasked with providing information for policy-makers in the field of nursing care planning, social planners’ primary aim is access to up-to-date KPIs on important developments in the field, concerning, e.g., availability of nursing care offers, personnel infrastructure, occupancy rates, and demographic trends, including prognoses. These KPIs are currently generated by means of manual data collection, i.e. via questionnaires directed at care facilities, a time-consuming and error-prone task. Therefore, the platform shall provide the infrastructure for continuous data collection to ensure actuality. In addition, the platform shall enable the social planner to explore available KPIs in an explorative fashion, so as to enable ad-hoc queries to be answered. An overview of selected KPIs can be examined in Tab. 1.

Social Workers. These stakeholders help family members and patients in all questions related to nursing care, particularly assistance in finding a suitable nursing care offer. In addition to the same services also provided to family members, the platform shall provide social workers with detailed prognoses on the availability of a given nursing care offer in a given district.

Facility Managers. These stakeholders often need to answer information requests from social planners, regulatory agencies, governmental entities, and family members. While answering a phone call for five minutes may not seem like a significant amount of time taken individually, collective they considerably burden facility managers and employee who should otherwise be engaged in patient care. To streamline this process, the platform shall enable facility managers to report information required by the other stakeholders in a standardized fashion, e.g., regarding service offering, available spots, personnel infrastructure, etc.

4.1.2 Non-functional Requirements

Non-functional requirements of the platform include the same set characteristics which users expect from modern web applications, concerning ease of use, fast response time and device independence, i.e., ability to use the software both from desktop and mobiles devices. Additionally, the possibility to easily extend the available KPIs shall be guaranteed by the platform.

Table 1: Excerpt of KPIs. Abbreviations: SP=Social Planner; FM=Family Member; FMa=Facility Manager; SW=Social Worker.

Key Performance Indicator	SP	FM	FMa	SW
Care Utilization	x		x	x
Available Capacity	x	x	x	x
Days of Capacity Overload	x			x
Number of People in Care Facility	x			x
Covered Days	x		x	x
Number of Nursing Staff	x			x
Nursing Staff Ratio	x	x		x
Nursing Staff Need	x			x
Waiting Time per Care Form	x	x	x	x
Demand on Care Place	x		x	x
Care Migration	x		x	x
Forecast on KPIs	x		x	x

4.2 Software Architecture

The elicited requirements were mapped into software components (application layer) within a web platform built upon an IMDB database infrastructure (data layer) which harmonizes the incorporated data sources. The resulting software architecture is depicted in Fig. 1. In the following, we provide a description of each of the individual software layers in top-down fashion.

Application Layer. The application components were built using the MVC architectural pattern, encapsulating component responsibilities in 'Facility', 'Waiting List', 'Prognoses', 'Information Reporting' and 'Visualization Tool'. The 'Facility' component manages facility information, geographical exploration, search capabilities, including search agent (F1-F5). A core functionality of the platform resides in the 'Waiting List' component which manages requests for nursing care offers in a centralized fashion across different facilities (F6). The KPIs available on the platform can be forecast by means of the 'Prognoses' component (F7). This component utilizes analysis routines available in the IMDB, such as time-series analysis. Facilities must provide different stakeholders with information regarding available spots, personnel availability, among others. This is enabled by the 'Information Reporting' component, with which facilities can avoid having to answer inquiries by phone or e-mail manually (F8-F10). The 'Visualization Tool' enables interactive exploration of KPIs by means of an external software tool that is able to consume OLAP cubes (F11-F13). Since the visualization tool is directly embedded in the platform, it is transparent for the user. Finally, security is provided by means of an authentication and authorization role-based access control components, implemented with the Ruby gems 'devise' and 'can-can'.

Application frontend was developed using HTML5 and Javascript with JQuery using principles of web usability in order to enable ease of use (NF1). In particular, for the geographical exploration component, we made applied caching strategies using the user browser's embedded off-line storage, allowing to cache network requests and thereby avoiding round trips to the web server, ensuring an interactive web application (NF2). This is particularly relevant with regards to shape data (GeoJSON) required to display municipalities on a map. Furthermore, the platform adapts to different devices flexibly, desktop or mobile, providing device-independence (NF3).

Data Layer. For the data layer, we utilized the IMDB building blocks column-oriented storage, lightweight compression, partitioning, and multi-core parallelization and OLAP cubes. In our platform, we utilize column-based storage for the data entities. This approach storage is beneficial both from a compression perspective and for analytical purposes. Besides, for database design, we strived to achieve the third normal form for all entities, futher improving disk utilization (Bernstein, 1976). This was implemented, e.g., to keep track of available care spots across all service types for a given facility. Furthermore, the partitioning and multi-core parallelization capabilities of the IMDB enables data belonging to different districts to distributed across different server nodes, optimizing response times (NF2). To enable data exploration, we developed virtual OLAP cubes which meet the analysis needs of social planners. Furthermore, virtual OLAP cubes provide the possibility of extensibility by adding new measures or dimensions without the need to recreate datamarts, as is usual with traditional Business Intelligence systems, ensuring ease of extensibility for KPIs (NF3).

Incorporated Data Sources. An important contribution of our platform is integrating different data sources within a central IMDB infrastructure. The incorporated data sources differ in the frequency with which they are updated, termed either master data (updated periodically) or transactional data (updated daily). Belonging to the former category, are data from health insurance claims, geographical data coordinates for districts and municipalities (e.g. GeoJSON), and statistical data, such as demographics for a given region, which are typically available from governmental sources. Transactional data sources relate to data provided by the care facilities themselves, concerning real-time occupancy rates, i.e., how many spots are currently available for a given service, and personnel infrastructure. Furthermore, the platform can gather non-sensitive information about users queries, e.g. geographical origin, services requested, waiting times, etc. Regarding, the claims data, we cooperated with a large German health insurance company which enabled us to obtain fine-grained information on nursing care utilization (Freitas da Cruz et al., 2018).

4.3 Process Standardization

The various user interviews helped us to identify the gap in the communication channels between the actors involved in nursing care. All four identified users are connected to each other directly or indirectly. Hence, all actors interact with each other by information exchange and are part of the decision-making process of all individual actors.

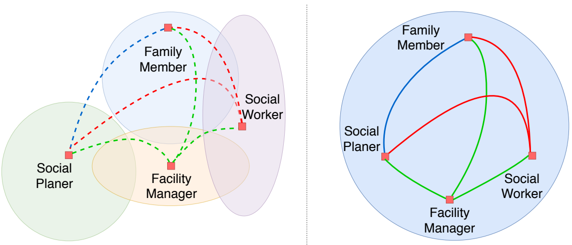

Figure 2: Image depicts the intersection of the different user groups: disjoint ellipses with dashed lines (left) vs. joint ellipsis with solid lines (right). The platform joins the user groups in order to save time and share common data rather than manually built bilateral communication channels.

As shown in Fig. 2 on the left, the family member e.g. is in direct contact with the care facility and nursing care support center for information-gathering about the facility. However, they are in indirect contact with the social planner. The social planner is interested in relevant KPIs on nursing care in order to derive recommendations from them. The collected KPIs depend not only on information coming from the direct interface with the facilities. They also depend on the search queries of the family members.

The flow of information between the facilities and all other actors takes place on an individual level. While family members' search queries are always answered by telephone or e-mail, queries coming from the ministry via social planner about personnel and care infrastructure are sent via non-standardized channels and in individual consultation. The entire data exchange between the individual actors does not take place in a given format but after bilateral agreement. With the help of our platform, as shown in Fig. 2 on the right, the entire communication channel is standardized and all information exchange is taking place at one single point. Standardization of the process improves and promotes quality and saves time (Knawy, 2017).

5 EVALUATION AND DISCUSSION

Requirements imposed on the platform were met as follows. From a functional perspective, the user is provided with a geographical exploration tool of all available care facilities in order to find the most suitable one in real-time without the need for additional help (F1-F5). A centralized waiting list helps both the care recipient and the nursing care facility to streamline the process of finding a suitable care spot (F6). In the future, we will provide linear regression models to deliver forecasts on the expected waiting time and fine-grained long-term forecasts on the demand for nursing care spots (F7). Data harmonization and process standardization are achieved by means of direct communication channels and minimum information reporting standards (F8-F10). Consistent information reporting from care facilities results in additional KPIs (F11-F13), which allow more precise analyses and prognoses in social planning.

Our platform fulfilled non-functional requirements, such as ease of use, through the use of HTML5 and Javascript with JQuery (NF1). The incorporated IMDB technology ensures fast response time (NF2) and extensibility (NF4). Furthermore, the platform can be accessed from different devices (NF3).

In its current state, our platform has a number of advantages over existing solutions. It supports family members with additional information on nursing care facilities and thus helps them to save time. In addition to the availability of real-time information, the centralized collection and integration of various user groups and data sources, such as insurance claims data, geo-information data, and statistical data coming from governmental bodies, provides a suitable measuring instrument for KPIs. This data collection and process standardization paired with the used IMDB technology facilitates the analysis and forecast for social planning.

The survey presented in Tab. 2 suggested that the platform is user-friendly and useful in finding care facilities and services. However, not all functionalities needed were found by the users. For instance, the possibility of entering a place name as a search criterion was missing. Currently, the search functionality for finding a care spot is constrained to postal code. A further question which we sought to answer by the survey was if the platform provides better support than existing solutions from the users perspective. However, only one person stated to had experience with a similar solution, the response was considered as not sufficiently informative.

The approach chosen to evaluate the application relied on a small sample size, thereby potentially providing biased the results. To address this limitation, a more comprehensive user evaluation involving other users and a wider sample is expected to be carried out in the future when new features are implemented.

Table 2: Results of the survey of family members. Questions were answered using a Likert scale with grades from "not applicable" (1) to "fully applicable" (5). This can be used to calculate a weighted mean.

Question	Weighted Mean
I got along with the platform pretty well.	4.14
I got along with the map pretty well.	4.27
I was able to handle the filter settings.	4.14
I understood the icons on the map.	3.89
I have found all the functionality I need.	3.23
I like the information on the available capacity of the nursing care facility.	4.14
I felt supported by the platform.	4.14
I would like to use the platform when searching for care places and offers.	4.11

6 CONCLUSION AND FUTURE WORK

With the help of our software architecture, process integration, and technology infrastructure, we developed a platform, that facilitates the searching process for a care facility and helps to derive more detailed analyses in order to improve the care offer of nursing facilities. The data foundation is comprised of master data by various institutions and transactional data generated by the incorporated user groups. The software architecture allows an easy extension for future work, e.g. finding a kindergarten or school place.

Future work concerns deeper analysis of social planning, incorporation of new user groups and new proposals to try different methods. The following ideas could be tested: 1) As we used linear regression models to forecast the waiting time and the demand for nursing care offers, the application of more sophisticated machine learning models could help to improve the forecast quality. 2) It could be interesting to include nursing care as a service. Offering help on an outpatient basis leads to a larger data collection and can thus further improve social planning. 3) Including clinical data could also help to enhance demand forecast accuracy.

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