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Collaborative Design of Process-Aware Information Systems on Handheld Devices for Mobile Health Workers

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Services increasingly gain importance but the usage of corresponding guidelines in field scenarios has not been particularly supported by IT. This paper will suggest an approach to process-aware information systems on portable devices integrating the users thus addressing this challenge. Scenarios for joint modeling and development considering the requirements of field service providers will be studied to meet the demanded specifics for workflow tool support or representation. Findings include a web-based modeling tool selection, are evaluated with a use case in Australian palliative community nursing to present experiences generally worthwhile for such a collaborative initiative.

Keywords: Process modeling, Process-aware information system, Workflow, Field service, Palliative care.

1 Introduction

The demand for mobile services rises steadily and affiliated performance quality depends a great deal on the availability of information (Sherry and Ratzan 2012). That is why the use of modern information technology (IT) has potentials: not only to avoid/ correct mistakes but also to improve relations to the client or to support decisions thus boosting outcomes; for instance with a widely available information basis and hence resulting in an accelerated orientation for service providers (Varshney 2007; Akesson et al. 2007; Bates and Bitton 2010). Therefore, many initiatives attempt to raise efficiency and quality using IT – also in field scenarios (Jha et al. 2008). With adequate modeling and electronic provision of workflow information, process quality could be supported in these environments (Berg and Toussaint 2003).

Ammenwerth et al. (2010) request contemporary data access means as a necessity for usable IT infrastructure. Positive results for field service workers using mobile IT applications are described by Legner et al. (2011), Birkhofer et al. (2007). Although mobile IT solutions have been existing for years (Tachakra et al. 2003), there still is demand in field scenarios (Pryss et al. 2011; Wälivaara et al. 2009). To date, most of portable solutions have been analyzed or evaluated for ‘immobile’ scenarios, e.g. in hospitals or doctors’ practices (Chatterjee et al. 2009; Breitschwerdt et al. 2011).

Field environments as in home care or ambulances still lack IT-supported workflows. There, corresponding standards and guidelines do exist and provide information on indication, symptoms and execution of care activities or medication (Schoenbaum and Gottlieb 1990). A portable tool intuitively representing them misses at the point of care: Ambulant providers would thus be supported to efficiently deliver high quality. Clients should also profit from the improved availability of – e.g. evidence-based – information (Breitschwerdt et al. 2011; Sadeghi et al. 2011).

It is explored subsequently how process-oriented support can be realized to meet mobile service providers’ need, here in the health arena. Considering prospective users’ perspective should hereby generate acceptance (Legner et al. 2011). Therefore, we look at related work (chap. 2) before defining (3), executing (3.1-3.3), evaluating (4) and discussing (5) our approach.

2 Related Work

Process-orientation represents an important instrument for ensuring quality (Lenz and Reichert 2007). Breitschwerdt et al. suppose information deficits of mobile healthcare providers regarding mandatory workflows. Modeling them could help with generating added value like achieved in mobile service industries also focusing on complex caring processes and documentation (Walter 2009). Technical field service providers are seen in analogy (Breitschwerdt et al. 2011; Rügge 2007; Rügge 2003; Picot and Schmid 2007) because of similar (Winston 1980) work (esp. complex ‘maintenance’).

Here, the authors focus on treatment processes: prevention, diagnosis, therapy, nursing/ care and other client-centered workflows. Compared to administrative processes they are of higher complexity and therefore offer more potential for support (Lenz and Reichert 2007). Standards like expert-consented or evidence-based guidelines arise more and more amongst them. These standardization efforts are challenging but can be facilitated by IT (Pedersen et al. 2011). In turn, they represent a basis for IT-supported execution (Kaiser et al. 2011). IT, though, needs to be integrated further into service delivery: workflow representations help better if they are not simply published online, but embedded using process-oriented systems. Those help with defining and setting standards reducing costs without a loss of quality (Berg and Toussaint 2003). Also, they organize the information provided along the workflow and are to be flexibly adjusted. That functionality is attributed to process modeling respectively process management tools (Lenz and Reichert 2007; Reichert 2011; Ben Dhieb and Barkaoui 2012). Amongst them, tools running on mobile devices currently gain significance (Pryss et al. 2011; Houy et al. 2011).

Process-aware information systems (PAIS) support workflows based on underlying process models thus preserving user requirements and confidence in reliable, correct system operations before its deployment (Mans et al. 2010). PAIS provide all phases of the workflow lifecycle, i.e. its specification and design, development and configuration, validation test and implementation (Reichert 2011; Mans et al. 2010). On mobile devices they

can be key for integrating such support into field service delivery like ambulant care (Pryss et al. 2010; Pryss et al. 2011; Breitschwerdt et al. 2011).

3 Approach to Collaborative Realization in a Field Scenario

A well-defined procedure is necessary to eventually achieve an improvement for this field: Integrating design-oriented methodologies for both information systems, as e.g. in Hevner et al. (2004), Hevner (2007), Österle et al. (2010) and healthcare (Rouse 2009) is pursued, here: we conduct iterative revisions thus approaching to find innovative problem resolutions by

1. defining methods to
2. identify, describe problems in application domain as in the context of field service providers here, before we
3. create and evaluate our artifact solutions based on the previous steps.

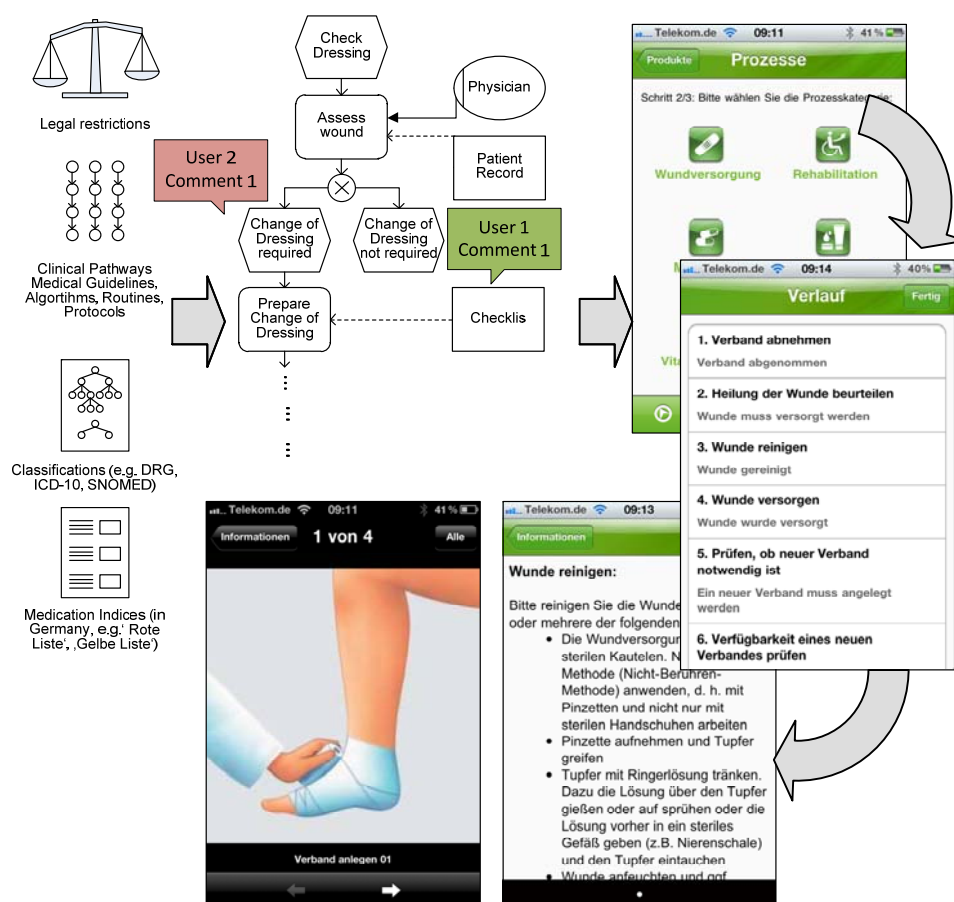


Figure 1. Guidelines, algorithms or legal aspects need to be represented in process models for expert/ user feedback so that transfer of valid processes to user interfaces of a PAIS succeeds

As methods serve analogy, focus groups, the integration of workshop-based and virtual end user feedback for development of artifacts like requirements, process models and systems. Application scenarios (Frank 2010; Berg and Toussaint 2003) and – for evaluation – a use case analysis (Mouttham 2012) in chapter 4 were used to check the viability of our solutions. The challenges described throughout the previous chapters – here e.g. guidelines to be represented in models for solution development (see Fig. 1) – and the requirements as collected in chapter 3.1 are the problems to be addressed. Since effectiveness of IT is a complex collaborative achievement (Lenz and Reichert 2007; Mouttham et al. 2012; An et al. 2009), we considered joint design, development and (test) usage (combined: creation) concerning software and devices with the users (e.g. by feedback-enabled workflow modeling). During the whole approach we involve them for collaborative solution conception (An et al. 2009; van de Kar and den Hengst 2009; Lee 2007; Pedersen et al. 2011; Ammenwerth et al. 2010).

3.1 Approach to Collaborative Realization in a Field Scenario

The profile of stationary work scenarios as per Pryss et al. (2011) has certain requirements also valid for field service delivery, e.g. synchronization, “physical problems like broken connections or mal-functioning devices (...) to be handled by the supporting infrastructure, but without burdening users”. But they lack some specific ones differing mostly regarding additional mobility and information needs demanded (Chatterjee et al. 2009; Breitschwerdt et al. 2011). Analog to Pryss et al. (2011), we elicited requirements R1 - R11 (see Table 1) by scrutinizing different field application scenarios, e.g. of

- community nurses
- paramedics,
- rescue staff acting in disaster management or
- specific home care providers (e.g. physical therapists visiting patients at home).

They were confirmed during consecutive two hour focus group sessions (Tong et al. 2007; van de Kar and den Hengst 2009): one in late 2011 with twelve (physicians, nurses, therapists, managers, IT administrators) then one in early 2012 with five (nurses, managers with nursing background, IT administrator) staff of Australian community healthcare providers (Tong et al. (2007) set a minimum of four, van de Kar and den Hengst (2009) of six participants) from the Sydney metropolitan area. Afterwards, we refined them with four IT developers holding a B.Sc. degree in Information Systems and a paramedic with a Master degree of the same subject. Finally, we categorized them as per Mouttham et al. (2012) for easier allocation during further development efforts. The requirements also reflect (cp. R9) that ambulant service providers as users are often on the fly and virtually interact with coworkers via mobile devices (Mouttham et al. 2012; Breitschwerdt et al. 2011).

Table 1. Requirements identified for PAIS in field scenario

<i>No.</i>	<i>Categories according to Mouttham et al. (2012)</i>	<i>End user requirements</i>	<i>Sample consequences for development</i>
R1	Processes	Intuitively understandable representation of processes and instances is to be supported.	Deliberate selection of process modeling language.
R2	Processes	Processes in system must be compliant to medical guidelines, pathways, etc.	Use of standardized/ recommended processes.
R3	Processes/ Data	Attaching data to executed process instances for post-processing, esp. via free-text entry fields, needs to be possible.	Enabling data transfer with other systems of the provider.
R4	Data	Data is exchanged compatibly with standard interfaces.	Data created/ processed should be e.g. DICOM, HL7-compliant for integration into enterprise architecture.
R5	Data	System conception follows data security and privacy required by patient, caregiver and law.	The system conception needs to consider different national laws in an international setting.
R6	Data/ Technology interoperability	The system enables artifact-based (back-) office processing.	Offering e.g. 'print-to-PDF' functionality.
R7	Data/ Technology interoperability	Easy invite-functionality for sharing patient-related data with authorized persons must be provided.	User/ role concept and data security according to legal restrictions applying.
R8	Technology interoperability	The installation and update of the software is easy and fast.	Software version deployment procedure needed for testing.
R9	Technology interoperability	The system runs best possibly platform-independent on stationary and mobile touch-screen devices.	Certain adequate operating systems need to be considered.
R10	Technology interoperability	The solution needs to be low cost since funding critical in the domain, especially its ambulant scenarios.	Use of existing systems to be pursued (individual solutions costly): Free or open source software might be preferred.
R11	Technology interoperability	A support and maintenance concept is required.	Administrator roles and event logging have to be considered, a potential handover to the provider's IT service prepared.

3.2 Process Representation for Conceptual Modeling

Modeling as a necessary step during requirements engineering means abstracting and capturing the essence for facilitating the interaction with the users (Berg and Toussaint

2003). An adequate process modeling language as a basic prerequisite also helps with a successful implementation e.g. of (clinical) pathways or guidelines (Reichert 2011; Jun et al. 2012). For integrating healthcare process knowledge into information systems, it has to be computer-interpretable or even formally modeled for executable usage (Kaiser et al. 2011; Mans et al. 2010). That “translation” into such a conceptual model is still complex from an interdisciplinary (here: healthcare vs. information systems) domain perspective and difficult since it needs to be complete for successful implementation (Mans 2010; Berg and Toussaint 2003).

Meanwhile, standard process modeling languages like Business Process Management Notation (BPMN) have become widespread alternatives for conceptual modeling and analyses of workflows (Peleg 2011; Becker and Janiesch 2008; Petersen et al. 2010). However, the authors have only been aware either of usage contexts in stationary scenarios or not specifically for ambulant care (Pryss et al. (2010), Pryss et al. (2011) analyze various field domains at once). Corresponding to R1, we propose the use of BPMN solely for these environments: this language is supposed to be easily understandable even for users inexperienced with or beginners in modeling (OMG 2006), such as field service providers like community nurses or paramedics. At the same time, it is advocated and preferred, e.g. to UML, for service modeling (Heß and Meis 2011). Therefore, we use BPMN to bridge between conceptualization and implementation of the processes for the users needing to understand them. Workflow representation thus enhanced makes treatments more transparent for stakeholders other than the aforementioned ones: this would concern patients, their relatives and – as a synergy – designers of other domain-specific supporting systems respectively solutions (Kaiser et al. 2011). That is why an intuitive notation matters especially for model representation.

3.3 Alternative Toolset Options

The outcomes of care can be enhanced when implementing workflows into (clinical) information systems so that they are enabled to provide advanced mechanisms as required by individual decision support or care delivery (Kaiser et al. 2011). As Pryss et al. emphasize, the IT infrastructure for such an approach must be user-friendly for proper configuration of processes, services, devices or applications (2011).

To date, at least 70 different tools support BPMN (OMG 2012) thus fulfilling R1. Considering financial restrictions (R10) and the demanded mobility (R9) as paramount, cost-/time-saving (R8) and web browser-based tools deployable on small portable devices like smartphones or pad/ tablet PCs (Breitschwerdt et al. 2011) were looked for.

Yan et al. (2011) recommend Oryx as such a BPMN tool. Since no longer online today (see www.oryx-project.org), we analyzed both Signavio (academic.signavio.com) originating from Oryx (Kunze and Weske 2010) and its ‘derivate’ Activiti (activiti.org). None of the other tools analyzed in Yan et al. (2011) is capable to support web-based modeling. So we searched the given 70 in comprehensive manner for any other fulfilling that characteristic and identified suites of Oracle BPM Suite (www.oracle.com/us/technologies/bpm/suite/), Rigr (rigr.rapilabs.com), Inubit (www.inubit.com/en/inubit-suite.html), IYOPRO (www.iyopro.com), Cordys (www.cordys.com/bpms-business-process-management-suite), EMC Documentum xCP (www.emc.com/products/detail/software/xcp-business-process-management.htm), Skelta BPM.NET (www.skelta.com/products/bpm/overview.aspx), ProcessMaker (www.processmaker.com) and jBoss BRMS (www.redhat.com/products/jbossenterprisemiddleware/business-rules/). However, most of them have not been supporting use of their full functionalities on mobile devices, so far; they only offer process

design, not execution via browser, too (see Table 2 with features relevant for the requirements identified).

Activiti comprises all necessary components to serve as a comprehensive PAIS itself and runs on mobile iOS devices. Signavio does the latter, too, but is a modeling tool in the first place. In comparison, it does not require any user-driven installation and additionally offers a role concept with invite options (cp. R7), print-to-PDF (cp. R6), commenting features, automated versioning and glossary as well as syntax checking. These features make it superior to other, costlier tools running on mobile devices like from Cordys and Inubit. Requirements 2, 4, 5 and 11 are rather not affected by the tool chosen and were therefore not considered in this section.

<i>Feature</i>	<i>Signavio</i>	<i>Activiti</i>	<i>Rigr</i>	<i>Cordys/Inubit</i>	<i>EMC/Oracle</i>	<i>IVOPRO</i>	<i>ProcessMaker/iBoss BRMS</i>	<i>Skelta</i>
Workflow engine/ supports process execution as instances (cp. R3)	no	yes	no	yes	yes	yes; but not in free version	no or not via browser	not via browser
Client installation(s) required (cp. R8)	no	yes	no	yes	yes	yes	yes	yes
Specified compatible with mobile platforms (cp. R9)	iOS	iOS	no	yes	no	no	no	no
Freeware (cp. R10), not considering support	only for re-search	yes	yes	no	No	yes (for free version)	yes	no

Table 2. Features of browser-based BPMN tools for PAIS realization field environment

4 Evaluation

4.1 Case Study in Ambulant End-of-Life Care Scenario

We have evaluated our approach by means of studying a use case in the context of an international project integrating both researchers from Information Systems and Health Science domains. Australian community nursing providers were involved as prospective users from a mobile service field. Since part of an intercontinental initiative, follow-ups and work (e.g. the workflow modeling) between or after meetings only happens via phone or mostly virtually because of time zone difference to Europe.

Palliative care represents a complex domain dealing with individual physical, social, psychological and spiritual needs of people in the process of dying from a life-limiting con-

dition (Mouttham et al. 2012; von Reibnitz and Nussbaumer 2011; Sadeghi et al. 2011). Recognizing death as the final stage of life, paramount goal is integrating holistic approaches to assess and ensure the concerned persons' quality of life. This comprises e.g. supporting the dying and their relatives as well as providing relief from symptoms/ pain (Kralik and van Loon 2011, pp. 370-371).

Per year, about 140,000 Australians (most of them 70 years or older) decease. The demographically aging population (Kralik and van Loon 2011, p.63: 25% share of the population older than 65 years by 2040) and patients surviving their chronic illnesses longer will increase the need for (palliative) care additionally (Mouttham et al. 2012; Gianchandani 2011). Even to date, specialist end-of-life care cannot be provided in every case. That is why Australian initiatives, especially Palliative Care Australia (www.palliativecare.org.au), try to integrate it into generalist community nursing. This targets that each dying individual can be looked after by primary care providers, usually community nurses not trained for end-of-life situations, with input from specialized staff when/ if necessary. Affiliated services required have to be addressed by development of novel provision models (Kralik and van Loon 2011, pp. 370-371), to ensure quality especially for nursing in patients' homes (Mouttham et al. 2012; Segal and Leach 2011). This setting is interesting for two reasons: 1. regular community nurses need to deliver palliative care because of a lack of corresponding specialist nurses, 2. every healthcare professional is likely to face end-of-life situations (Kralik and van Loon 2011, pp. 373-374). In any case, the caregivers require additional input to reach an adequate skill level.

Also, (community) palliative care is a collaborative usage scenario where IT-based solutions can provide a significant deal of help (Johnston et al. 2012; Martinez et al. 2009), not only in inpatient (Ash et al. 2012; Hong et al. 2009) but even more in remote (McCall et al. 2008; Pitsillides et al. 2006) outpatient settings (Sadeghi et al. 2011; Wälivaara et al. 2009). Australia is a vast land and community nurses even in metropolitan regions have to take rides from one patient to another for hours and use advanced mobile IT like smartphones and pads on a regular basis. Mouttham et al. recommended mobile devices as well as use of process and guideline models in this environment, but not considering collaborative conception (2012). However, goal of this project had been to jointly model workflows and develop a PAIS for generalist community nurses to get to know, initiate and continue end-of-life care as per the Liverpool Care Pathway for the Dying Patient (Ellershaw and Wilkinson 2003) (LCP; see www.mcpcil.org.uk/liverpool-care-pathway/): that means providing information and decision support on portable devices, e.g. concerning diagnosis of dying, guidelines for symptom management, pain assessment prompt, nausea and vomiting prompt as well as guiding through data like vital signs to be collected.

4.2 Results

In order to challenge the findings of chapter 3 we cross-checked them against the aforementioned project. They proved not only mostly valid throughout iterative personal and virtual collaboration with palliative care providers including generalist community nurses, specialist palliative nurses, their management and IT administrators over several months. We also assessed them in a workshop with experts for information system development, nursing and IT infrastructure.

This mostly confirmed the requirements, but with interdependent preferences on the case-specific significance for realization (see Table 3). Some aspects were more negligible, e.g. R11, than others. Already for the modeling phase, a web browser based tool requiring basically not any installation had been mandatory. The Oryx-based tools were preferred to

the others because of their iOS compatibility. Activiti with its partly complex installation and multi-component usage was denied, however. Therefore, Signavio was used for modeling and commenting, even though not providing direct process execution as instances. Thus requiring additional development efforts to realize the PAIS, a workflow engine to be connected and a way to transfer the process models there had to be come up with. This was achieved by means of an export from Signavio via bpmn.xml format for further handling in the PAIS (see Fig. 1 for screenshots of sample realization as an ‘app’).

Table 3. Evaluation if requirements in ambulant scenario

No.	End user requirements	Application successful in case
R1	Intuitively understandable representation of processes and instances is to be supported.	Yes, BPMN approved as process representation.
R2	Processes in system must be compliant to medical guidelines, pathways, etc.	Yes, is maintained by use of expert-consented LCP
R3	Attaching data to executed process instances for post-processing, esp. via free-text entry fields, needs to be possible.	Yes, requested, but not possible with selected tool, additional development for realization has to follow.
R4	Data is exchanged compatibly with standard interfaces	Yes, data created with/ processed by system should be HL7-compliant for later coupling with existing clinical information system.
R5	System conception follows data security and privacy required by patient, caregiver and law.	Yes, Australian legislation needs to be applied; if use considered for other country partnering in the project that aspect has to be revisited.
R6	The system enables artifact-based (back-) office processing.	Yes, ‘print-to-PDF’ functionality required (featured by Signavio during modeling, to be implemented in PAIS).
R7	Easy invite-functionality for sharing patient-related data with authorized persons must be provided.	Yes, inviting colleagues and patient relatives required. User and role concept exist in selected tool, additional development for realization in workflow engine has to follow.
R8	The installation and update of the software is easy and fast.	Yes, the users dislike installing software respectively systems more often or at all. Delivery via most common ‘app’ stores would be welcomed.
R9	The system runs best possibly platform-independent on stationary and mobile touch-screen devices.	Yes, especially Apple iOS operating system should be supported for users’ mobile devices.
R10	The solution needs to be low cost since funding critical in the domain, especially its ambulant scenarios.	Yes, the solution to be developed cannot be funded additionally by the provider. Only freeware tools with then limited functionality can be selected.
R11	A support and maintenance concept is required.	Yes, a handover to providers’ IT service for post-live support is pursued, but to fulfill R10 of limited significance.

5 Discussion and Outlook

We have elicited requirements, recommended BPMN as a corresponding process modeling notation including corresponding tools and developed a representation approach.

That was practically challenged by a palliative community nursing case according to a clinical guideline. The degree of integration of users and their specific needs while generating the solutions, especially modeling the workflows, has been advanced regarding PAIS conception in ambulant scenarios. Some of the requirements could be addressed by means of mobile application systems running freeware process management tools for both modeling and developing a PAIS.

According to design science, the evaluation shows that our approach has provided insight to a problem of field service delivery and some measures to address it. However, it is rather a qualitative-argumentative experience report than an empirical study for demonstrating its practical usefulness. More cases will be needed to prove its overall validity, prioritize respectively discover additional requirements or more sophisticated ways to represent the processes and their instances with adequate tool support.

Predefined workflows represent significant routines to follow. However, they depend interactively on situation, might always be decontextualized, incomplete, quickly outdated and have to be correctly interpreted (Berg and Toussaint 2003). If this kind of process-oriented support is provided via mobile IT systems, acceptance of the system amongst users like community nurses needs to be determined (Zhang et al. 2010). Same applies to the clients' side who are suspicious of tools for correct provision of service (Lenz and Reichert 2007) and want to be involved more about providers' IT use in their homes (Wälivaara et al. 2009). Additionally, a positive impact on the outcomes has to be proven. Helpful proves that many field service providers do already use mobile devices for professional reasons: a PAIS deployed on that could help with learning and delivering certain services (Lenz and Reichert 2007) especially in undersupplied more rural or vast areas.

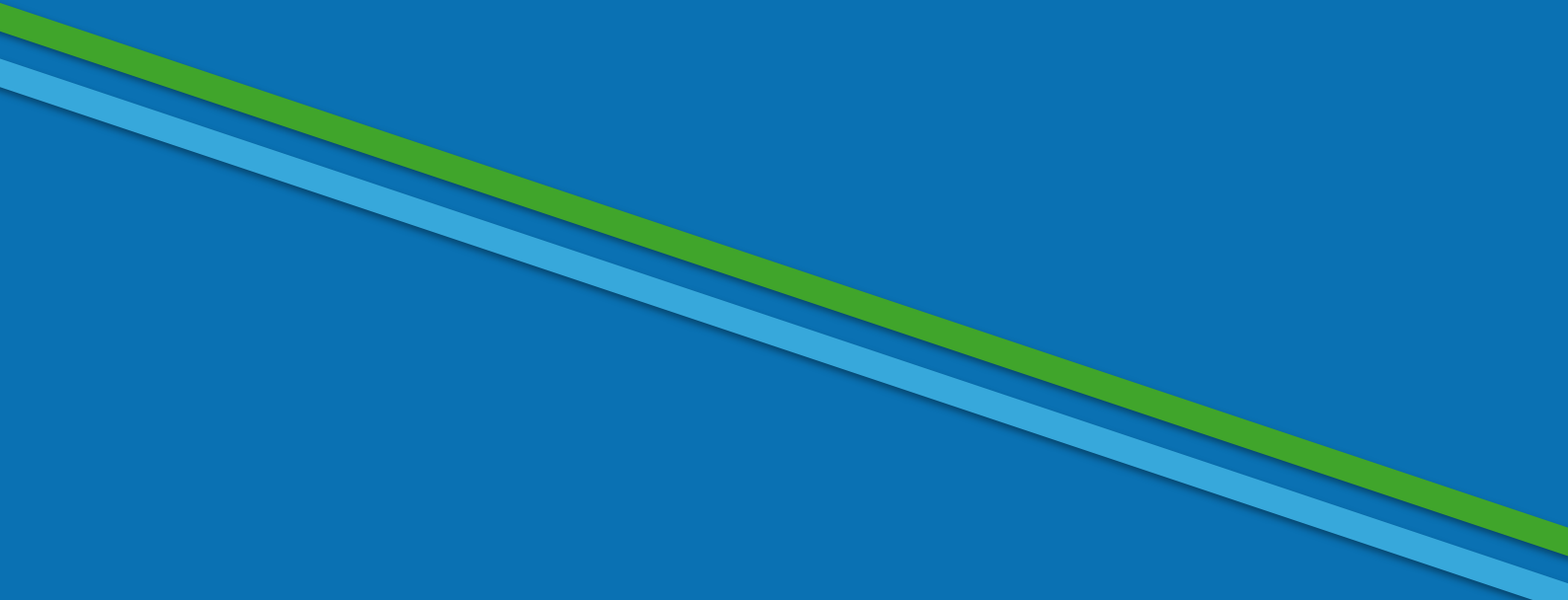
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