The alpha-Flow Use-Case of Breast Cancer Treatment – Modeling Inter-Institutional Healthcare Workflows by Active Documents

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***Abstract*—In healthcare, inter-institutional process support implicates decentralized and ad-hoc workflows. From the perspective of system integration, the autonomy of the sites which are participating in a healthcare network is mostly untouchable. Traditional activity-oriented workflow models or content-oriented workflow models do not provide adequate support in such system environments and workflow scenarios. The objective of the alpha-Flow approach is to enable distributed, ad-hoc process support with initially unknown sets of actors and institutions. In its document-oriented workflow model, electronic documents become active documents and act as software agents as the primary means of coordination. This paper details the healthcare use-case for the alpha-Flow model by the example of cooperative breast-cancer treatment scenarios.**

***Keywords*-Healthcare, information systems, document-orientation, inter-institutional, dynamic collaborations**

I. Motivation and Challenges

Inadequate availability of patient information, such as prescriptions or the results of laboratory tests, is a major cause for medical errors [1]. Such problems are aggravated by the rise of healthcare networks and an increasing number of parties that are involved in a treatment: Chronic diseases and multimorbidity, like cancer, diabetes, asthma, and cardiac insufficiency, require more healthcare parties than common diseases.

The autonomy of the sites which are participating in a healthcare network will be mostly untouchable. It is our objective to provide process support in spite of missing system integration. Our approach evaluates options to provide process support such that minimized requirements are demanded from the participating systems.

The traditional approach to manage large-scale inter-institutional processes in healthcare is based on paper documents with a dedicated semantics, such as a referral or a discharge letter. We pick up this interaction paradigm and try to extend it to support complex cooperation scenarios: The basic idea is to use electronic documents as self-contained units of information interchange which also carry process related information. This paper details the healthcare use-case for the α-*Flow* workflow model by the example of breast-cancer treatment scenarios. Compared to related content-oriented workflow paradigms, which all require a structured and predefined content schema, there are two distinguishable features of the proposed approach: 1) to apply document-orientation as instrument of arbitrary inter-institutional system integration and 2) to separate content from decision support and both of them from coordination work. The primary goal is to foster inter-institutional information exchange in healthcare, bridging the gap between institutions of the primary and secondary care.

II. Background

A. Supply Chains in Healthcare

A short overview of the domain participants is given: The focus of the medical supply chain in Germany are the patients who are treated by office-based physicians foremost, collectively described as the *primary care*. The *secondary care* adds hospitals, laboratories, pharmacies, and ancillary medical institutions as participants of the medical supply chain.

Electronic medical record (EMR) and *electronic health records* (EHR), e.g. [2], are popular approaches to share patient related information among institutions. They typically contain data that can be extracted on demand. Yet, it is unclear how these systems scale and how direct communication between institutions can be effectively supported in large-scale scenarios. A conceptual change from messages and records to documents is provided by HL7[1] v3 CDA[2]. CDA provides a framework for XML-structured medical documents. EMRs and EHRs fit in the notion of our approach by specifications like the *continuity of care document* (CCD), a U.S.-specific standard, which is a constraint on HL7 and focuses on document-oriented medical content types. Standards like CCD do not consider process history or coordination information.

B. Content vs. Coordination

The two basic aspects for collaborative activities are the support for content manipulation and the support for coordination. An information system traditionally focuses on the

[1]Health Level 7, http://www.hl7.org
[2]Clinical Document Architecture

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manipulation of content. Support is given for the gathering, the storage, access control, structuring, classification, and presentation of the information as well as the reaction to new information.

By definition of CSCW[3], collaboration extends this focus with the concern of *coordination* [3]: The information system must support "articulation work". Articulation support must enable cooperating actors to partition work into units, to divide it amongst themselves, and to schedule, mesh and interrelate their collective activities.

C. Traditional Workflow Approaches and Unsolved Issues

The dominant approach to formal workflow models is based on the *activity-oriented workflow paradigm*, like Petri Nets with states and transitions or like BPMN[4] with actors and activities. The characterization of tasks or actions by preconditions, postconditions, and possible exceptions is dominant. In contrast, the *content-oriented workflow paradigm* [4]–[6] implement coordination based on state-changes of an artifact life-cycle model. The characterization of artifact states is dominant, for example content states like "private", "submitted", "reviewed", and "published" in as publishing scenario. Both approaches require predefined semantically rich schemas.

There exists strong methodical support for *predefined* workflow schemas. Technological support, in form of process control and monitoring, is provided by *central* enactment engines. Decentral approaches exist that apply an agent metaphor [7]. Yet, to put workflows into practice, comprehensive and *prospective conceptualization* of the activities is necessary, and task automatization has to be provided by service implementation. There still exists barely support for *decentralized* workflows. *Ad-hoc workflows* are not considered traditionally, and support for *initially unknown sets* of actors, states, and transitions is not present.

D. Active Documents

The α-*Flow* representation of information artifacts is based on *active documents* [8]. Basically, an active document is a document that allows a direct interaction with itself.

As we have described in [9], the α-*Flow* approach fuses the activity-oriented workflow paradigm with the content-oriented workflow paradigm into a combined model: In essence, workflow schemata are represented as documents which are shared coequally to content documents. We extend the notion of active documents by instrumenting them as software agents [10] which enable coordination work. Each active document in α-*Flow* carries the workflow context in addition to the medical content and provides autonomous coordination logic in form of a rule-based action library. The intent is to allow access, viewing, and editing of the original content documents in standard ways like general editors without corrupting the workflow semantics.

[3]Computer Supported Cooperative Work

[4]Business Process Modeling Notation

III. α-*Flow* Objectives

This section explains two distinguishable features of the proposed approach. 1) From the perspective of system integration, the autonomy of the participating sites is mostly untouchable. On that account α-*Flow* motivates and requires a document-oriented integration approach. 2) α-*Flow* strives to provide process support in spite of missing system integration. For this reason the separation between content, decision support, and coordination is an essential consequence.

A. Document-oriented Systems Integration

In [11] we described the similarities and differences between interface-/message-oriented integration and document-oriented integration: In essence, *interface-oriented integration* focuses on available functionality, the integration method affects semantically rich interfaces. The information being passed is not necessarily viable on its own but often in the context of the service request only. The passed information, by parameters or messages, represent transient fine-grained information that is assimilated by the targeted system.

The *document-oriented integration* focuses on information units that are self-contained and viable independently of an application system. The integration method affects the semantic scalability of document models, using standardized and minimal interfaces for hand-over. Redundancy in data distribution is not critical with documents: due to the self-containedness a synchronization in the classical sense is not required, instead, document versioning and variant management solutions are effective. In [12] we presented a mediated publish-subscribe system which enables document-oriented artifact propagation in large-scale inter-institutional healthcare scenarios.

B. Content and Decision Support versus Coordination

The basic α-*Flow* assumption for inter-institutional workflows is that human or computer supported decisions can always be represented in a newly occurred demand for further information, as it is well-known by the diagnostic-therapeutic cycle [13] in healthcare. A treatment episode ends when no further information is required for the particular goal. Any decision that is made in the course of a cross-organizational treatment can be represented by the creation of a record keeping document artifact.

In clinical environments, the automation of processes is often understood as the automation of decisions by adequate supporting systems [14]. The commingling of decision support and workflow causes misunderstandings in inter-institutional scenarios. Decision support systems depend heavily on a semantic interpretation of medical content like patient information. This requires a canonical content

standard for medical information. Such only exists in *regional healthcare information networks* (RHIN) [15]. Considering large-scale inter-institutional processes, it is necessary to strictly separate decision support from the cooperative workflow and the necessary coordination work. In fig. 1 the interrelationship and differences between content, decision support and coordination work is outlined.

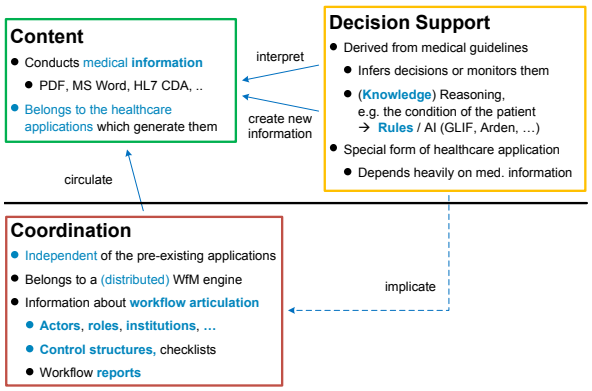

Figure 1. Coordination vs. Decission Support

The *content documents* conduct medical information and are of arbitrary type, from binary Adobe PDF files to well-structured HL7 v3 CDA documents. Content documents belong to the healthcare applications which generate them. The *coordination documents* are independent of the application system and belong to the distributed workflow. They conduct information about actors, roles, and institutions, as well as system topology information, and control structures like checklists.

Despite of existing standards like HL7 v3 CDA or CCD, reality is still far away from any vision of large-scale healthcare system environments that are integrated by common standards. Today, IT support for healthcare processes is typically limited to intra-institutional approaches and IT-support for inter-organizational patient treatment processes is an unsolved issue. The α-*Flow* approach tries to adopt to this boundary condition with the separation of decision support and coordination work.

IV. The α-*Flow* Use-Case

Collaborative treatment scenarios can be described as distributed medical treatment processes with physician teams from different institutions interacting closely meshed for treating complex chronic diseases and multimorbidity. For some years now, in Germany, the treatment of breast cancer is organized by accredited in-station breast cancer treatment centers cooperating with manifold accredited partners like oncologists, radiologists, and the post-operative care [16]. This section details the primary use-case scenario of the α-*Flow* approach and explains how to consider workflows in a document-oriented fashion.

A. Initial Breast Cancer Episode: Classification

The initial episode of breast cancer treatment is outlined in fig. 2. The goal of this treatment episode is to find out whether or not a knot in a breast is actually malignant cancer. The treatment begins with a patient visiting her gynecologist. After the anamnesis, the gynecologist[5] Gyn^A conducts a sonography. If the result is either malignant or dubious he/she will send the patient to a radiologist for mammography. After the radiologist's treatment, the mammography report on diagnostic findings is sent back to Gyn^A. The gynecologist evaluates the radiologist's findings, primarily the medical indicator BI-RADS[6], and decides whether the patient has to be send to a hospital for a biopsy. The biopsy involves another gynecologist at a clinic[7] (Gyn^C_B). The tissue is taken by Gyn^C_B and sent to a pathologist for histological diagnosis. The histology provides definite evidence. The Gyn^A is the one who takes the histology result and is responsible for informing the patient. In the malignant case, another episode begins now by sending the patient to a breast cancer treatment center for primary therapy.

As simple as this treatment episode is, there are three significant characteristics in the activity diagram of fig. 2: a) Each treatment is outlined, b) there are two conditionals elements ("malignant|dubious" and "BI-RADS$\geq$4") that explain medical decisions, and c) the arrows that cross the swimlanes (i.e. the data flow between the participants) do neither name nor specify any exchanged artifact.

B. Rethinking Activities in Documents

α-*Flow* tries to eliminate any modeling of expert activities in its coordination model. This is necessary, because any decisions for process routing requires either a domain- and section-specific decision support system (e.g. based on rule-based artificial intelligence) or a human decision. Activities are fused into the α-*Flow* approach, completely represented by their result artifact. Optionally, an order artifact can also be part of the representation (as the originator of an activity demand) – in fact, most healthcare processes require so due to legal boundary conditions.

On this account, we will reinterpret the initial treatment episode for breast cancer (see fig. 3): For this simple example and in our notion, no formal process exists until the anamnesis documentation is written by Gyn^A. (Note, that we could easily set the process begin ahead with an initial appointment artifact, but such aspects of primarily intra-institutional process perspectives are skipped for the sake of simplicity.)

Furthermore, the sonography results in an according report. If the sonography report suggests evidence to send

[5]The participant's superscript A stands for ambulant, i.e. office-based primary care, in contrast to C for clinical, i.e. secondary care.

[6]Breast Imaging – Reporting and Data System

[7]Superscript C for clinical; subscript *B* for biopsy.

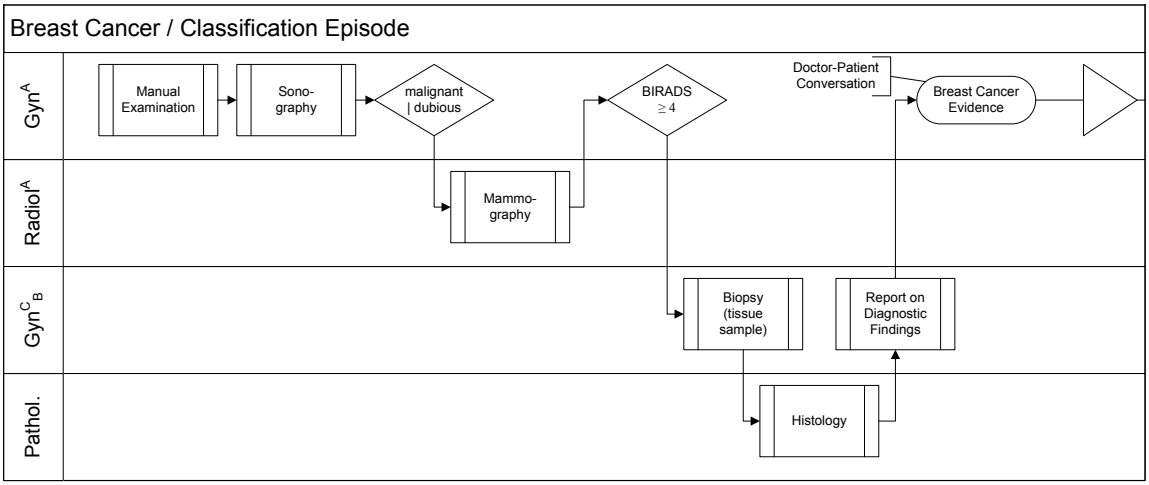

Figure 2. The initial breast cancer treatment episode: classification

the patient to a mammography, a referral voucher[8] RV^I_M is written by Gyn^A. After the radiologist's treatment, a mammography report is written and sent back to Gyn^A. If the BI-RADS suggests evidence for a biopsy, another referral voucher[9] RV^I_B is created. After the biopsy itself, taking the tissue sample, a third referral voucher[10] RV^I_H is used to send it to the pathologist. The pathology writes a histology report. The histology report is sent back from the pathologist to the clinical Gyn^C_B, who bundles the report with a short report about the biopsy operation and finally delivers the reports back to Gyn^A.

Again there are several characteristics about the α-*Flow* diagram of fig. 3: a) The whole treatment episode, with its goal to find out whether or not a knot is actually malignant, can be considered as one report which is successively filled by the participating institutions. b) Each contributed artifact has a dedicated ownership, c) the communication edges are not modeled, and d) the conditional elements of the medical decision processes are absent.

The characteristic (c) could be criticized as a deficit. Yet, bilateral communication can be considered as a special case of publish/subscribe and, after all, complex cooperative scenarios require a multi-cast distribution configuration [12].

Regarding (d), conditional elements in activity-orientation are insufficient for most expert decisions or process routings in healthcare because most activities are human tasks or require complex local health-care applications. In many intra-institutional scenarios workflow formalizations have the objective to ensure process compliance. For inter-institutional process support in healthcare, the workflow facility has to strictly follow any human decisions. In α-*Flow*, we want to achieve such flexible coordination support by considering the artifacts themselves sufficient as triggers for workflow control.

[8]Superscript I for instruction; subscript M for mammography.

[9]Subscript B for biopsy.

[10]Subscript H for histology.

C. Non-Linear Episode: Primary Therapy

The primary therapy begins when a patient is referred to a clinic that is part of a breast cancer treatment center. The α-*Flow* representation of the involved artifacts is provided by fig. 4. The referral voucher[11] RV^H_{BC} stems from the Gyn^A, who will later on execute the third episode, the adjuvant therapy.

After the initial anamnesis by Gyn^C, the patient undergoes three additional diagnostic steps: i) The upper abdomen sonography, the ii) pulmonary X-ray and iii) the bone scintigram. All three diagnostic treatments are subsumed under the name "staging". Each of the three additional diagnostics is provided by different actors – namely an internist, a radiologist, and a nuclear medical physician. The

[11]Superscript H for hospital; subscript BC for breast cancer.

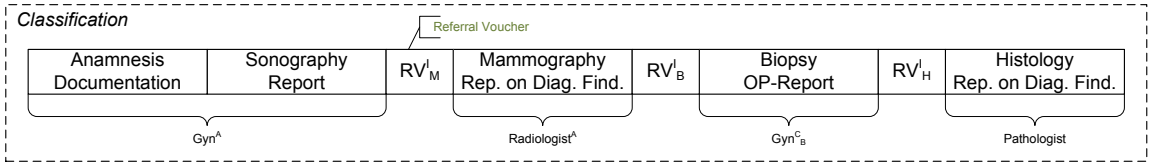

Figure 3. The initial treatment episode remodeled in documents

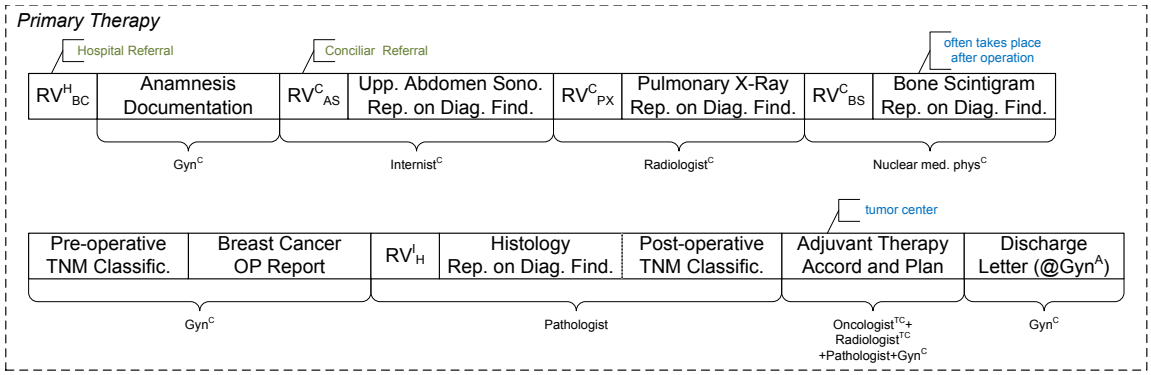

Figure 4. The second breast cancer treatment episode: primary therapy

referrals to these participants are conciliar (RV^C_{AS}, RV^C_{PX}, and RV^C_{BS}).

The order and the completeness of the staging is decided ad-hoc. The upper abdomen sonography and the pulmonary X-ray are always done, and commonly they are accomplished on admission day. The bone scintigram may or may not be done, it doesn't need to take place before the operation, and if it is done it actually is applied after the operation in most cases.

Before the operation, a preoperative TNM classification of the tumor is done by the Gyn^C, based on whichever diagnostics have yet been made. The preoperative TNM defines the exact surgical method (e.g. lumpectomy vs. mastectomy). Gyn^C then performs the surgery, which commonly takes place on the day after admission. The extracted tumor, tissue, and lymph nodes are sent to the pathologist by a referral voucher[12] RV^I_H. The pathologist contributes a detailed histology report along with the postoperative TNM classification.

From an organizational perspective, the tumor center itself is considered as a separate institution. The oncologist is the head of the tumor center, in contrast to Gyn^C, who is generally in charge of the patient treatment at the hospital and specifically for the surgery. Gyn^C contributes all reports on diagnostic findings to the tumor center as preparation of a tumor conference. The participants of the tumor conference are the oncologist as host, a radiologist, the pathologist, and the Gyn^C. Whereas the pathologist is the same one who has provided the histology, the radiologist must not be the one who has taken the pulmonary X-ray, but can be another radiologist Rad^{TC} assigned to the tumor center. The duty of the tumor conference is to accord and plan the adjuvant therapy for the individual patient. The adjuvant therapy will consist of chemo therapy, radio therapy, and hormonal therapy. For each of them there exists a spectrum of medical variations. The adjuvant therapy plan of the tumor conference becomes manifest in a document. In a final step, Gyn^C will write a discharge letter which is addressed to Gyn^A.

The characteristics of the initial classification episode are also true for the primary therapy episode: Primarily that the whole treatment episode can be considered as one report, that is successively filled by the participating institutions, and that each contributed artifact has a dedicated ownership. Additional characteristics become clear by the primary therapy episode: a) The involved conditionals in each activity require medical experts which cannot be formalized or automated, b) the results of each activity is again represented by an artifact but is shared to multiple participants during the episode, c) the exact number of steps and participants is not necessarily decided at the initialization of the workflow, and d) the sequence of several of the activities is commonly decided ad-hoc. (For cancer, as for multimorbid or chronic diseases, the exact treatments and participants are in general unknown in advance [17].)

An important aspect is that all the documents from the initial classification episode ideally act as a single document input to the primary therapy. Again after primary therapy, all the successively contributed documents from the primary therapy act as a single document input for Gyn^A who will act out the adjuvant therapy. Obviously there are two levels of granularity for the artifacts: The units of validation and organizational accountability, analog to paper-based documents, are named α-*Cards*. The coherent collection of such documents, considered as a successively written collaborative report, is named α-*Doc*. Therefore, in α-*Flow* there exists always exactly one distributed α-*Doc* for one α-*Episode*. One α-*Doc* consists of several α-*Cards*. Choosing this assignment of terms emphasizes that an episode with multiple collaborating participants has one common goal. In regard to the considerations of document-oriented systems integration (sect. III-A), both α-*Docs* and α-*Cards* are required to provide the essential characteristic of a document: being self-contained and viable independently of an application.

[12]Superscript I for instruction; subscript H for histology.

V. Future Work

The α-*Flow* approach adopts electronic documents as the primary means of information exchange. The collaboration is considered as a feature of the artifact and not of the application system. In the future it is our vision to formalize the α-*Flow* artifacts in form of active documents. A reference architecture is required based on α-*Doc*s as autonomous agents that carry active properties and workflow status information. By their active properties, the documents themselves become triggers for workflow progress. Workflow progress is considered as successive fulfillment of necessary content documents. Workflow schema change means editing the list of required documents and adopting the progress actions that occur at state change. The presented use-case will provide a foundation for a realistic evaluation scenario.

VI. Conclusion

We analyzed the requirements in healthcare for distributed and ad-hoc process support with initially unknown sets of actors and institutions. This paper detailed the healthcare use-case for the α-*Flow* model by the example of cooperative breast-cancer treatment.

The fundamental boundary condition in our scenario is the strict autonomy of the participating sites in a healthcare network. On that account we provided a summary of the document-oriented integration approach in contrast to interface-oriented integration.

This paper explained the rationale behind separating content, decision support, and coordination work – driven by the objective to provide process support in spite of missing system integration. Decision support requires a profound semantic understanding of rich medical content. In order to support heterogeneous systems, we need to decouple collaboration functionality from the existing applications.

We are currently in the process of formalizing generic rules for document-oriented coordination. In parallel, we are validating several technological platforms for implementing such rule-library in form of active documents.

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