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Research Topics

Contents

1. Building information system specifications from integration of stakeholders' concerns

In order to reach a short- or long-term objective we, the humans, should fill the gap between a current unsatisfactory situation and a future one which fulfills the objectives. This gap represents a problem to be solved for us. The problem is nothing else than some our concerns (needs, interests, desires, or beliefs) regarding the current situation which should be changed to reach our objective. These concerns are the causal elements of our subsequent actions. Let consider the case of a new product that should satisfy the changing needs of some categories of people interested in that product (the product stakeholders). To design such a product many needs, interests and desires of the product stakeholders turn into the designer's own concerns. Furthermore the designer's intentions, but also plans and actions are structured according to the product stakeholders' concerns.
In [9] we introduced the "facet" concept as a model of the future product as it is shaped in the designer's mind by his/her concerns. Each facet corresponding to a concern is represented as a frame where the product properties or behavior that are relevant from the point of view of the concern are put together and related to each other. Many facets are needed to model the product according to all stakeholders' concerns. This is why in our approach the specification of the future product itself results as a faceted entity. This fact is already recognized in current design methods where are promoted several types of models to be built in order to develop a new product. For instance to develop a software product the following model types are compulsory: functional, structural, and behavioral models. Our claim is that these models should be structured in turn in accordance with the stakeholders' concerns are also multiplied according to several points of view on the product.

In the followings some excerpts from [9] make clear the approach when applied to products delivered by the software process. But the same approach can be used for any other human artifact

USER VIEW CLUSTERING

"When we analyze an existing Software Object (SO), we study it only through its facets. We claim that the most suitable schema for SO modeling is the *facet cluster*. Each facet in a cluster is a model of the object that the cluster represents, a user's view of this object. (Here the user is someone who uses the SO, for example, the developer, the manager, or even … a software tool.) It is also possible that several users may have different views of the same object as a consequence of *different occasional interests, structuring criteria, or level of concern*. This relativity in the approach to SOs is vital for SO understanding and processing."

DESIGNER'S VIEW

"To overcome the inherent complexity of the objects (here and in the followings objects are artifacts) of the design process, the designer has to build each object from many parts – in fact, various views of the object – called *facets*. Each facet will be useful sooner or later in a certain step of the process for a certain operation. All facets of an object should be sufficient to completely analyze or evaluate it. *Thus they define the object itself.* "

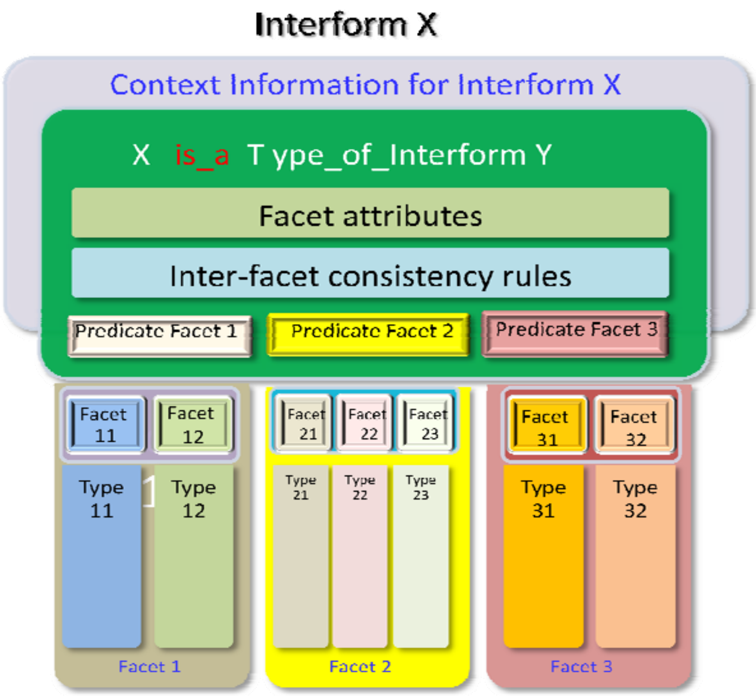
"… following valuable suggestions found in the domain of semantic nets, we can imagine the mental representation of a SO as a collection of knowledge conglomerates, each of which is a facet of the SO. The developer's metamodels are used to structure these conglomerates into nets, resulting in mental representations of other objects.

… the facets of a SO are linked together by various associations … The link is semantically based on the affiliation of the facets to the same object. .. the link should express the information that brings together the knowledge residing in all models of the object. The linkage should also explain how, from knowledge residing in one model, we can infer knowledge residing in other models of the same object or how the models of the object should be updated as a result of one change in one of its models.

The linkage counterpart in our model should be the unique means to preserve the mutual consistency of the facets. There must be a mechanism to both unify and allow the user's view without influencing their content. Let us call this mechanism the *designer's view*.

… Access to the SO viewed as a whole and through each facet should be ensured. This is why the designer's view into the object should include both its components (its facets) and their mutual relations. The unifying task of the mechanism is accomplished by a set of consistency rules. A consistency rule is a constraint between two facets i and j that insures their mutual consistency, the fact that they belong to the same object. Therefore, any change in a facet should be accompanied by changes in all other facets which are not orthogonal with it. These changes must preserve the mutual consistency of the facets. To perform such a change, which is compulsory when the objects are not only to be represented, but effectively built, transformation procedures to preserve object consistency are needed. The procedures and the rules are redundant items, but both are useful at different times.

From where mental representations of the product to be designed arise in our mind and how they are assembled in increasingly more complete beliefs on the future product? What are the most appropriate representations to describe this process of continuous aggregation of these models and their adaptation to the designer's (themselves evolving) concerns? Such questions and others like them led us to the concept of *Interform* as a means of describing complex products. We define *interform* (intermediate form) as the amount of information we are able to represent at a certain moment during the design phase for the various logical parts of the future program. The concept is derived from Minsky's *frame* concept [13] and was initially used in [9] to specify evolving models of software products, but it can be easily expanded to model other products [10,18-22]. It refers to the collection of knowledge, beliefs, and practical experience that make up all what is necessary to a designer to imagine the future product during the design process.


Interform X
Context Information for Interform X
X is_a T ype_of_Interform Y
Facet attributes
Inter-facet consistency rules
Predicate Facet 1
Predicate Facet 2
Predicate Facet 3
Facet 11
Facet 12
Type 11
Type 12
Facet 21
Facet 22
Facet 23
Type 21
Type 22
Type 23
Facet 31
Facet 32
Type 31
Type 32
Facet 1
Facet 2
Facet 3

2. Using storyboards for domain model consolidation

An excerpt from L.D.Serbanati, "*Catre o proiectare dirijata de concern-e* ", in A. Bazac, G.C. Constandache, C. Ionita, L. Pana (coord.), „*Logica si provocarile sociale. Omagiu Profesorului Cornel Popa*", Politehnica Press, 2008., explains this research topic when applied to the healthcare domain.

O vizita medicala inregistrata de un observator (A medical visit as it is recorded by an observer)

Storyboard (narrative text in Romanian)

Dan Gheorghiu este *pacientul* doctorului Ion Popescu, un *medic* care isi primeste pacientii in cabinetul din *policlinica* in care este angajat si ofera pacientilor *servicii* de asistenta medicala. Dr. Popescu trateaza pe dl. Gheorghiu de o *boala* depistata cu ceva timp in urma, drept care intre cei doi deja au avut loc mai multe *contacte* de tip *vizita medicala*.

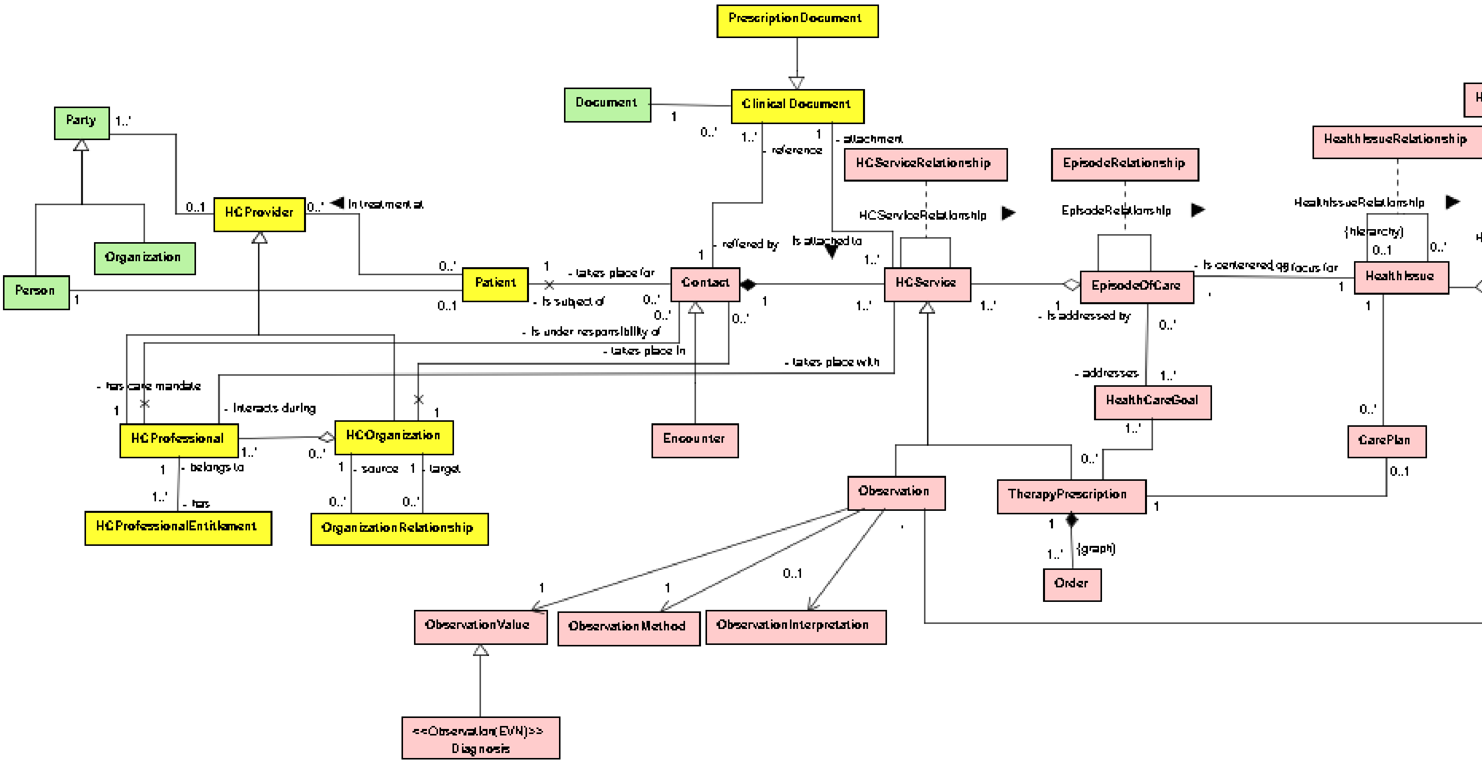
Nota 1. O *boala* , uneori chemata *afectiune*, este o modificare organică sau funcţională a echilibrului normal al organismului uman. Ea se manifesta ca un proces patologic care afectează parametrii vitali ai organismului modificand starea de sanatate a unei persoane. In general, *starea de sanatate* este o evaluare generala, validata de profesionisti certificati, a nivelului de bunastare fizica si mentala sau eventual de boala a unei persoane, nivel descris printr-un numar de indicatori, unii obtinuti prin *observatii* directe sau ca rezultate ale unor masuratori obiective, altii derivati din informatii furnizate de persoana evaluata.

Nota 2. *Contactele* sunt intalniri pe care un pacient le are cu un profesionist in domeniul sanitar sau cu o structura sanitara (policlinica, laborator de analize, spital, dar si casa proprie daca pacientul este luat in evidenta sub ingrijire medicala acasa) in scopul tratarii unei boli. Contactele pot fi vizite medicale, spitalizari, analize de laborator, proceduri de fizioterapie etc. In cursul unei vizite medicale un medic observa starea de sanatate a pacientului, emite un nou *diagnostic* sau confirma sau schimba diagnosticul precedent, prescrie pacientului un *tratament* nou sau confirma continuarea tratamentului existent, toate acestea cu *obiectivul* de a ajunge la insanatosirea pacientului.

In cursul vizitei dr. Popescu inregistreaza simptomele declarate de pacient, face propriile *observatii clinice* consultand pacientul, consolideaza sau schimba *diagnosticul* si decide sa ii schimbe tratamentul anterior, prea costisitor, cu unul mai ieftin. Tratamentul prescris prevede administrarea unor *medicamente* pentru care medicul elibereaza *retete* si respectarea unui regim alimentar special, dar si efectuarea unor *analize de laborator* cu scopul de a obtine noi observatii asupra starii de sanatate a pacientului rezultata dupa administrarea medicamentelor. Pentru aceasta dl. Gheorghiu va trebui de asemenea sa continue seria vizitelor medicale lunare pana la completa insanatosire care este *obiectivul* tratamentului ales de dr. Popescu pentru rezolvarea *episodului clinic* asociat *bolii* de care sufera pacientul.

Nota 2. Se numeste *contact initial* (*trigger*) vizita medicala in care pacientul s-a prezentat pentru prima oara cu simptomele unei boli pe care doctorul curant o *diagnosticheaza* ca noua in istoria clinica recenta a pacientului. Seria contactelor necesitate de rezolvarea problemelor provocate de aceasta boala si pe care pacientul le are cu medicii si diverse structuri sanitare se va incheia in momentul in care simptomele bolii respective vor disparea, iar medicul curant va putea confirma ca pacientul s-a insanatosit. Se numeste *episod clinic* al unei boli de care sufera un pacient secventa temporala a contactelor pacientului cu medici si structuri sanitare, contacte necesare pentru tratarea bolii din momentul observarii ei (contactul initial) pana la disparitia ei datorita tratamentului (*inchiderea episodului*).

All (or at least the most representative possible) such storyboards should be collected from the investigated domain. The concepts identified in these storyboards should be defined with the aid of other concepts and of their semantic relationships as they are highlighted in storyboards. Definitions should be as accurate, complete and unambiguous as possible using formal languages such as OWL or semi-formal languages such as UML. A UML class diagram representing the domain model of the Contact concept is presented in the following figure:



The ultimate goal is to define these concepts through **a** formal ontology and **a** semantic language**.**

3. Structuring digital world in digital ecosystems by mapping real systems to digital

A natural life ecosystem is defined as a biological community of interacting organisms plus their physical environment. Applying this definition to the health domain we can define a health ecosystem as the network of a multitude of care providers (physicians, nurses, pharmacists, and other health professionals), health suppliers, together with their organizations and information systems, care consumers, plus the socio-economic environment and including the health institutional and regulatory framework.

An ecosystem is a biological environment consisting of all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, water, and sunlight. The entire array of organisms inhabiting a particular ecosystem is called a community.

Ecosystems are functional units consisting of living things in a given area, non-living chemical and physical factors of their environment, linked together through nutrient cycle and energy flow.

Central to the ecosystem concept is the idea that living organisms interact with every other element in their local environment. Eugene Odum: "Any unit that includes all of the organisms (ie: the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e.: exchange of materials between living and nonliving parts) within the system is an ecosystem."

Arthur Tansley: "The whole system, … including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment"

Human ecosystems are models of complex cyber-physical systems that are increasingly being used by ecological anthropologists and other scholars to examine and model the ecological aspects of human communities in a way that integrates multiple factors as economics, socio-political organization, psychological factors, and physical factors related to the environment.

The digital ecosystem approach transposes the concepts of a given natural domain to the digital world, reproducing some of the mechanisms of natural ecosystems. For instance digital business ecosystem is a self-organizing digital infrastructure aimed at creating a digital environment for networked organizations that supports the cooperation, the knowledge sharing, the development of open and adaptive technologies and evolutionary business models. Such a digital ecosystem is populated by “digital components” which evolve and adapt to local conditions thanks to the re-combination and evolution.

Boley & Chang: Digital ecosystem is an open, self-organizing agent environment containing human individuals, information services as well as network interaction and knowledge sharing tools along with resources that help maintain synergy among human beings or organizations, where each agent of each species is proactive and responsive regarding its own benefit/profit but is also responsible to its system .

We claim that a Digital Ecosystem is any distributed, adaptive, open, socio-technical IT-based system, with properties of self-organisation, scalability and sustainability, inspired by natural ecosystems.

<u>Problem</u>

Given a natural ecosystem or any natural system which verifies the condition to be a jurisdictional area with own population and behavior regulation that roughly behaves as an ecosystem, how can we design a digital ecosystem able to interact with the natural system in order to improve the last one’s behavior.

Hints:

1. Consider the natural system as a jurisdictional system with own business rules (constraints), model its structure and behavior, and try to identify those echosystem characteristics of the system that should be emphasized, extended, or optimized with the aid of a digital ecosystem that supports it.

2. Identify the services of the new digital ecosystem that enable the natural system to evolve as a optimized ecosystem.

3. Design and implement a software architecture for the digital ecosystem supporting the natural one. Any architecture that currently satisfy these requirements should be layered and service-oriented. The most natural software technology able to implement such digital ecosystems is the intelligent agent technology.

Software agents are software components that act autonomously across distributed environments by observing and acting upon their environment to carry out some tasks usually established at design-time. A software agent is intelligent when it directs its activity towards achieving some goals on behalf of its users concerns. To achieve these goals intelligent agents may use embedded knowledge and7or learn it from their context. The paradigm of intelligent agent-based systems technology can be used to specify, design, and implement digital ecosystems. Applying the intelligent agent-based paradigm to complex applications may require multiple agents that work together for solving problems in a Multi-Agent System (MAS) on behalf of organizations, professionals, suppliers and consumers, or even agents themselves.

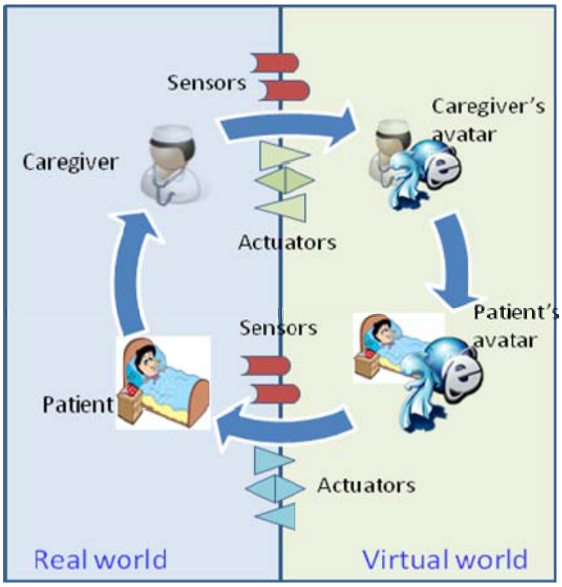
4. Strengthening Context-Awareness of Virtual Species in Digital Ecosystems

ICT is giving us the ability to present information anywhere and anytime. Despite this ability, there is often a large gap, in fact a cognitive distance, between physical spaces and virtual information (computing) spaces. Ambient Intelligence is about how this cognitive distance can be reduced, i.e. how to create an environment that is sensitive, adaptive and responsive to the presence of people, in order to create the desired atmosphere and functionality. This environment should be aware of human presence, needs, and personalities, and capable of intelligent interactions with humans. Ambient Intelligence is not only *Intelligent User Interface*, and *Ubiquitous Communications and Computing*, but also *Context Awareness*. A technological challenge in ambient Intelligence is represented by *smart objects* (Internet of Things).

The *context* concept that software applications explicitly use can be extended and refined as a multifaceted collection of information about the situation in which an entity, be it person, thing or application is. This information may reshape the interpretation that other entities involved in interactions with that entity give to the entity state or behavior. Studying the context-awareness of species in the domain of digital ecosystems highlights new facets for the context of entities in the real and virtual world, and enriches interaction scenarios with added conversational bandwidth.

Context is a collection of information that entities in health systems (usually stakeholders, but also software applications) can use to characterize the situation of another entity (usually a person, but also a software application) in its environment and to reshape their interpretation of the state or behavior of this last entity.

Let consider the health domain where we identified the (natural) health ecosystem and its IT support, the Digital Health Ecosystem (DHE). The following figure schematically shows the interactions between the world of real entities (patients, caregivers, etc.) and the virtual world of online communities of digital applications and resources, be they avatars and virtual organisms in a DHE. The two worlds are bridged by boundary components in the real world that can be either information sources (*sensors* that generate data representing some measurements in the real world) or information sinks (*actuators* that consume data representing some commands to modify something in the real world) for digital species in the virtual world.



According to our definition of context the approach to studying the interaction between the real world and the virtual world demands that a distinction be drawn between the context of a person, the context of its avatar and the context of any other resource used by the avatar.

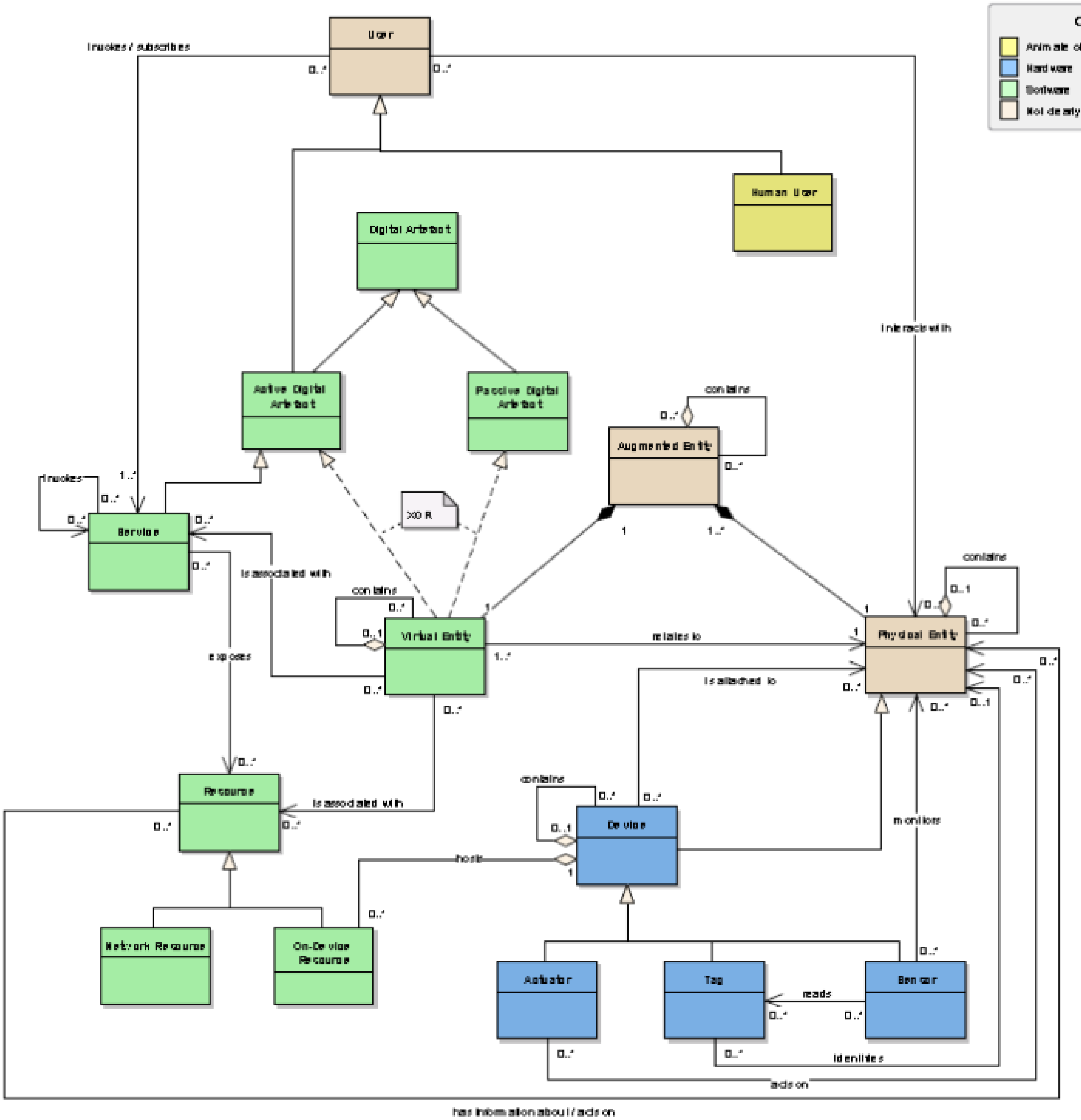
1. Let take into consideration the context of a person, engaged as a patient in a care process. The medical history, that is the historical record of the health-related events and episodes of care (past diseases, immunizations, etc.), heavily influences the caregiver's interpretation of the patient's health state. To formulate a diagnosis or provide medical care a caregiver must also know which are the treatments in progress, the most recent measured vital parameters, in other words the patient's *current health state*. We extended the patient's context with this information as the *clinical context*, a distinct facet with respect to the *ambient* facet (location, time, and activity) of the whole context.
2. In the case of any person, be she/he a patient or caregiver, engaged in a care process we found useful to extend her/his context with her/his BDI. Such an information regarding the patient may subjectively weigh on the caregiver's care decisions and the same information regarding the caregiver may influence the patient's confidence in the caregiver's professionalism. As a consequence we extended the person's context used in DHE with this information as *emotional BDI context*, a distinct facet with respect to the *ambient* and *clinical* facets of the whole context. In the caregiver case we added to this facet information on her/his previous professional activity.
3. The avatar, as a software application, should include all the characteristics of such an entity in its context: its own computing environment and interoperability, that is the ability to connect to and exchange messages with any other resources, in particular with other avatars. But, as a consequence of the virtualization process, the avatar also represents its owner`s interests in the virtual world, in our case in DHE. Accordingly, the context of an avatar should also include all information in its owner context.
   a. When the avatar's owner is a patient, in order to represent her /him as accurately as possible her/his health situation should be translated into virtual as a specific digital object, the clinical context, that includes information on the patient's medical history, the current health state (health issues and vital parameters), and envisaged workflow of health services for ongoing treatments. We consider that all this information is found in our authoritative VHR. **Errore. L'origine riferimento non è stata trovata.** This is why we decided that the avatar, in its interactions with other digital entities, has to access by means of its agents the services exposed by the patient's VHR for either selecting required information for a given situation or updating the VHR content with authorized information.
   b. When the avatar's owner is a caregiver, her/his professional profile, schedule, patients, work load etc. should be translated into the virtual. In this way the caregiver's avatar can authoritatively collaborate with avatars of other caregivers and patients. For instance, in order to care a patient, it can negotiate with some "colleagues" its participation to virtual organizations, i.e. ad hoc created medical teams. In the caregiver case, the avatar should carefully maintain the ambient, emotional BDI and social context facets.

Once the context characteristics of various entities belonging to the two worlds in the health system are established, we have to define associations between the contexts of related entities. Such a relationship enables interactions between the roles participating in the association. For instance, a caregiver avatar enriches the owner's context, by replicating, maintaining and augmenting the social component of the owner's context any time the participation to a new virtual organization is negotiated. The avatar can subscribe, on the owner`s behalf to such virtual organizations constructed on different basis such as disease-oriented, location-oriented or centered around an episode of care.

Using such an extended context has the advantage to increase the conversational bandwidth in interaction scenarios. By virtualizing the patient context in the patient avatar we strive for a bigger payload of meta-data in the interaction with other avatars, increasing the semantic load of conversation and facilitating the achievement of its goals.

5. Behavior of smart object communities, networks and ecosystems

In our approach a **Smart Object** is a physical or virtual entity that is augmented to interact with not only people but also with other smart objects: physical world but also virtual (computing environment) entities. The interaction is based on semantically interoperable messages. A smart physical object may be created either as an ad hoc artifact or by embedding electronic tags such as RFID tags or sensors into a non-smart physical object. Smart virtual objects are created as software objects able to communicate with other smart virtual objects but also with physical world objects enabled to interact with the virtual world using sensors and actuators. In the following diagram the domain model of the smart objects is proposed.



The IoT Domain Model [82]

Smart objects vocation is to communicate and reason on messages received and sent. They may inform others smart objects on some event occurrence: own state change or something happened in the environment. When this interaction has an objective, the smart objects collaborating for this objective make up a community. This community can be studied in its isolation, but also in its evolution in a wider environment. This community can be a community of species in an ecosystem, too.

The goal of this research is to create an ecosystem of **sensing**, **reasoning**, and **action** around smart objects as species.

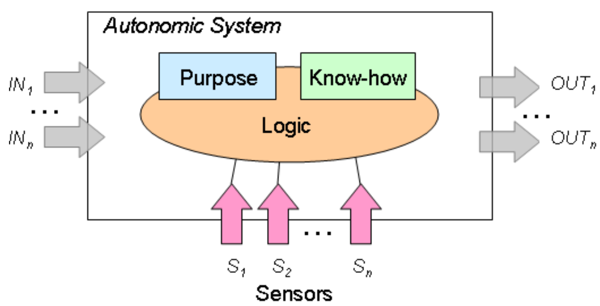
6. Autonomic computation

Autonomy-oriented computation is a paradigm proposed by Jiming Liu in 2001 that uses artificial systems imitating social animals' collective behaviours to solve difficult computational problems. In the same year IBM launched Autonomic computing, an initiative that aims to develop computer and information systems capable of self-management, in order to control the rapidly growing complexity of computing systems management. The initiative is inspired by the autonomic nervous system of the human body that controls important functions (e.g. respiration, heart rate, and blood pressure) without any conscious intervention.

So, **Autonomic computing** refers to the self-managing characteristics of distributed computing resources, adapting to unpredictable changes while hiding intrinsic complexity to operators and users. It represents the ability of an information system to manage itself automatically through adaptive technologies that further computing capabilities and cut down on the time required by computer professionals to resolve system difficulties and other maintenance such as software updates.

In an autonomic scenario the autonomic system makes decisions on its own, using high-level policies; it will constantly check and optimize its status and automatically adapt itself to changing conditions.

The conceptual model for autonomic systems includes some essential components. First of all, a building block representing the sensing capability (*Sensors* Si), which enables the system to observe its external operational context. Inherent to an autonomic system is the knowledge of the *Purpose* (intention) and the *Know-how* to operate itself by bootstrapping, configuration handling, external information interpretation, etc.) without external intervention. The actual operation of the autonomic system is dictated by the *Logic* building block, which is responsible for making the right decisions to serve its Purpose, and influence by the observation of the operational context (based on the sensor input).



For example, not only the classical ant colony optimization topic, but also adaptation aspects of digital ecosystems could be studied in this paradigm. Like in autonomic systems the actions in an ecosystem are purpose-driven. A “mission” exists in any ecosystem, as policies exist that define the basic behavior), and finally a “survival instinct” exits in both paradigms. A true digital ecosystem as any autonomic system should be essentially based on a control system loop with its feedback error function complemented with some heuristic algorithms that bounds the system to its environment.

According to all above this topic may be considered a specialization of the topics 4 and 5. In fact, the characteristics of every autonomic system include: automation, adaptivity and awareness. As a consequence, automatic computing includes four research areas: self-configuration, self-healing (error correction), self-optimization, and self-protection that cross both context awareness and adaptivity in digital ecosystems.

7. New architectures for health information systems

Although the demand for use of information technology within the healthcare industry is intensifying, relatively little has been written about guidelines to optimize IT investments. A technology architecture is a set of guidelines for technology integration within an enterprise. The technology architecture is extremely valuable to health care organizations both in controlling costs and promoting integration. The architecture is a critical tool in the effort to control information technology (IT) operating costs by constraining the number of technologies supported. A well-designed architecture is also an important aid to integrating disparate applications, data stores and networks. The student research should lead to the development of a thorough, carefully designed technology architecture for a large and rapidly growing health care system. Purpose and design criteria should be identified in the current standards (HISA, CEN) and information systems presented in papers from the literature.

The use of middleware to develop widely distributed healthcare information systems (HIS) has become inevitable. However, the fact that many different platforms, even sometimes heterogeneous to each other, are hooked into the same network makes the integration of various middleware components more difficult than some might believe.

This research discusses the HISA standard and proposes extensions to the model that, in turn, could be compliant with other various existing distributed platforms and their middleware components.

The deliverable should:

- Discuss emerging trends in health information technology (such as mobility, Web services, Internet, wireless).
- Identify some of the major issues in the adoption of information technologies in health care organizations.
- Discuss why it is important for a health care organization to adopt an overall information systems architecture.

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"When one encounters a new situation (or makes a substantial change in one's view of the present problem) one selects from memory (instantiates) a structure called a Frame. This is remembered framework to be adapted to fit reality by changing details as necessary. A frame is a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child's birthday party. Attached to each frame are several kinds of information. Some of this information is about how to use the frame. Some in about what one can expect to happen next. Some is about what to do if these expectations are not confirmed."

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