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CASMAS-WOAD to Achieve Integrated Care and Coordination among Heterogeneous Care Communities

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***Abstract*: The highly distributed cooperation that characterizes several domain, like healthcare, collaborative design and cultural resources management, often raise coordination conflicts and collaborative problems. These problems require a suitable technological support that can make the members of the groups involved in these collaborative practices aware of the crucial information that is generated in the other groups. In this paper, we propose a framework for the design of such technological supports and illustrate its application by means of an articulated healthcare scenario. Our framework allows users to: manage the creation and execution of rules that are specific and "local" to specific groups; manage the exchange of rules, and hence of "procedural knowledge", across and among different groups; conceive predefined procedures that are considered as "carriers" of contextual information rather than models of prescriptive behavior; become mutually aware of interdependent task articulation as a basic support of inter-group collaboration; get facilitated access to the relevant information that supports their collaborative activities.**

Keywords: integrated care, coordination, awareness, care communities, CASMAS, WOAD**.**

I. Introduction

An increasing number of application domains is characterized by a form of cooperation that raises challenging requirements to the design of supportive technologies. On the one hand, cooperation involves different groups of people, whose members have specific competencies and responsibilities and exhibit a high degree of autonomy in their decisions and interventions; on the other hand, these groups are supposed to smoothly and seamlessly coordinate their interventions to achieve the common goals toward which they collaborate (e.g., the recovery of a health problem, the achievement of a performance target). In these domains, which are characterized by the involvement of heterogeneous and loosely-knit communities of workers, cooperation cannot rely on a predefined or standardized set of procedures and protocols that actors are supposed to strictly adhere to and comply with: even if such models of inter-organization processes were collaboratively defined to meet possibly diverging needs, no central agency or authority could actually exist in charge of imposing control points, checking information flows and supervising activity articulation in a top-down fashion. Examples of those application domains are: integrated and shared care [1], as in rehabilitative programs and chronic disease management; arrangement of assistive programs for the elderly [2]; collaborative design [3], cultural resources management [4], and the like. In these domains, it is highly questionable if the coordination problems caused by high distribution, group heterogeneity and vague responsibility boundaries can be effectively solved by those technologies that are usually collected under the umbrella of "inter-organizational workflow systems" [5]. In the specialist literature to date, an insufficient number of success cases for these technologies in such demanding domains is reported, and even a more formal and theoretical validation is lacking [6].

In this paper, we propose a complementary approach to workflow-based technologies. Our point is that actors involved in a loosely-knit, distributed collaborative effort need a support that makes them aware of the crucial and relevant information that is generated within the other groups involved in the effort, so as to gain a richer context for their own activity and for inter-group hand-over and coordination. In other words, we focus on technologies that could collect, filter, enrich and distribute a contextual information that regards not only one specific group but that also crosses the boundaries of the groups that are dynamically involved in the common action. What is interesting in those application domains is that forms of predefined or standardized sets of procedures do exist but are interpreted by the groups' members as a sort of procedural knowledge that is shared (at various degrees) among them, is part of the context where cooperation happens, and finally makes cooperation effective since it provides the relevant pieces of information to collaborate and it allows for the definition of conventional behaviors in front of routinary situations.

The technological support that we envision should therefore be conceived within a design approach that takes this unavoidable condition into serious account. First of all, the technology is required to manage both locality (i.e., the rules holding within a specific group only) and the exchange of procedural knowledge (i.e., explicit representations of procedures, process models, rules, etc.) across groups; it should consider procedures (i.e., their representations) as a carrier of contextual information and not as prescriptive and ostensive models [7] of organizational behaviors; it should promote mutual *collaboration awareness* [8] as a basic support of inter-group collaboration, beside the obvious functionality to provide users with facilitated access to the information that supports their collaborative activities. In this paper, we take healthcare as an illustrative and exemplifying domain: we derived the above considerations from a series of field studies that we undertook in the last five years and from similar findings from the specialist literature in the CSCW research field. In this domain, the main problem deriving from distributed collaboration among heterogeneous communities of care givers and healthcare professionals is fragmentation of care. This is recognized as one of the main sources of ineffective care and reduced patient satisfaction [9].

In what follows, we shortly describe the CASMAS architecture which takes the concept of "community of strategic communities" [10] as a first class object. Then we illustrate a reference scenario of fragmented care that focuses on the main problems that can occur in that condition. Finally, we describe how CASMAS can be applied to solve problems of care fragmentation, as those characterizing the scenario mentioned above.

II. The CASMAS architecture

According to the above considerations, we have defined a conceptual model and architecture, called Community-Aware Multi-Agent System (CASMAS) that is based on the metaphor of human cooperation. Here. the concept of *community* is a first class object (see Figure 1): the members of the community, called *entities*, are associated with a Common Information Space (CIS) [11], called *fulcrum*, which contains the coordinative information, possibly articulated in coordinative artifacts [12].

Moreover, the fulcrum contains protocols expressed in terms of *behaviors;* these are assigned to each entity to make it an active member of the community in quite a similar way as in the Actor Model [13]. As in this model, in CASMAS communication is asynchronous but it is not based on message exchange. Instead, entities *post a request* in the fulcrum, other entities will *react to this request* according to the behaviors associated with them. An entity can be member of more than one community at the same time: in this case, such entity can play the boundary leadership [14] and allow the exchange of information among the communities the entity belongs to.

Thus, an *entity can be located in one (or more) community space* (see Figure 1). A community space is where *awareness information* [15] is propagated from a source along the space structure (topology), and possibly changes its intensity (in the line of [16, 17]). Typically, information about presence is

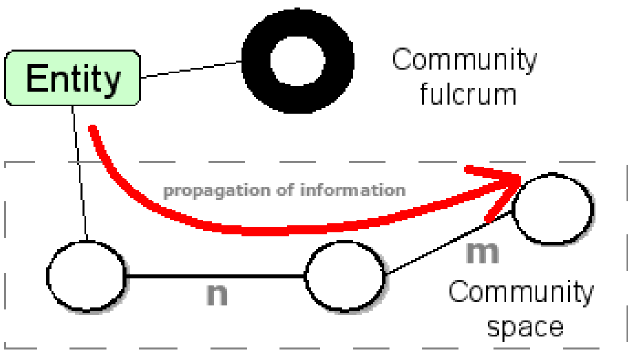


Figure 1. The CASMAS model.

propagated in a community space resembling the physical space of the cooperative setting, while domain dependent information is propagated in logical spaces: for example, the space can represent a set of roles and their relationships as edges connecting them, along which information about a critical situation (e.g., a delay) can be propagated and reach each role with different intensity, according to its involvement in the delayed activity [18].

In fact, an entity can perceive the awareness information available at the location where it is positioned (as in everyday life, a person can hear a sound according to its intensity at the place where the person is located). On the other hand, the entities can filter their perception according to a threshold depending on their interest in the kinds of information managed by each space and according to the specific information they access (e.g. the name of the delayed activity).

The model outlined above is associated with a language to specify entities, their behaviors and the policies of "awareness management". This declarative language is expressed in terms of facts and rules (i.e., modular if-then constructs). This choice is motivated by the possibility to express behaviors in a highly modular way, without the need to define complex and exhaustive control structures [19, 20].

Moreover, the basic constructs of the language can be uniformly used to express entities' behaviors at any level of abstraction (see Figure 2) where each level can use the primitives defined at the underlying level(s).

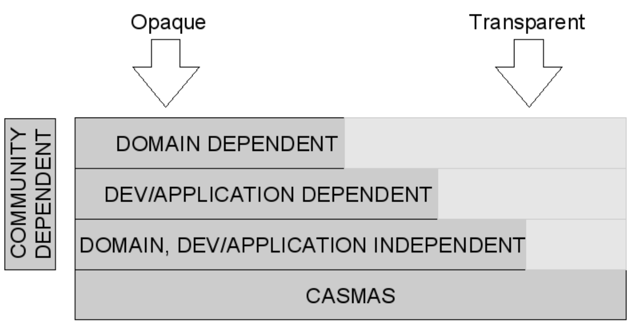


Figure 2. Abstraction levels.

CASMAS provides the following basic constructs (only the constructs to manage coordination and awareness are presented here for the sake of presentation): *assert*, *retract*, *modify* a fact in a fulcrum; *move* an entity in a space; *makeAware* entities about an information; and lastly, *AwareOf* to test if an entity the perceives a specific awareness information.

Each entity can dynamically take part to a community, by means of a *join* (and *disjoin*) primitive function; the main parameter of this function is the name of the community fulcrum to connect to. According to the community's policies, the entity "docks" to the fulcrum, interacts with the others entities by asserting (and retracting) information to (from) it, and acquires the behaviors that are specifically defined for it or for the roles that the entity plays in the community through the following predefined rule (here presented in natural language for clarity's sake):

IF in the community fulcrum there is a behavior addressed to me or addressed to a role I play, THEN load this behavior into my rule base.

This rule is loaded in the behavior of an entity when it joins a community and through the *loadBehavior* primitive loads the specified behavior into the entity and makes it executable.

The next level makes available domain-, application-, device-independent primitives, like *postRequest* and *copyFact*, and predicates like *Request* and *Response* that express coarser and recurrent pieces of behaviors that are likely to facilitate the development of collaborative applications. The level immediately above (refer to the stack depicted in Figure 2) contains the interfaces (services) provided by domain-independent applications/devices: for example, the basic I/O primitives of a handheld tablet or the basic functionalities of a Document Management System. This corresponds to building a sort of wrapper for the applications/devices to be orchestrated. Then the domain dependent behaviors can be defined at the highest leveling response to the needs of the community. Notice that the same declarative pattern is applied at each level either to define/modify/compose the primitives/predicates that are available at that level, or to enrich them by using the primitives/predicates of the underlying levels [21]. A best practice is to organize each level so that it is clear what it makes available the knowledge that is required to operate at this level: the knowledge only, since the language is always the same.

Actors, devices and software applications are modeled as entities [22] that are linked to both community fulcra and community spaces, for sake of coordination and awareness respectively. A specialized entity called *community assistant* is in charge of supporting the community as a whole by applying community-based policies that no particular entity should manage on its own. In Section 4.2 we present how community assistant of a care community can support their community to anticipate the workload they should expect because new patients are approaching.

We integrated the CASMAS language with LWOAD [23], a notation developed within the WOAD framework [24] to design applications that support document-based collaboration among members of distributed and loosely connected communities. LWOAD is a declarative and rule-based language that can be used to express conventions related to documental practices within a given care community, in an abstract manner that is independent of the implementation details of the underlying architecture. LWOAD provides primitives and types of facts at the *domain- device- application-independent* level to manipulate documents (e.g, changing their affordances), which can be used to write domain dependent rules. In the case presented in this paper, we derived from the reference scenario the entities, the fulcra, and the behaviors that are domain-specific and expressed them in CASMAS-WOAD terminology.

As part of our current research we integrated with CASMAS the ProDoc web-based application (presented in Section 5). ProDoc was previously realized to support practitioners from different domains in integrating protocols into their documentation (e.g., records, charts, forms) while they document their work in a process-oriented fashion. ProDoc provides services that are used as primitives at the *application dependent* level: in fact, ProDoc functionalities (such as associating documents to activities in a dynamic way) can be further specialized to specific domains (as it will be hinted to in Section 5). In [25], we described how CASMAS manages the interactions among devices in regards to what device should display awareness(-related) information, how and when. In this paper we concentrate on the logic generating this kind of information and sketch how this information can be conveyed to the users by means of ProDoc.

III. A fragmented care scenario

The case of Mrs. P, first mentioned in [26] is sometimes drawn on to illustrate a typical scenario of fragmented care and how fragmented care often results in bad care and, unfortunately more often than not, in unfavorable outcomes. Mrs. P is an independent elderly person who suffered from high blood pressure and that used to see her Family Doctor (FD) seldom. Her closest relative, a niece (N), maintained weekly phone contact with her and visited her periodically. Once her niece took Mrs. P to the family doctor; there he told to both that she had to keep taking the beta-blocker medication as she was standing that medication well and that, on the contrary, she had to be careful with any ACE inhibitors as he discovered that she could have a serious adverse drug reaction. More often than not, Mrs P. forgot to get all the intended medications, as she was feeling just fine and those drugs sometime caused her some minor inconvenience like nausea. Probably also for this reason, one day Mrs. P had a stroke attack. She was found by her niece by chance, simply because she did not answer to her phone call, and so she was brought to the Emergency Department (ER) with a delay that caused her a permanent brain damage that required immediate treatment and a rehabilitation programme. At the ER her conditions were stabilized and then she was admitted into the Medical Floor (MF). In this transfer, yet, the information related to the seriousness of Mrs. P conditions got lost and she did not receive immediate attention. Probably also for this reason, later the MF doctor on duty had to adopt a more invasive treatment that caused Mrs. P an adverse drug reaction; this could probably have been prevented if the anamnestic information that was reported by her niece at the ER triage about the fact that Mrs. P was allergic to *some* inhibitor (as her niece could not remember the name exactly) had triggered further inquiry and then had been correctly passed to the MF doctor; this, in lack of this information, decided to administer a dose of ramipril to Mrs. P as this was an effective active agent for the treatment of stroke and, incidentally, an ACE inhibitor. Once transferred into the Rehabilitation Unit (RU), Mrs. P had soon to go back to the MF for a high fever attributed to an urinary infection due to an indwelling catheter that was not removed in a timely manner, probably because the RU staff was experiencing an usual workload at that time. Once also this health problem had been solved, Mrs. P was admitted in a Nursing Home (NH) for full recovery. Yet, from the NH she had to go back home prematurely for what some months later was considered as a misunderstanding, or better yet, a lack in communication on how she could get some facilitation in having her bills reimbursed by her health insurance company. This latter problem affected her full recovery and probably compromised the quality of the rest of her life.

Although the case of Mrs. P could seems particularly unlucky and, also, *unlikely*, nevertheless it is articulated according to what are the most frequent cases of complications, medical errors, adverse events and bureaucratic hitches. At least one of these events occurs in more than a tenth [27] of all hospital cases. Our main aim and motivation is to show hoe a suitable technology can reduce the impact and odds of these adverse events, at least in all those cases these events are due to lack of coordination between different care providers and poor access to common and critical health information.

IV. Towards an integrated care scenario

The number of problems that occurred in the very first month of care we illustrated in Section 3 can be mainly traced back to two dimensions: lacks of information, and gaps in coordination. In regard to the former dimension we can detect that, (a) relevant information (on the importance of complying to the Family Doctor prescriptions) had not been fully appropriated by the patient when she stays at home (in H in Figure 3): in fact, she did not comply with the intended prevention program and thus undermined the actual effectiveness of the treatment; b) accurate information (on the potential allergy of Mrs. P to some, unspecified, drugs) was not duly passed to the Hospital staff (arc 1 in Figure 3), nor it was properly managed (ER in Figure 3), nor handed over to the Medical Floor (arc 2 in Figure 3) for the subsequent treatment of Mrs. P health condition; and lastly, c) pertinent information (on the reimbursement facilitations) was not timely discussed at the right place (i.e., at the NH in Figure 3) but months later at Mrs. P's home when it was too late to have a positive impact on her quality of life.

In regard to issues of poor coordination, we can detect: i) a gap between primary (i.e. the Family Doctor) and secondary care (the hospital ER staff who ignored the treatment program followed by Mrs. P and her drug allergies); ii) a lack in proper information technology that, by supporting peripheral awareness [28], could notify the niece of falls or other emergencies regarding Mrs. P; iii) a gap in coordination that occurred in the case of the handover between the ER and MF (arc 2 in Figure 3), as Mrs. P was left in a somewhat 'no man's land' with respect to responsibility while waiting for further treatment; iv) a problem in work balancing and task articulation that occurred at the RU when not complying with policies of periodical catheter monitoring caused the onset of an iatrogenic infection [29]; v) a missed opportunity of care that occurred when Mrs. P had to anticipate her discharge since she could not afford her stay at the Nursig Home any longer (arc 6 in Figure 3).

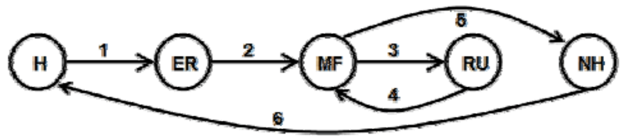


Figure 3. The involved places and transfers mentioned in the scenario. Numbers indicate chronological order of transfers.

A. *Coordinative information conveyed through the fulcra*

The solution enabled by the CASMAS-WOAD architecture addresses both the dimensions mentioned above by providing a way to have timely access to relevant situational information and domain knowledge, and by bridging coordination gaps between different facilities while guaranteeing interoperability at device level (from, e.g., simple fall detection accelerometers to much more complex software applications like Electronic Patient Records).

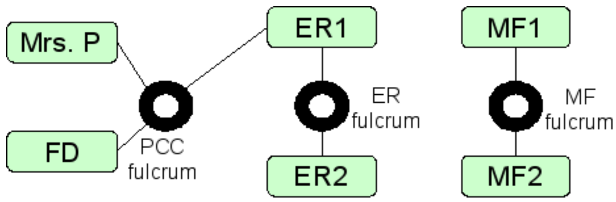


Figure 4. CASMAS entities and fulcra.

Figure 4 shows the entities and fulcra involved in this case: there is a fulcrum for the community leaving in each hospital departments and a fulcrum for the community of stakeholders who dynamically take care of the patient during her illness trajectory. The same figure shows the links holding among entities and fulcra when a practitioner (ER1) of the Emergency Department is involved together with the Family Doctor (FD) – *in absentia* – in the care of Mrs. P; ER2 is a practitioner of the same department but she has not joined the Patient Care Community (PCC) fulcrum since she is not involved in the direct care of Mrs. P. MF1 and MF2 are members of the Medical Floor community and one of them (namely, MF1) will be involved in the care of Mrs. P once she will have been transferred to the MF department.

The PCC fulcrum contains all the relevant information regarding Mrs. P., i.e., the so called health personal record. This is a standard data structure where identification, anamnestic and current health status information is stored, as well as indications about the current treatment she is undertaking (i.e, beta-blocker drugs) and who her attendants (i.e., the niece) and reference care providers are (i.e., what family doctor). In their turn, both the ER and MF fulcra contain a reference to the information contained in the Electronic Patient Records (or EPR), that is the application that is "opened" for Mrs. P. when she is admitted in a healthcare facility and where data about her stay, such as interventions, lab exams and therapeutic interventions are managed and stored.

In order to make these repositories of factual information active and pro-active with respect to the unpredictable unfolding of the Mrs. P's illness trajectory, the fulcra of the care communities involved in the reference scenario are also endowed with reactive knowledge. This knowledge consists of running and context-aware "clinical algorithms" and rules, such as proactive reminders, reactive alerts, and customized data monitors. These reactive behaviors are expressed in terms of WOAD constructs that are sensitive to factual information in their IF-parts and create Awareness Promoting Information (API in [30]) by means of their THEN parts. An API is any meaningful indication by which the members of the community of care of Mrs. P. can become aware of relevant information about her case. The reactive behaviors are local to the fulcra, but by means of CASMAS mechanisms they can be shared across different communities to become sensitive to local factual information and represent a support in sharing practices and useful information.

For instance, the information regarding the potential allergy for ACE inhibitor drugs could have been supplied to the Patient Fulcrum (and to her personal health record, as well) when Mrs P. went to the Family Doctor (FD) office. In addition to this, a simple rule conceived by the regional health agency and addressed to the hospital practitioners could have been inserted in the fulcra of all the FD's patients holding that:

IF (patient X is allergic to active principle Y) AND
(patient X is involved in care programme Z) AND
(active principle Y is encompassed in the drug kit of care programme Z)
THEN (patient X is allergic to active principle Y) becomes a "relevant information"

This rule would be transferred from Mrs. P fulcrum to the ER1 and MF1 entities by means of the *loadBehavior* rule presented in Section 2, once these entities will be involved in the care activities: in fact, the rule is addressed to all the hospital practitioners roles. The two facts *(patient 'Mrs. P' is involved in care programme "Stroke")* and *(drug kit of 'Stroke' encompasses 'Warfarin', 'Clopidogrel' and 'Ramipril')* have been previously asserted in the ER fulcrum by the entity ER (which is the community assistant entity) according to the information retrieved from the EPR application, and therefore the rule would be executed by ER1 entity since the fact *(patient X is allergic to active principle Y)* was asserted in the fulcrum of Mrs. P (i.e., the PCC fulcrum). This rule asserts the *(patient X is allergic to active principle Y) becomes a "relevant information"* fact into the PCC fulcrum in order to have this relevant information shared among the practitioners that will join the patient community.

Consequently, a CASMAS-WOAD mechanism that is sensitive to data previously tagged as "relevant information" could be executed to convey such piece of information in terms of Criticality API [30], that is in ways that this information is rendered in some highlighted or more visible manner either in the anamnestic records or in the charts by which doctors prescribe drugs.

IF (information X is a relevant information) THEN (convey criticality API on X).

This presentation rule, which is sensible to new relevant information, is executed by the MF1 practitioner once Mrs. P has been transferred to the Medical Floor: the related information is rendered on the devices of the MF practitioners accordingly, by means of compatible proper applications, such as ProDoc (see Section 5).

The same mechanisms that we outlined above to make the care-givers aware of particular conditions that can lead to an adverse drug reaction are at stake also in the other cases we described in the fragmented scenario: specific rules could be designed to i) highlight in the EPR the critical condition of a patient transferred from the ER to the MF and notify this event, e.g., on the pagers of those whom it concerns; ii) monitor the time passed until a patient is visited by a MF doctor and convey a timely alert if the critical condition we mentioned in the previous point has been asserted in the practitioners community fulcrum; iii) monitor the time elapsed since a catheter has been inserted (assuming that the insertion has been documented in the patient record concurrently) and convey a reminder if it is passed too long and the patient risks an infection; or lastly, iv) detect if a patient with a particular income or health insurance (as both pieces of information are likely to be reported in her personal health record for general reimbursement policy and hence in her fulcrum) has right to get some facilitation at a particular facility; in particular this rule would match the facility's name with those enlisted because they have an agreement with the patients' insurance company or because they operate within the national health service; once executed, this rule would generate what we called Inquiry API [30], that is a series of hyperlinks to external resources (e.g., passages from the insurance contract, or to step-wise procedures to get a reimbursement) that could inform the patient, as well as the caregivers of the admitting facility, of any facilitation.

The interesting point about these rules is their modularity and "atomicity": a CASMAS-WOAD approach does not need a consistent and comprehensive ontology of medical interventions and events (like, e.g., the HL7 reference information model), but only the wrapping between the facts contained in the community fulcra and the corresponding data managed by the third-party applications that are connected to the fulcra as entities.

In the scenario outline above, we fancied that the allergy-detecting rule had been conceived at regional level and be spread into the patients' fulcra by the family doctor to be fetched in all the entities (associated with healthcare practitioners) where it can find application; in fact, we believe that only with a top-down commitment of a healthcare agency a common way to indicate drugs and express conditions can be enforced between different facilities for interoperability's sake. On the contrary, rules that regard how long a patient should wait a treatment in a particular condition or after how long a catheter can harm a patient depends on local policies and conventions concerning how ward work is organized, what resources are employed and what devices (e.g., catheters) are used in a particular facility. For this reason, these latter rules are to be considered local to the MF and RU communities although they must match how contextual conditions are declared in the fulcra to be activated and executed to produce the opportune APIs.

B. Awareness information conveyed through the spaces

In the medical literature, the term Clinical Pathway (CP) indicates a process model that represents how clinical interventions and decisions have to be temporally articulated in the management of a particular clinical case according to the latest medical evidences and local best practices [31]. More specifically, a CP represents the specific treatment plan that a group of clinicians have agreed to establish as their reference in treating a specific acute disease in order to reduce the odds of inappropriate interventions and improve quality of care. Recently, also Integrated Clinical Pathways (ICP) have been proposed [32, 33]: they are plans of best clinical practice that involve multiple and heterogeneous teams that take turns with each other to manage the unfolding of either long, chronic or complex illness trajectories requiring a multidisciplinary approach. In this case, ICPs can be seen as models of processes that unfold across different communities and groups of practitioners and that are employed in order to represent mutual interdependencies explicitly and to improve the quality of coordination among the involved practitioners. An interesting case is that when an ICP comes out from the articulation of multiple CPs that are connected together. In this case, the single CPs, pertaining to a given community of care-givers, encompass 'exit conditions' that trigger the starting (or continuing) of CPs of a different community of care-givers. A typical case of this occurs when a patient is admitted into a facility (e.g., hospital department or ward) and her treatment plan includes her transfer to another facility in few days. The referring and referred communities have then to agree on how to hand over the clinical case in hand and ICPs can be used to support this exchange in a transparent and effective way.

As presented in the fragmented care scenario (Section 3), moving a patient from a care community to another one could be a source of problems due to the loss of important information (e.g., Mrs. P.'s allergy to ACE inhibitors) but also for the lack of awareness about what is going on in the care trajectory by the members of the care departments that are not currently involved in the care process. To provide awareness about patient care and to support collaboration among care departments and avoid fragmented care, we can define an integrated community space that is accessible by the entities belonging to different care communities: this space is defined on the basis of the ICP that, assigned to the patient at the ER triage, defines the overall caring process that involves these communities. For sake of simplicity, let us consider in what follows only one of the many possible ICPs involving the communities mentioned above and, even more specifically, the part of the ICP that is managed by a single community. In the reference scenario we can assume the existence of such portion of ICP (that for sake of clarity we still call CP) and define the integrated community space in accordance with this CP as shown in Figure 5: each site of the space represents a task of the CP and an arc is created between two sites if in the CP there is a link between the two tasks that these sites represent. In addition, let us suppose that the relevant information that is to propagate in the space concerns the amount of patients that are handled by each task of the CP: that is, the integrated space hosts patient entities at the related sites. Typically, this kind of information is propagated following the causal relation of the tasks in order to make the entities involved in the following tasks aware that a certain number of patients can be expected to get access to their facility. As described in Section 2, an arc can be weighted for each type of awareness information and that weight can be different in relation to the information flow. By using this feature, the situation described above can be modeled by assigning appropriate weights to the arcs as shown in Figure 5 (where the symbol / means "no propagation"): the arcs of the space are weighted for the patient presence information. The resulting space, shown in Figure 6, contains an oriented arc from node A and node B to let the information propagate from A to B (and to avoid information propagation from B to A). Instead, the arc between the node F and the node G is oriented in both directions because in the ICP there is a loop between the two tasks represented by the nodes F and G.

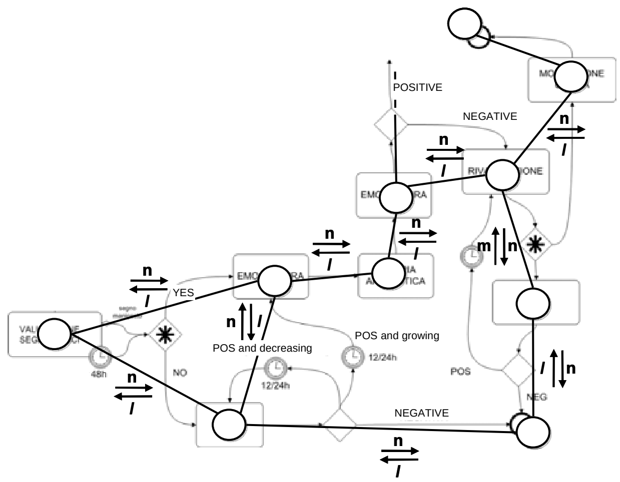


Figure 5. The weighted (for the patient presence information) space mapped over the ER's CP.

An integrated community space based on a CP is instantiated the first time that a care community applies the CP to a patient; then the new space is shared for all the patients to which the same CP is applied (Figure 6). In our scenario, the instantiating community is a single hospital department, namely the ER community. As anticipated, in the community space each patient is situated in the site that is related to the current task that doctors are executing about/on her; instead the other departments (e.g., the MFs) and laboratories of the hospital are situated according to the task that involves (or could involve) them. The ER practitioners' entities are situated according to the position of the patient they are currently treating, in fact a practitioner takes care of one patient at a time (for sake of simplicity we represent ER entities only on Figure 7 because they are directly involved in the perception of the awareness information).

Each patient entity emits its presence information and this is propagated in the space. The presence information of all the patients is composed on every reached site. The department

and laboratory entities perceive the composed patients' presence and, in so doing, they all become aware of what is going on in the care process and in particular of how much workload/effort they should expect in the near future because new patients are approaching. For instance, let us suppose the task G is about preparing a patient to be transferred to the MF department and that the task H is the actual transfer, i.e. the CP terminates: when Mrs. P. is transferred to the MF department, the entity corresponding to her is situated on site H (Figure 6) of the adopted CP. The MF entity is situated on the same site H but also on site G since this task concerns the MF too. The MF entity perceives the presence information about patient Mrs. P. with a high intensity at H because Mrs. P. is at the same site (thus the Mrs. P. presence information has the highest intensity), but the MF entity perceives also the presence of three other patients in sites that are close to the site H, two patients from the site G and one from the site C (Figure 6): in this latter case with a lower intensity since the MP entity is not situated in C. This choice has been adopted because the transfer to the MP department does not imply an immediate use of its facilities and it is less likely to happen.
Due to the awareness information perceived by the MF entity, the MF department can plan next due activities to be prepared to accept new patients in the near future. When Mrs. P. is transferred from the ER to the MF department, she is no longer situated on the ER's CP space and consequently the MF entity perceives the patient presence at a lower intensity. In fact, Mrs. P. will be situated in the MF's part of the whole ICP space that corresponds to the local CP that the MF doctors will adopt to treat her disease. On this new portion of space similar awareness promotion strategies can be defined to support the stakeholders involved in the underlying CP that informs the handling of new part of Mrs. P.'s illness trajectory.

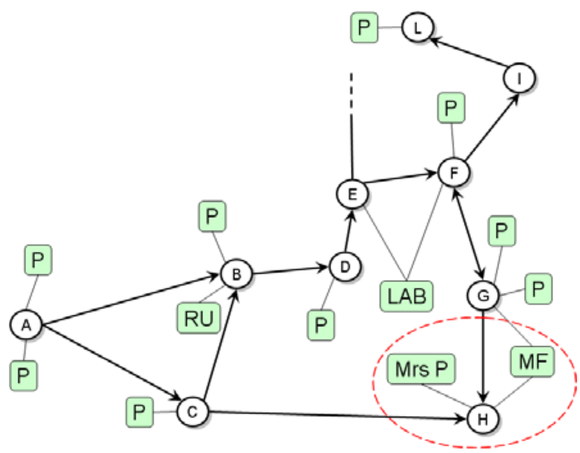
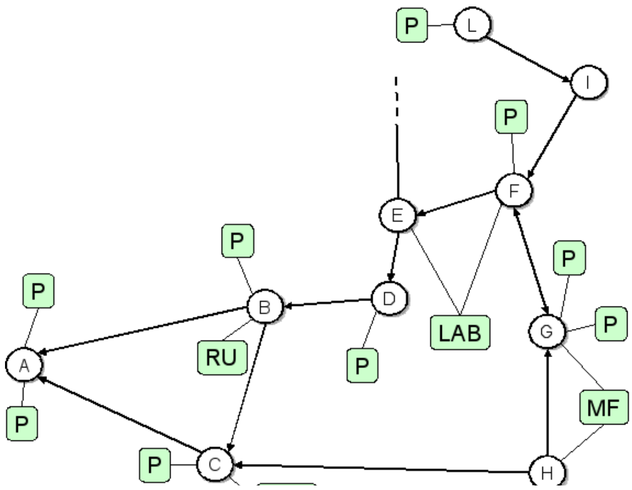


Figure 6. Department, laboratory and patient entities situated on the ER's CP space.

To avoid problems during the handover between departments, when Mrs. P is transferred from the ER to the MF, the MF entity emits a "taken on" awareness information on the node H once the MF staff has actually taken the patient on. The "taken on" awareness information is propagated on the same space defined for the patient presence information but the arcs are weighted differently (recall that arcs can be weighted for each type of awareness information): the resulting space shown in Figure 7 contains two oriented arcs from node H to node G and C to let the information propagate from H to G and C (and to avoid information propagation form G and C to H). The same principle holds for the other arcs. The information is propagated with the same intensity on all the nodes of the space. In this way, the awareness information reaches the ER practitioners entities (e.g. ER1) wherever they are situated: ER1 is informed that MF has taken Mrs. P on while he is treating another patient P (see Figure 7).
To avoid information overload, each ER entity can only perceive the information regarding her patients thanks to the filter on the patients IDs (e.g. Mrs. P), and only in those moments when the practitioner can be informed without too much disturb, by means of the perception threshold. In fact, the perception threshold can be changed so that the "taken on" information can be blocked at all.

V. ProDoc

In order to validate our model, we integrated the ProDoc (Process-oriented Documentation) with CASMAS-WOAD (as presented in Section 2). ProDoc is a web-based application that we had previously realized to support practitioners from different domains in integrating protocols into their documentation (e.g., records, charts, forms) while they document their work in a process-oriented fashion. This twofold goal is declined with two main features. On the one hand, ProDoc allows users to build, customize and use a graphical interface for data entry and retrieval that closely resembles the 'look–and-feel' of their usual paper-based artifacts so as to mimic the typical interaction with paper forms. This means that, instead of presenting a set of masks to (and views from) the underlying database, ProDoc manages and displays a set of *persistent* documents and forms, like these were concrete sheets from a regular paper-based medical record. In so doing, ProDoc allows users to natively treat and use data in the very terms of the documents they progressively compile. In addition, ProDoc presents user-defined active maps that depict the process schema according to which work should be carried out in the same interface hosting the document to work on. In so doing, ProDoc allows users to get access to any part of the documentation out of any rigid workflow and promotes their awareness of the intended flow of activities as it has been defined locally on the basis of practitioners' consensus.
We experimented the prototype in the domains of hospital work [34, 35] and of archaeological excavations [36]: in both cases we received encouraging success and useful indications on how to improve the application. In the hospital domain, ProDoc was used to facilitate the filling in of the charts and forms of the patient record adopted in two hospital departments: in particular, its process maps were used to represent clinical pathways explicitly and facilitate their inclusion in daily practice, especially by novices and practitioners who were new to those departments. On the other hand, archaeology is a domain with deep and interesting analogies, especially with respect to the high level of flexibility and adaptability that is required in adopting standard procedures and to the likewise pressing requirement of safety, whereas the risk to damage a find is similar to that of



injuring a person (in terms of irreversibility of action, at least) and it requires users to learn well how to cope with unexpected situations in apt and effective ways.

To convey the two features mentioned above, the main interface of ProDoc has been divided in two sections (see Figure 9): the Process Panel and the Data Panel. Shortly put, the former one provides functionalities of process overview and document navigation; the latter one provides user with access to data through paper-looking documents. In its current version, these documents are PDF forms that users can enrich with either textual and graphical annotations supplied by the Acrobat platform.

The Process Panel allows users to have a quick glance of the process map, through the so called Process Map (on the right in Figure 9), to manually set the current activity of the process through the Activity section (on the left), and consult the history of past interventions, through the Timeline (beneath these two sections).

For the aims of this paper, we now focus on the Process Map: this is a window where the system displays a graphical, flow-chart like representation of the CP that is currently applied to a specific patient. The process map is an active map in a twofold way: on the one hand, the diagram elements are active links since they make their associated documents be displayed in the Data Panel according to the current activity. According to the outcomes of the ethnographic studies we undertook in the same settings where we deployed ProDoc [37, 38], ProDoc highlights the activity under execution in green, while any other activity on focus is conveyed in yellow when it does not coincide with the former: e.g., when the user wants to access information contained in some documents associated to this activity. On the other hand, the Process Map is active in the sense that it can convey the API generated by the CASMAS-WOAD layer by changing how the process schema look like. In relation to the scenario discussed in the previous sections, an element of the diagram can have associated tokens (i.e., graphical icons) that represent where the patients are within the abstract trajectory of her hospital stay, or in what activity of other portions of the ICP other practitioners are involved (see the red icon and the green and blue ones, respectively in Figure 8). Another possibility could be to highlight a crucial activity in the same line as the some pieces of crucial information can be highlighted in the associated documents (as described in the scenario). All these mechanisms are expressed in the WOAD language and specify in their THEN part the kind of API under concern. In the ProDoc architecture this information is passed to the module in charge of managing the appropriate rendering at the interface level as shown in Figure 8 .

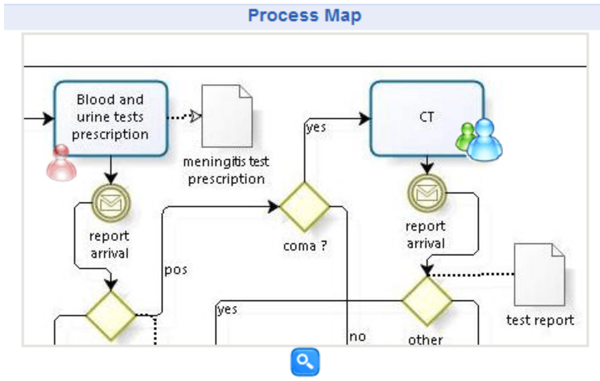


Figure 8. A detail of the process map depicting the indications of what the patient (in red) and the care givers are doing at a particular time.

VI. Conclusions

In this paper, we discussed the problem of inter-organizational process fragmentation. As a step toward the solution of this problem, we presented how the CASMAS architecture and the WOAD framework can be used to model some mechanisms aimed at improving mutual coordination and awareness among the involved actors.

We illustrated the point focusing on a typical case of care fragmentation where the lack of mutual awareness and multiple gaps in knowledge sharing among the members of communities of professionals and relatives created serious problems to an elderly person who had previously had a stroke. This example is paradigmatic of several problems in healthcare as well as in other domains that are characterized by heterogeneity, fragmentation and high demand of support to cooperation, coordination and knowledge sharing. Another typical domain is the domain of cultural resource management, where we are now applying CASMAS-WOAD for the design of coordination supports. In both cases, CASMAS-WOAD provides constructs that are adequate to capture the main requirements raised by these domains, and to govern accordingly the specialization of general-purpose collaborative applications that can be used for the construction of prototypes to be validated with potential users. In this paper we gave such an example, presenting ProDoc, an application we developed to give a flexible support to document-based processes, but the same approach can be taken for any other application with the suitable degree of openness and interoperability guaranteed by adequate application programming interfaces.

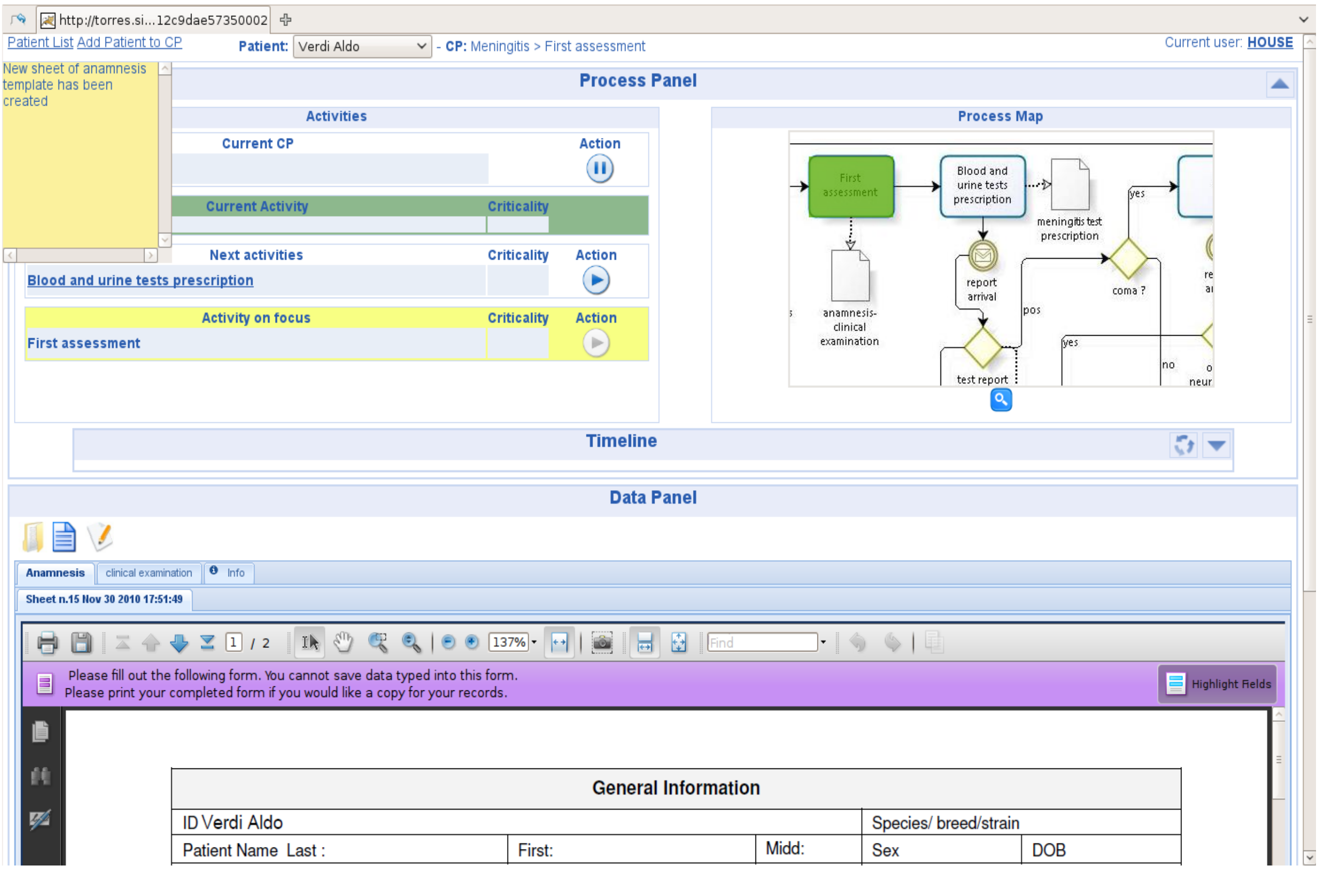


Figure 9. The main interface of ProDoc. On the top, the Process Panel with the Process Map and Activity section open and the Timeline minimized; on the bottom, the Data Panel

Future developments regard the development of a framework where the constructs of CASMAS-WOAD can be defined to make its usage easier in the conception and design of cooperative applications. In the meanwhile we will continue the ethnographic studies to identify additional user requirements to improve the usability of the framework and of the collaborative applications it allows one to construct.

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