Influences of the Unified Service Action Model on the HL7 Reference Information Model

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Modeling information for the electronic medical record (EMR) builds on a century of study on information and its relationship to cost and quality improvement. An initiative to examine the focus of cost and quality improvement and its relationship to information modeling resulted in the development of the Unified Service Action Model of healthcare processes, which focuses on the action as the center of cost accounting, quality accounting and privacy management. The application of this model to the HL7 Reference Information Model produced a simplification of the HL7 model at the cost of increased reliance on vocabulary terms for actions.

Introduction

Support for information systems in healthcare depends on the ability to demonstrate cost and quality improvements in the care of patients and the management of healthcare organizations. However, it is really the information model of healthcare information systems that defines the structure for healthcare data and enables analyses for cost and quality improvement.[1,2] Healthcare is a series of actions that are performed to benefit patients. Of the costs that might be captured in the data model of an information system, the cost of actions by labor is the largest percentage of the cost of running a healthcare organization.[3]

The HL7 Technical Committees Patient Care and Orders/Results created an information structure for expressing the relationships between actions in healthcare in HL7's Reference Information Model (RIM). This initiative, called the Unified Service Action Model (USAM), was inspired by the foundation work on action and meaning by the Pragmatic Philosophers Peirce[4–6] and James[7,8] in the late nineteenth century and the resulting popularization of quality improvement processes by Deming[9,10] in the mid-twentieth century. The thread that ties the geologist Peirce, the physician James and the statistician Deming to the USAM is the recognition that *managing actions* is central to the problem of improving quality and controlling cost.

Outline of the Model

The Action Centered View

Actions occur within a context of who, whom, where, when, how, and why. Actions in human language are verbs that unite all the nominal phrases, the actor (nominative), the targets (accusative), and beneficiaries (dative). Where the nominal entities contribute most of the information content of a sentence, the one essential key to the meaning of the sentence is the verb.

For example, "Dr. Smith examines Mrs. Doe," represents the action *to examine*, with Dr. Smith as actor and Mrs. Doe as target. "MicroLab tests a specimen of Mrs. Doe" is another action *to test*, with "MicroLab" as actor, and specimen as direct object.

Any representation of an action should identify the kind of action (*what happens*), the actors *who* accomplish to the action, the objects or targets *whom* the action influences. Adverbs of location (*where*), time (*when*), manner (*how*), and other information about circumstances, such as reasons (*why*) or motives (*what for*) are additional pieces of information that may be required or optional in given situations.

Figure 1 is a model in the Unified Modeling Language (UML) that excerpts the RIM classes essential to the USAM. The action is at the center of the USAM. In this modeling style, an action class captures the operations that produce state transitions in the participating entities.[11]

Attributes of the action class are the *kind* of action (e.g., physical examination), the *status* of the action (e.g., intended, ordered, in process, completed),[12] and the *time* when the action happens. Attributes of an action also include the *cost* of the service and the *privacy level* of the action or its result.

Actors can participate in an action in different ways. For example, primary surgeon, assistant surgeon, sterile nurse, and nurse assistant are all actors in a surgical procedure, who are more or less immediately involved in the action. However, payors, supervisors, provider organizations (e.g., "MicroLab") and their delegates may be actors too, even though they might not be individual persons who have their "hands on" the action.

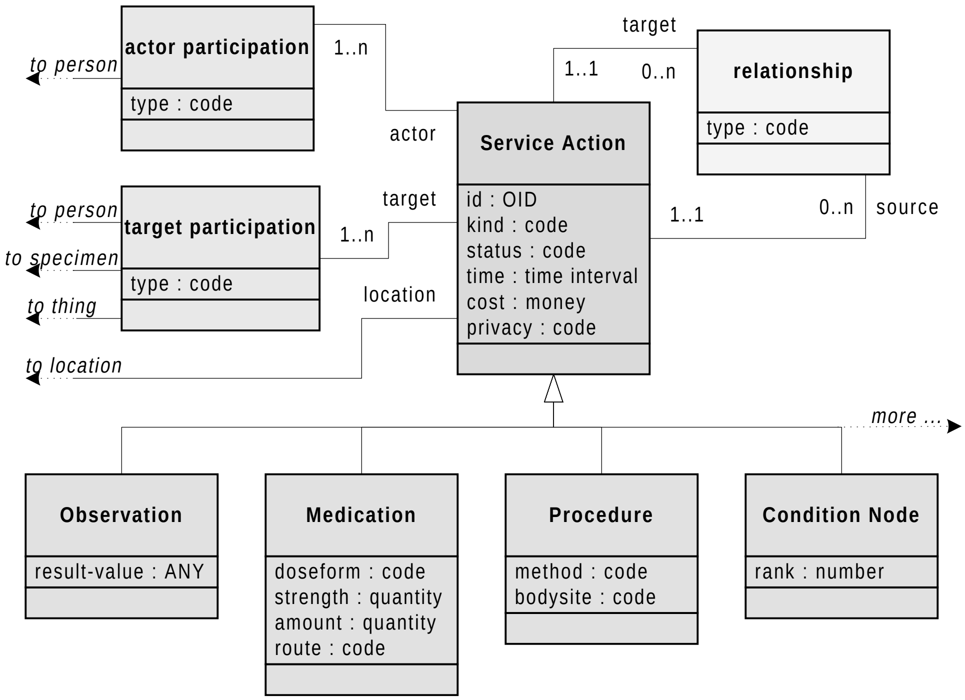

Figure 1: The Service Action is the focus of the clinical classes in the RIM. A variety of Service subtypes allow expression of different data sets for different Action subtypes.

Just as with actors, different participation types can be identified for targets. By "target" of an action we basically mean objects* of a verb. Objects appear in different cases: direct objects, indirect objects or adverbial objects according to their roles in the sentence. Target participation type codes distinguish those different roles. For instance, patient, guardian, contractor, and specimen are examples of target participation types.

The substantial entities (e.g. person, organization, patient, provider, things, etc.) that can be actors and targets of an action are not shown in Figure 1. The action-centered part of the model is decoupled from this variety of nominal entities by the two participation classes for actors and targets. Those participant classes are *association classes* that work like interfaces between real things and actions, and thus facilitate reusability of the model constructs for action.

Action Structures

Consider a surgical procedure, e.g. a laparoscopic cholecystectomy, as a typical action in health care. This action obviously consists of many smaller actions that must occur in the right order and relation to each other. Preoperative preparation is a precondition. Anesthesia is conducted in parallel to the entire surgical component. The operation itself includes a sequence of steps, such as incisions, preparation of the gall bladder, ligature of the vessels, excision and extraction of the gall bladder, sutures and bandages. Close analysis reveals that even the simplest of actions can be split into smaller actions.

Because actions are "infinitely" decomposable, keeping track of all the sub-actions is neither possible nor desirable. Since healthcare is a collaborative process involving many different perspectives, the level of detail needed may not be the same for everyone. However, the level of detail described in an information model must be the most granular level of detail needed by one customer of the data. For instance, the surgeon reports on every major milestone his operation for communication with the next surgeon and the legal system, but the payer usually only wants to know about the cholecystectomy at the very top level. Since the detail level needed may vary, the model must incorporate a method of mapping between individual actions and collections of sub-actions.

Analysis of action relationships also revealed the need to associate individual actions to collections of past actions, e.g. this test was performed because of the results of two earlier tests. In the USAM we therefore introduced a general recursive association, the service *relationship* shown in Figure 1. The relationship can be interpreted as an "arrow" pointing from a "source" to a "target" service. The meaning of the "arrow" varies depending on the *type* code. In general the arrows point "upwards", i.e. from part to whole, from earlier to later, from cause to effect, etc.

* However, since the patient is the most important target in healthcare we try to avoid the term "object."

With this recursive service relationship one can group actions into "batteries," e.g. LYTES, CHEM12, or CBC, where multiple routine laboratory tests are ordered as a group. Some groupings, such as CHEM12, appear more arbitrary; others, such as blood pressure seem to naturally consist of systolic and diastolic pressure. All those sub-actions are connected to the super-actions by relationships of type "part-of" where the arrow points from the part to the whole.

Actions may also be grouped in a sequence along a time line called "temporal collections." Examples of longitudinal grouping patterns include the phases of a clinical trial or the steps of the cholecystectomy outlined above. Actions may be explicitly timed, and may be conditioned on the status or outcome of previous actions. Additional temporal collections of actions include the combination of parallel longitudinal groupings, which can be organized to form multiple layers of nesting, in accordance with the workflow management methodology.[13] Clinical trials, plans, and guidelines group battery and temporal collections of actions in order to express the full complexity of the relationships. Regrettably, full discussion of the action relationship class in workflow management is beyond the scope of this paper.

The relationship class is not only used to construct action plans but also to represent clinical reasoning or judgements about action relationships. Prior actions can be linked as the reasons for more recent actions. Supporting evidence can be linked with current clinical hypotheses. A flexible way of managing problem lists consistent with the requirements addressed by Rector[1] also uses the action relationship as its key component.

The USAM focus on action suggests a strategy for privacy management. In the USAM, identification of the privacy level of an action also identifies the privacy level of the result. Consequently, aggregations of data may assume the privacy level of the most private action in the aggregation.

Taxonomy of Actions

USAM divides actions into very coarse categories. The more common subclasses are displayed in the lower part of Figure 1. As usual, subclasses are identified mainly because different categories of actions have different basic properties, which are reflected in the attributes. Attributes of a sub-class should be both useful and unique to that sub-class. Each sub-class of action inherits the attributes described in the superclass, Service Action, e.g. kind, cost and privacy level.

Observations are actions performed in order to determine an answer or *result value*. Observation result values are specific information about the observed object. The type and constraints of result values depend on the kind of action performed.

In USAM, the observation action and observation result are modeled as being the two sides of the same concept, just like the two faces of a coin are not separable from each other. Most other published healthcare models, including the earlier HL7 models, separate the activity of observing and the observation result into different classes.[14,15] These models label the kind of action in one class and the kind of observation result in the other, an unnecessary redundancy.

Procedures are typically surgical actions or direct nursing care activities, which share attributes and can be combined. Medication, as a care intervention, could be modeled as a procedure. However, medications are characterized through their unique attribute set needed to specify dosage.

Problem lists can be managed using another subclass of the action. The primary purpose of the problem list management action is to arrange other actions of the patient record into a longitudinal thread that represents the patient's condition through linked *condition nodes* lined up along the time axis. Each condition node action may modify attributes, e.g. the importance ranking of the condition. More importantly, the condition node action may be associated through the class *relationship* with observations or other actions that name the condition. Consequently, conditions may carry multiple names or changed names to support progression of disease, changing knowledge about the disease or conflicting opinions about the disease.

The Model in Use

Mrs. Jane Doe is a 53 year-old woman who underwent a laparoscopic cholecystectomy on 3/3/1999. On 3/7/1999 she develops increasing abdominal pain and fever. A white blood cell count (WBC) is performed and yields a result-value of 15000/µl. The doctor records a tentative diagnosis of "peritonitis" supported by the mentioned facts.

Figure 2 is an instance diagram showing the instances of the service action class as boxes. Instances of

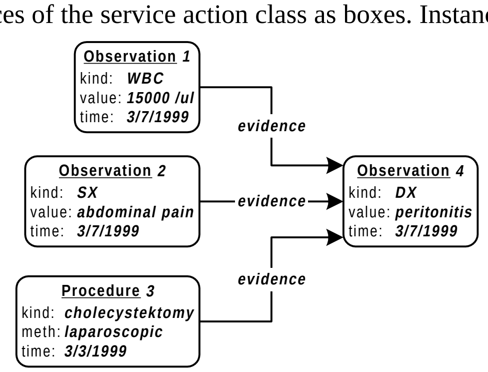

Figure 2: Simple example of medical reasoning–existing service actions as supporting evidence for a diagnosis. The "evidence" links are instances of the relationship class.

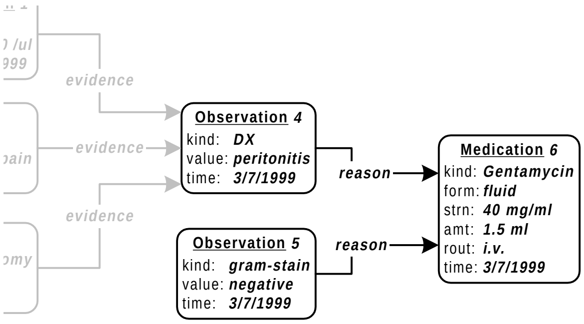

Figure 3: Two existing actions describing gram-negative peritonitis as the reason to perform another action: administration of Gentamycin. The "reason" links are instances of the relationship class.

the relationship class are simply shown as arrows annotated with the relationship type. Two observations (***1***, ***2***) and the procedure (***3***) are linked to the diagnosis (***4***) through relationships of type *evidence.*

A gram stain smear is taken from the fluid produced by the drainage and shows gram-negative rhabdomal bacteria (Figure 3, Observation ***5***). At the same day a gentamycin medication with 60 mg i.v. (Q8H) is initiated (***6***). The diagnosis of peritonitis and the negative gram-stain are recorded as *reasons* to order gentamycin.

At the end of the day, the doctor creates a new problem list, and he assigns the working diagnosis as the temporary name of the problem (Figure 4, Condition Node ***7***.)

Two days later an exploratory laparotomy is performed (Figure 5, Procedure ***8***) which shows a perforated ascending colon near the flexura hepatica (Observation ***9***).

Subsequently the doctor enters the post-operative diagnosis as "perforated colon, secondary to cholecystectomy" (Figure 5, Observation ***10***) and links the original cholecystectomy (Procedure ***3***) and the recent intra-operative finding as supporting *evidence* for the new refined diagnosis.

Finally, the problem list is *updated* by a new condition node (***11***) that assigns the post-operative diagnosis as a name of the condition.

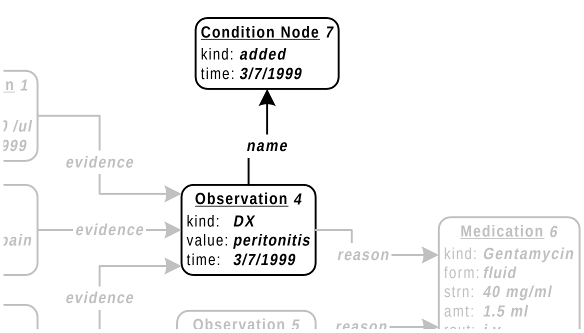

Figure 4: Diagnosis added to the problem list. The problem list consists of nodes that can be named by any action. The "name" link is an instance of the relationship class.

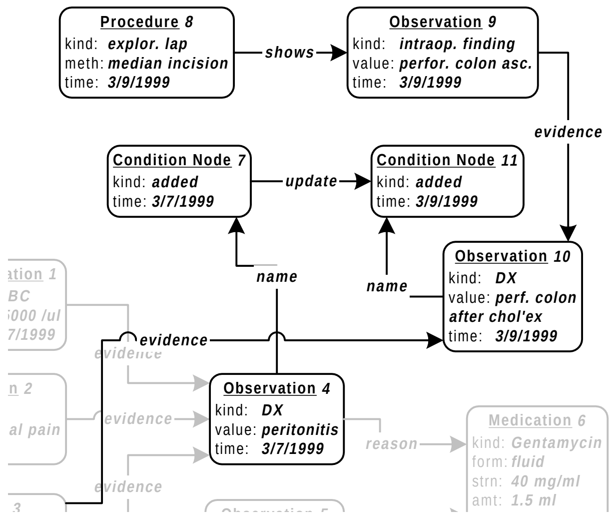

Figure 5: The problem list is updated by the finding of the laparotomy captured as condition node 11 named by observation 10.

Discussion

Modeling the Electronic Medical Record

USAM builds on the application of health problem analysis to quality improvement, as described by Weed[2], and the improvement in management of the observation[1] as incorporated into the European Heath Care Record Architecture (HCRA).[16] It builds as well on the "event" model expressed in earlier versions of the HL7 RIM. However, the benefits of USAM derive from the additional understanding that the observation is just one subtype of action important to the electronic medical record. Management of cost, quality, and privacy depend on the management of more types of actions than observation alone. The contribution of the USAM is that it breaks with the result-oriented traditions of systems that capture the results of actions instead of the actions themselves. When a surgeon removes a gall bladder of a patient, the cost and quality implications of the surgery itself are incurred as well as the cost of documenting the results of the surgery.

An information model for an action-based electronic medical record is complementary to vocabulary modeling efforts that continue to occur.[17] At the same time, the presence of an action-based information model will change the focus of vocabulary development to support vocabulary terms which are useful in an electronic medical record. For example, formal terminologies today do not specify many of the actions required in an action-based model, especially granular action descriptions for history taking questions, kinds of diagnostic actions and resource management actions.

It must be stressed that the EMR is actually built on *complementary* models of information and vocabulary.

Effects of the USAM on the RIM

Initial versions of the RIM treated many of the core USAM entities as separate classes that were interconnected through a tangle of associations. As analysis identified the common sets of attributes and associations, the number of distinct super-classes in the RIM was reduced along with the number of associations. With this reduction of distinct super-classes, the number of attributes was also reduced. For example, the concept of a diagnosis was initially modeled as a separate class with the diagnosis code and diagnosis type as primary attributes. However, when diagnosis was modeled as a type of action similar to observation, many attributes of the Diagnosis class could be matched to attributes of the Observation class. Consequently, both the diagnosis class and its attributes were deleted from the RIM along with associations to participant classes. Now, Diagnoses of different kinds, e.g. admitting dx, post-operative dx, discharge dx, are delegated to the action name vocabulary and are not explicit in the information model.

It is likely that further analysis will reveal other classes that may more efficiently be modeled as sub-classes of action. If so, the RIM will become simpler to understand and simpler to implement.

However, another impact of the HL7 RIM is that information systems will need more robust vocabulary resources to record various distinctions implicit in the vocabulary rather than explicit as separately named attributes or classes. In other words, the fewer attributes in the RIM, the less likely the model will change with changing healthcare practices. However, the fewer attributes, the more pressure on applications to extract needed inferences from the vocabulary. Huff[18] has taken this principle to its natural extreme.

In the future, other action sub-classes will be added, but the model is able to address the management of these actions and the related cost accounting and management of privacy through inheritance from action.

Acknowledgements

The authors depended on a large group of people from many organizations to successfully implement USAM in the HL7 RIM, notably George Beeler, Anita Benson, Karen Keeter, Ted Klein, Deb Weiss and all other members of the Patient Care and Order/Observation Technical Committees of HL7 who offered important criticisms during development of USAM. Some of this work was supported by the National Library of Medicine (Contract #N01-LM-6-3546).

The modeling initiative described in this paper was done in two technical committees of HL7 and has been incorporated into the HL7 RIM. However, the RIM is not balloted by the general HL7 membership, which is why this paper does not represent official HL7 positions.

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