

Bridging the Narrative Gap in Healthcare: One Framework at a Time

Udaya Varadarajan* and Biswanath Dutta**

* Documentation Research and Training Centre, Indian Statistical Institute Bangalore Centre, 8th Mile, Mysore Rd, RVCE Post, Bengaluru, Karnataka 560059, Department of Library and Information Science University of Calcutta, 87, 1, College St, Calcutta University, College Square, Kolkata, West Bengal 700073

** Documentation Research and Training Centre, Indian Statistical Institute Bangalore Centre, 8th Mile, Mysore Rd, RVCE Post, Bengaluru, Karnataka 560059

* udayav@drtc.isibang.ac.in, ** bisu@drtc.isibang.ac.in



Udaya Varadarajan is a research fellow at the Documentation Research and Training Centre (DRTC), Indian Statistical Institute, India. She is a doctoral student in the Department of Library and Information Science at the University of Calcutta, Kolkata, India. Her current research interests are in ontologies and knowledge graphs.



Biswanath Dutta is an Associate Professor at DRTC of the Indian Statistical Institute Bangalore, India. He holds a Ph.D. in LIS from the University of Pune for his research conducted in ISI Bangalore. He was a Post-Doctoral Fellow at the Department of Information Engineering and Computer Science of the UniTn, Italy (2009-2012). He worked as a research assistant at the Department of Computer Science, Dalhousie University, Canada. He actively worked on EU-funded research projects. Currently, he is handling research projects on “COVID-19 and knowledge graph” (<https://www.isibang.ac.in/~>) and on “Facility for transforming library data to linked library data” funded by ICSSR, Govt. of India. His current research interests lie in ontology, metadata, knowledge graph, data science, and semantic technologies.

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Abstract: The goal of this study is to develop a semantic artifact for capturing and inferencing medically significant information from the patient narration. The motivation for such a framework emerges from the understanding of the significance of patient narration and its underutilization. The ontology which borrows from the theories of narration and its components, supports the capture of the narrative detail in medicine. Existing ontology-based narrative models also contributed to this study. A phased approach was adopted to fulfill the objective. A foundational framework was established during the initial phase, while the subsequent phase involved data modeling. A three-way evaluation was also performed to validate the model.

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1. Introduction

Electronic health records (EHRs) are a major tool for data capture in the medical domain. Applications such as OpenEMR, OpenMRS, etc. capture medical data. The medically significant data captured by such a system include demographic details, vitals, reason for visiting, medications, allergy details, and so on (Dick et al. 1997). These medical data captured in EHRs are mostly structured data. Another area of medically significant data is the clinical narration. This narration is mostly unstructured and capturing un-

structured data in the medical domain is challenging (Stewart and Roter 1989).

The narrative data is often not captured. If such data is captured, they are often recorded in the notes section of software systems as free text. These narrative data encompass various aspects such as concerns, expectations, feelings, and thoughts (Robertson and Clegg 2016; Stewart and Roter 1989). Narrative information helps clinicians (i) work more efficiently, (ii) obtain a better understanding of their patients and (iii) deepen the “therapeutic, personal, and social dimensions of patients’ and doctors’ lives. They

can also supplement existing evidence-based care in medicine (Barber and Moreno-Leguizamón, 2017).

According to Charon et al. (2017) narrative medicine “began as a [...] discipline to fortify healthcare with the capacity to skilfully receive the account persons give of themselves, to recognize, absorb, interpret, and be moved to action by the stories of others”. Narrative medicine finds a place in various medical specializations such as veterinary study (Ware 2017), nervous system, pulmonary diseases (Cappuccio et al. 2018; Cappuccio et al 2019), genetic conditions (Ragusa et al. 2020), gastrointestinal (Zhang et al. 2020), oncology (Mohanti 2021), dental practice (Huang et al. 2021), and psychiatric practices (Dosani 2021). It has also affected the practices of clinical notes and records. Patients now add to the record by sharing their experiences, thoughts, and feelings concerning the disease (Murphy et al. 2017). Other studies (Ciotti et al. 2018; Lemogne et al. 2020; Wesley et al. 2018; Yang et al. 2018; Zaharias 2018) detail the impact of narrative in medicine including the personalization of rehabilitation goals and programs, increase in the care and concern, and emphasis on factors such as communication, movement, personal care, people and social life (Muneeb et al. 2017).

Domains such as literature and cultural heritage have adopted ontologies to capture the narrative information [1]. Certain works are detailed in the literature review section. However, despite the significance of narrative information in medicine, the capture of the narrative data is unorganized and is regrettably underutilized beyond its immediate use in patient treatment (Varadarajan and Dutta 2021). Such information has the potential to provide valuable conclusions or inferences.

With this motivation of capturing and inferring the patient narration, the present ontology was developed. While there are various data capture and inferring methods, ontology-based capture was selected for the current study. Gruber (1995) defines ontologies as formal and explicit specifications of a shared conceptualization. They encompass various features, including knowledge structures, conceptual definitions, relational connections, and categorization (King and Reinold 2008; Gruber 1993). They help in extracting the non-explicit relations, navigation, creation of a “web of connections” (King and Reinold 2008), reasoning the knowledge base, formally representing computable models, and so on (Dutta 2017; Sinha and Dutta 2020). Specifically, in the domain comprising narration, the ontologies are used for their ability to pull out genres and media types, support narrative argument and automatic reasoning, help AI-based systems in their early stages, express, understand, and reason about the order of events, and allow them to work together. The current study contributes towards:

- Identification of the common elements of narrative for modeling narrative information
- Ontology for patient narrative grounded on the canons of narrative theories, biomedical philosophies and principles of knowledge representation

The paper is organized as follows: the Literature Review in section 2 discusses the related work. The methodology in section 3 describes the steps followed for accomplishing the goal as well as the designed ontology. Section 4 concludes the paper by discussing the observations and future work.

2. Literature Review

A literature study was conducted to review the existing works on ontology-based narrative models. Here, we analyze literature on ontology in support of narration across domains. This study will help identify the elements required for modeling narrative information. The studies of Winer (2014) and Varadarajan and Dutta (2022) provide a review of the existing ontology models for narration. The study identified domains of cultural heritage, literature, mythology, and transmedia as major areas of application of ontology for narrative capture. Some works that have ventured into modeling the narration or have been implemented in some systems are also detailed in this section.

Some of the earliest works on ontology for narrative capture were carried out in the 2000s. Peinado et al. (2004) developed an ontology for automatic story generation using Propp's principles of fairytale narration with the following major classes of the model:

1. Roles (example, agent, donor, hero, etc.)
2. Place (city, country, etc.)
3. Character (animated objects, animal, human)
4. Description (family, human and place)
5. Symbolic object (ring, towel, etc.)

The classes were linked using the spatial, temporal, and descriptive properties such as before, after, during, starts-before, inside, outside, has a description, and so on. Mulholland et al. (2004) developed an ontology that ran in the back end of an application “Story Fountain.” The ontology was constructed to map the cultural artifacts of the heritage sites with an ability to reason. The intended users of the application were tourists and guides who used the system to navigate through the artifact via stories. Swartjes and Theune, (2006) developed a character-centric model for the literary domain. The model, named the Fabula model, captured the event chronology and the causality of the events and highlighted causal relationships. It is developed on the principles of transitions in the event, spatial, temporal, tonal or character and its elements are Event, Perception, Internal Element, Action, Outcome,

and Goals. Connections among these elements are established by properties such as motivation, cause, and enablement. For example, the Action of killing a dragon causes the Event, death of the dragon. Fabula model provided an understanding of the elements involved in a narration that is character-centric. Around the same time, Nakasone and Ishizuka (2006) attempted to develop a domain-independent model for narration. The model was majorly event-centric, but the intention was a generic model, as indicated by the top-level classes of the model. They are Concept, Story, Scene, Act, Agent, Event and Relation. Role is a specific topic that is a story or a part of it; Event is a single piece of meaningful information. The class Concept contains the topic or theme for the Story. Story class is the overall story, and the Scene class details the scenes of the story. The relation between these classes is established by the relation hasScene. In a Scene, there is an Act, an Agent and a theme associated with it. These classes are connected via the relations hasAct, hasAgent and hasConcept. Figure 1 provides a diagrammatic representation of the framework.

Archetype Ontology was developed by Damiano and Lieto (2013) for navigating resources in the digital archives through narrative relations. This model elevates the user experience of navigating through resources that otherwise seem disconnected. The model connects the Archetypes to the Artifacts and their relation, building a bigger picture of the story. The classes and the properties of the model are given in Figure 2.

In the domain of journalism, Structured Stories (Caswell 2015) are a platform to document the events and narrative data of journalism. Event frames, produced by the extraction of discrete journalistic events, are termed editorial artifacts. These event frames consist of EventID, Role(s) and Time. The image, audio, etc., are categorized as Discourse elements, while the relationships are categorized under Causal relationships. The ODY- Onto built by Khan et al. (2016) characterizes the narration of a fictional text. The ontology is deployed in the system developed for querying information from literary texts. The structure given in Figure 3 depicts the chief classes of ODY-Onto.

Transmedia Ontology (Branch et al. 2016) was conceptualized for the information retrieval in the context of the transmedia worlds. The ontology helps in inferring connections between elements associated with characters, objects, locations, and events. The connections enable reasoning. A glimpse of transmedia ontology is illustrated in Figure 4.

Biographical Knowledge Ontology (BK onto) captures the life account of people. Used in the StoryTeller system (<http://dlm.csie.au.edu.tw/>), this ontology contains four modular structures. They are the storyline, event, history, and timeline (Yeh 2017). Figure 5 represents sample instances and the classes.

The Drammar ontology is a formal representation of elements of drama that helps the user community by offering a formal description and an autonomous reasoning tool. The

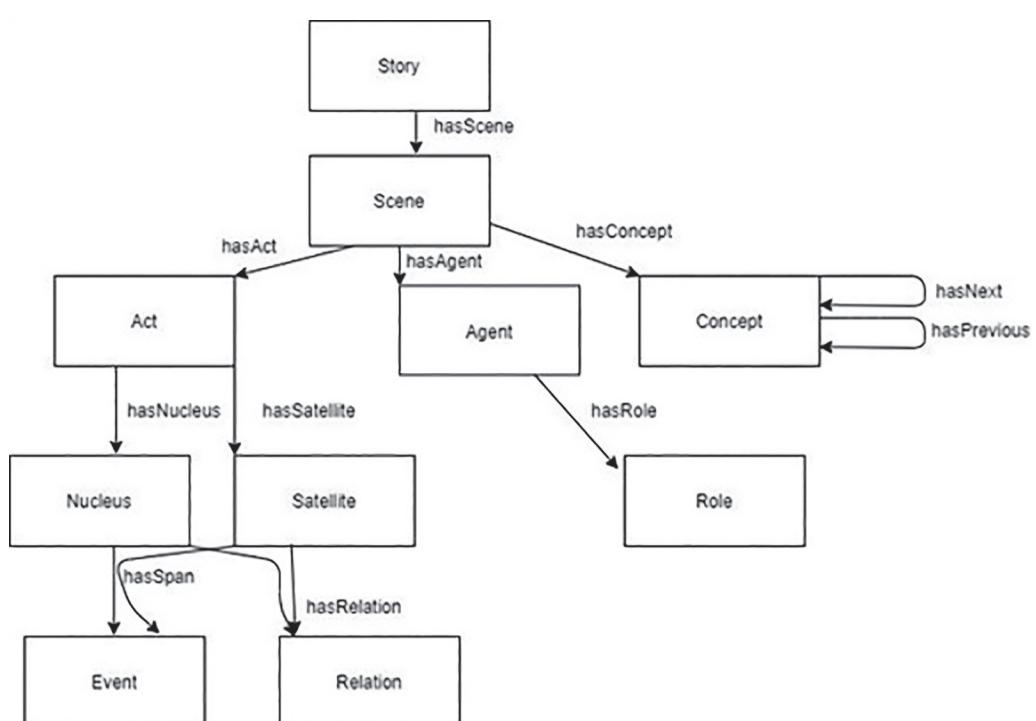


Figure 1. Diagrammatic representation of the domain independent framework for narration by Nakasone and Ishizuka (2006)

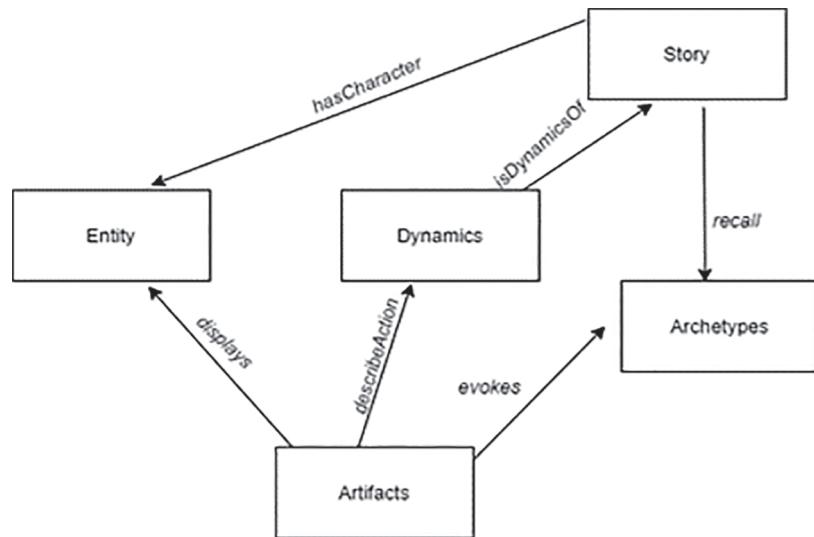


Figure 2: Top-level classes of Archetype Ontology

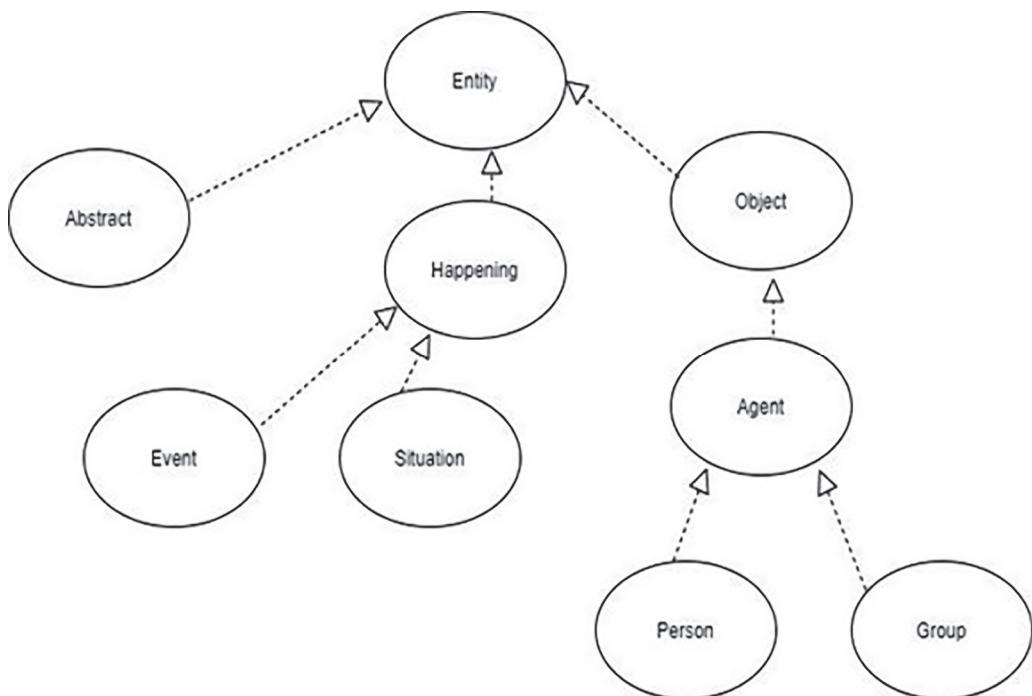


Figure 3. ODY Onto top-level classes

top-level categories of dramatic entities are (1) DramaEntity, (2) DataStructure, (3) DescriptionTemplate, and (4) ExternalReference. These entities represent the things that are exclusive to drama, guidelines for representing drama and connection between theatre, linguistic and resources ideas found in outside sources (Damiano et al. 2019).

Observing the study, it is possible to see that certain elements are common across the domain, acting as the skeletal layer for any narrative information capture. These elements

are story, which captures the whole story; scene, which captures the events that make up the stories; acts, which are the actions happening in an event; agents, who carry out the actions; cause and effect of these actions.

We carried out literature review of narrative capture in the health and medical domain aiming to develop an ontology for the patient-doctor narration. A biomedical model (Jing et al. 2007) was developed for cystic fibrosis to be used as a plugin in any EHR related to cystic fibrosis. The model

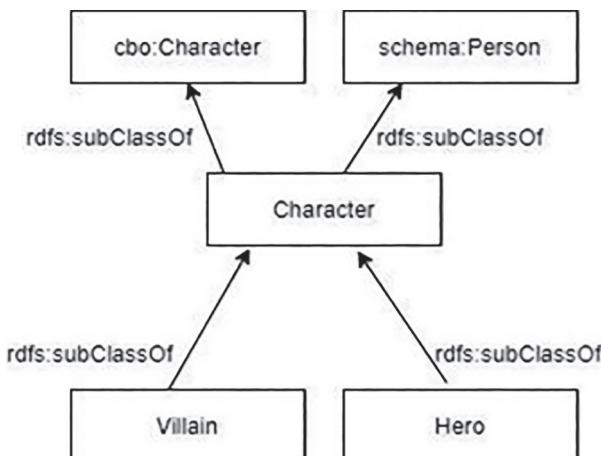


Figure 4. A glimpse of the Transmedia Ontology

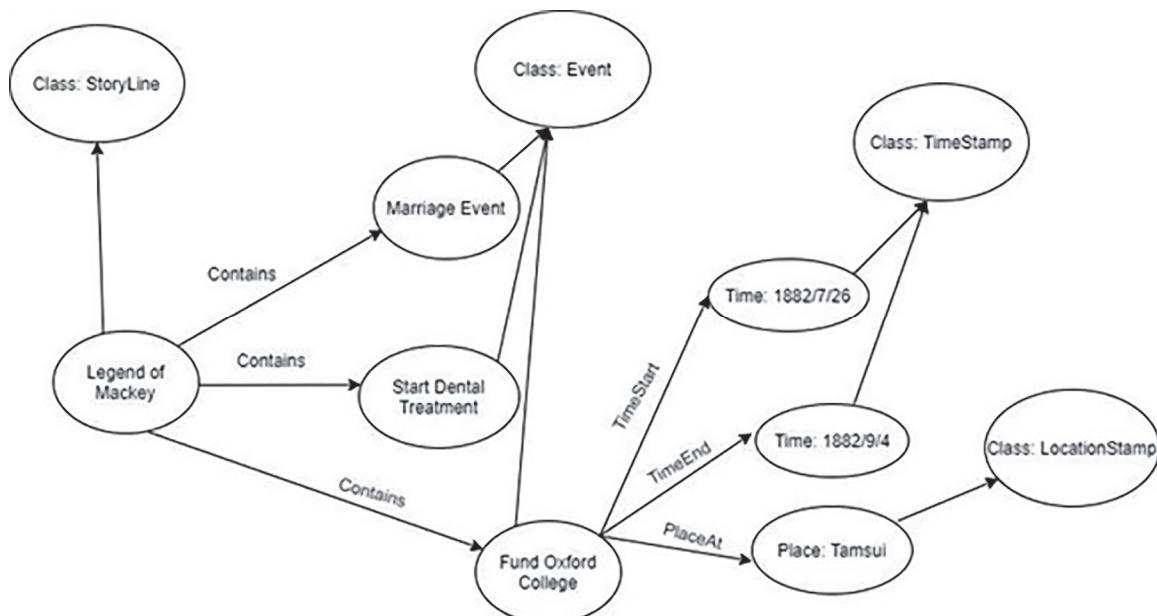


Figure 5. A glimpse of the BK onto:

takes on a modular approach and contains the various areas of gene mutation, cystic gene mutations, amino acid change, etc. The work (Ogbuji 2011) describes a CPR Ontology. With the example of a real-world use case, the author constructs an ontology for the capture of the computer-based patient record. The classes, associated relations and properties are illustrated in Figure 6.

El-Atawy and Khalefa (2016) present a solution for EHR in which ontology supports the management of concepts such as space, time data, credentials, digital photos, and fiscal dealings. For a domain that depends on collaborative decision-making, there is a need to integrate the data present in silos. Yehia et al. (2019) developed an Ontology-Based

Clinical Information Extraction System (OB-CIE) to extract clinical notions from free-text transcripts and convert the unstructured datatypes to structured information.

According to Ehrlinger and Wöß (2016), a knowledge graph acquires and integrates information into an ontology and applies a reasoner to derive new knowledge. The current work extends a knowledge graph created by Varadarajan and Dutta (2021) for narrative information in medicine.

Despite literature pieces of evidence of the significance of narration in medicine, few structures aid in capturing this narration. This is despite the existence of a framework for the capture of narratives across various domains. It is also with clarity that ontologies and semantic web technol-

ogies are used in the medical domain. Hence, this work aims to develop the framework for capturing narrative information in a medical setting.

3. Methodology

The methodology section describes the approach adopted to develop the ontology. Works from Uschold and King (1995), Gruninger and Fox (1995), Sure et al. (2004), Noy and McGuinness (2001), Suárez-Figueroa et al. (2015), Dutta et al. (2015) and Varadarajan et al. (2023) are some methodologies for ontology development. In the present work, to tackle the segmented nature of the concepts, the approach toward the ontology construction was carried out in two phases. Phase I involves the steps for the creation of a narrative framework. Identification, extraction, and formulation of elements of narration are the focus of this frame-

work. Phase II presents steps towards ontology construction. This phase brings together the elements modeled in Phase I with the data available for holistic ontology model development. The steps are detailed below. Figure 7 illustrates the workflow for the ontology construction. This methodology is adopted from the work of Varadarajan and Dutta (2021).

Phase I: Narrative Framework Construction

Phase one of the methodology involves the development of the narrative framework. This was accomplished by identifying the elements of narration from the theoretical models from the language and literature studies domain. The literature review methodology of Kitchenham and Charters (2007) was followed to identify the models. The steps for Phase I are as follows.

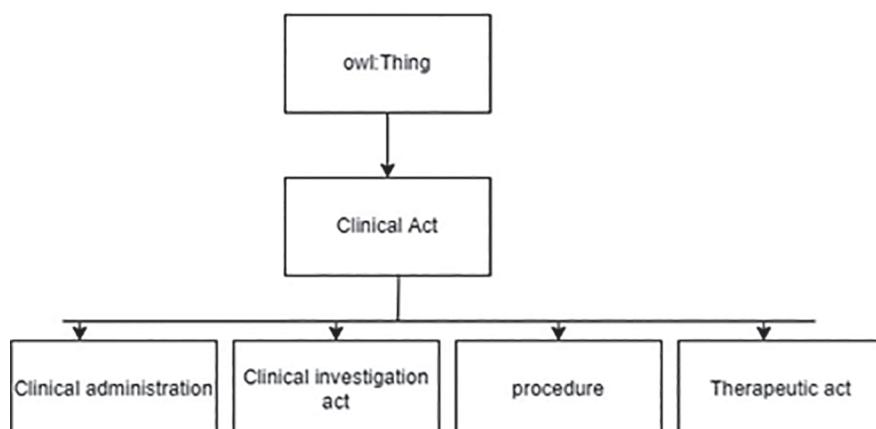


Figure 6. Clinical Act Taxonomy of CPR Ontology

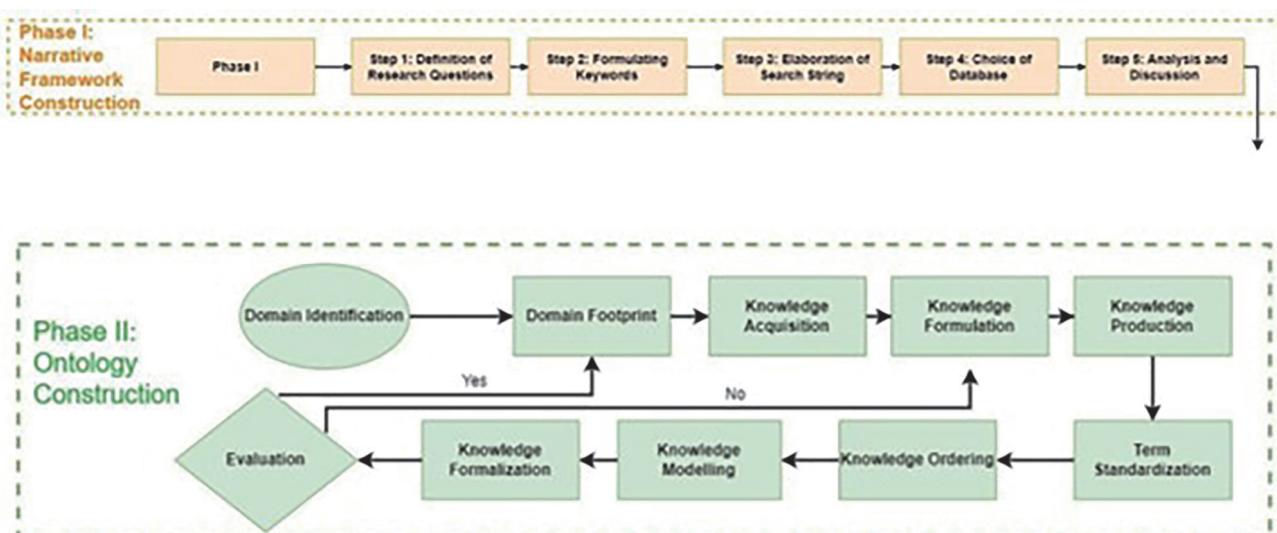


Figure 7. Workflow of ontology construction

Step 1: Research question development

Based on the aims, this stage generates the pertinent research questions. The research questions for the current work are listed from RQ1 to RQ4.

RQ1 What are the elements of narration?

RQ2 What constitutes the story?

RQ3 What are the components used in the story?

RQ4 What are the models for narrative information?

Step 2: Keyword formulation

Keywords were generated from the questions identified in the previous step. These generated keywords will assist in the search and retrieval of relevant literature. The keywords identified from the research questions are mentioned below and numbered K1 – K5.

K1 narrative models

K2 elements for narration

K3 models in narration

K4 aspects of narration

K5 fundamentals of a story

Step 3: Expansion of search string

Once the keywords are produced, the following step is to expand the keywords into search strings. This step means to transform the keywords by adding logic such as AND, adding quotes to retrieve the exact match, and including terms closely associated to retrieve relevant literature. Various combinations of the search strings are listed below.

String1 "narrative models"

String2 "narrative terms"

String3 "narrative information" AND "elements"

String4 "narrative" AND "terms"

String5 "model" AND "narration"

String6 "parts of narrative"

String7 "model for storytelling"

String8 "parts of the story"

Step 4: Choosing of repositories

Scholarly repositories were chosen by cherry-picking the features such as accessibility (or subscription-based), repute and topic covered. Databases examined are Google Scholar (<https://scholar.google.com/>), Scopus (<https://www.scopus.com/home.uri>), Web of Science (<https://clarivate.com/webofsciencegroup/solutions/web-of-science/>), IEEE/IET Electronic Library (IEEE IEL Online) (<https://ieeexplore.ieee.org/Xplore/home.jsp>), ScienceDirect (<https://www.sciencedirect.com/>), Gale Literature (<https://www.gale.com/intl/databases/gale-literature>), The Science Fiction and Fantasy Research Database (<https://sfrrd.library.tamu.edu/site/>).

Step 5: Study and Discussion

Examination of several resources returned the works pertinent to the study. The initial model was that of Aristotle's elements – exposition (preliminary situation in a narrative), crisis (disturbances in the preliminary situation), and denouement (resolve catastrophe leading to new exposition) (Klarer 2013).

Another linguistic framework for conversational narrative is the one of Labov and Waletsky (1967). The work is significant because, out of the existing models for narration, it is this model that finds a place in the literature that discusses storytelling in medicine.

The actantial model from Greimas includes six actants. They occur as units of two. The six actants are "subject, object, sender, receiver, helper, opponent" (Greimas 1973). The tasks such as search, aim, desire, communicate, support or hinder are performed by the actants (Herbert 2019; Barry 2009). The Freytag's Pyramid (Gustav 1900) is a narrative theory that describes the plot structure of a tale. The Pyramid's components are given in Figure 8.

Following this, another commonly referred work is the one for the fairy tale representation by Propp (2009) for functions and roles. The author asserts that there is an initial condition (the hero's introduction), which is followed by another circumstance that causes the hero to defy orders. The anti-hero has the chance to influence and harm the

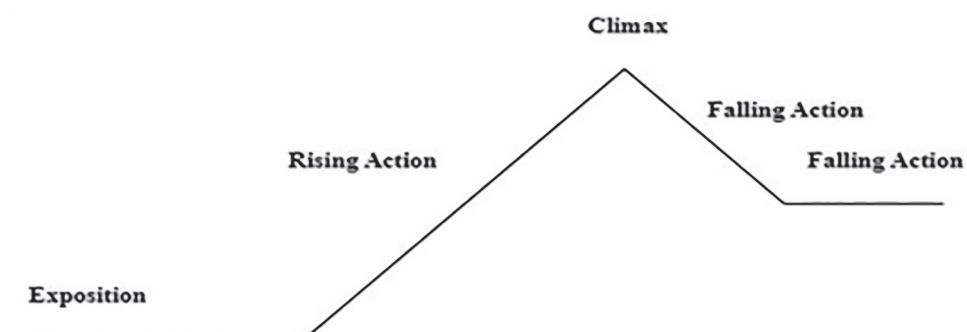


Figure 8. Freytag's Pyramid

hero or the things the hero values, which prompts the hero to make some decisions. The hero succeeds and is acknowledged. The anti-hero is overcome and penalised (Propp 2009). Traditional concepts of narrative include plot, characters, situation and setting. The plot directs to what happens. The characters are people present in the plot. The narrative situation encompasses the speaker and audience. Setting indicates the space and time of a plot (Klarer 2013; Barry 2009). "Stories have shapes which can be drawn on graph paper, and the shape of a given society's stories is at least as interesting as the shape of its pots or spearheads" (Case Western Reserve University 2016). The shape or the emotional arcs corresponds to the fall and the rise of the protagonist's journey. The arcs can be plotted on the x-axis y-axis. The start and end of the story are depicted in the x-axis and named 'Beginning-End' (BE axis). The y-axis plots the 'Ill Fortune-Great Fortune' (GI axis). All narrations occur in amongst these axes (Case Western Reserve University 2016). A summary is provided in Table 1. From the ancient to the contemporary, these ideas have divided the tale into many aspects. The present study grasps the narratological theories pertinent to modeling a narrative ontology.

Observations from the literature study and the model analyzed above lead to certain conclusions. Firstly, a basic framework for narration can be extracted from the study. Most of the models reviewed contain either one of the following elements. These common elements are presented in Table 2.

With these common elements as a guide, a domain-specific narrative framework can be developed. The concepts specific to the domain can be added, reformed and revised to suit the narrative across domains. From studying the literature there is a scope for developing a narrative framework for medicine. This facet has been least explored despite the literature pointing to the importance of narration in medicine. The limitations of the use of semantic web technologies, especially that of ontologies, are the difficulties in modeling the textual description with terms such as 'especially,' 'very common,' etc. in the OWL. The methodology now will proceed towards the development of the ontology.

Phase II: Ontology Construction

For the construction of any artifact, there are methodologies. Likewise, for the development of a semantic artifact

Model Name	Domain	Elements of the model
Model of personal narratives (Labov and Waletsky, 1967)	Domain independent	Abstract Orientation Complicating Actions Evaluation Resolution Coda
The Actantial model (Greimas, 1973)	Fiction	tasks such as search, aim, desire, communication, support or hindrance subject/object sender/receiver helper/opponent
Freytag's Pyramid (Gustav, 1900)	Domain independent	Exposition Rising action Climax Falling action Catastrophe
Morphology of the Tale (Propp, 2009)	Folklore	an initial situation absence of the family members instructed not to engage in activities hero disobeys villain manipulates family hurt hero acts hero victorious villain overpowered and punished
Aristotle's Analysis (Klarer, 2013)	Epics	exposition crisis denouement
Shapes of Stories (Case Western Reserve University, 2016)	Domain independent	BE axis depicting beginning and end. The GI axis, "Ill Fortune-Great Fortune" denoted the arcs of the story.

Table 1. Models for narration

Sl. no	Element	Definition
1	Story or storyline	that discusses the complete story
2	Actors/characters/agents	a person or organisation involved in the story
3	Events	Happening of something in space and time
4	Spatial factors	spatial or scene where an event occurs
5	Temporal factors	the time the event occurs
6	Theme	the overarching idea in a story
7	Relations or attributes	association between entities in a story

Table 2. Common elements for narration

(ontologies, controlled vocabularies, subject headings, thesauri, etc.), there are multiple development methodologies. Ontology development methodologies are activities associated with the process of developing ontologies, their life cycle, the procedures, apparatuses, and languages for building ontologies (Gómez-Pérez et al. 2004).

The most commonly cited and used methodologies include the ENTERPRISE methodology, which details the informal and formal stages in ontology development (Uschold and King 1995). TOVE (Gruninger and Fox 1995), highlights post-development stages of ontology development (evaluation and maintenance). METHONTOLOGY is another ontology development process (Fernández et al. 1997) with six phases - Specification, Conceptualization, Formalization, Integration, Implementation, and Maintenance of ontology development. Ontology Development 101 (Noy and McGuinness 2001) is the bible for ontology development. The On-To-Knowledge Methodology (OTKM) (Sure et al. 2004) covers ontology engineering, knowledge management, and knowledge processes. Pinto et al. (2004) developed DILIGENT (Distributed, Loosely-Controlled and Evolving Engineering of Ontologies) for a dispersed semantic web environment. For large scale building of ontologies, NeON methodology (Suárez-Figueroa et al. 2015) and Yet Another Methodology for Ontology or YAMO (Dutta et al. 2015) are two methodologies. YAMO is based on the analytic-synthesis approach, a combination of top-down and bottom-up approaches, and guided principles. This enables the complex concepts to be fragmented into their central concepts, studied and grouped by their characteristics, and a connection between concepts. This makes it flexible and accommodative during conflict. This motivates the use of YAMO for ontology construction. The step-by-step instructions for the ontology construction are detailed below.

Step 0: Domain Identification – As the first step in the development of ontology, it is a crucial step to identify the domain or field of study. The domain in which the artefact is developed is chosen keeping in mind the question or the user requirement (Dutta et al. 2015). The domain chosen for the modeling has to be computable, i.e., the domain can be divided into its last basic unit. The broader domain identified for the current work is medicine.

Step 1: Domain Footprint – There is a need to narrow from the broader domain identified in the previous step. Identifying the reason, purpose, and ideology behind the framework development can help in narrowing down the scope. With the literature studied, the purpose was identified, which was to capture, manage and infer the patient-doctor narration. The framework will gather data through subject interactions, observations, video data, audio tape, or note-keeping that is of major medical significance. A fictitious real-world situation is provided below to serve as an incentive (see “ad Step 1” below).

Generating competency questions (CQ) is a standard practice followed for ontology development (Noy and McGuinness 2001). From this used case scenario, competency questions were generated to evaluate the ontology and are given in the evaluation step of the methodology.

Step 2: Knowledge Acquisition – The artifact takes shape with the help of the concepts acquired from the domain. Knowledge can be acquired from multiple resources. Many use cases, literature, interviews, and other media can be sources for concept collection. The more specific the sources are to the domain the more standardized concepts are extracted. The concepts for the patient-doctor framework were collected from the literature, stories, and anonymized patient records. A few concepts gathered are as follows (see “ad Step 2” below).

Case 1: A lady goes to the doctor with a cough and a cold. She is given cold and cough medications as part of her therapy. The issue persists even after the course of medications has been completed. A follow-up appointment alarms the doctor. They enquire about the lifestyle. The patient describes everyday activities. They observe a shift in the ambience of her workplace as a result of this. The only difference in her workstation was the addition of a new 3D printer. Doubtful, the doctor urges her to relocate the printer to another area. The minute particles generated from the machine when working were the true cause of the cough and cold. The patient recovered when the alteration was made.

ad Step 1

lady, patient, micro particles, visit, cough, cold, treatment, prescribe, medicine, ulcer, mouth, no effect, complain, doctor, distressed, facial features, course, follow up, alert, enquire, lifestyle, change, office, cause, recover, not reduce

ad Step 1

Health Problem	
Disease	
Cold	
MouthUlcer	
Symptom	
Cough	
CoarseFacialFeature	

Table 3. Knowledge production of the concept of illness

Step 3: Knowledge Formulation – In this step, we analyze the concepts collected. The analysis involves grouping or splitting them based on the similarities or differences in meaning, and characteristics. From the terms collected in the previous step, for example, *cough*, *cold*, *mouth ulcer*, and *coarse facial features* were grouped as a chief complaint. The reason for this grouping is that these are the reasons for the visit to the health care centre. A similar process was conducted for other terms as well.

Step 4: Knowledge Production – The grouped terms are synthesized in this step. Hierarchy is created for the concepts collected. The categorization can be performed based on any number of factors. The synthesis for categorization for the current work was by identifying what these terms mean. For example, the synthesis of the terms *cold* (a disease involving the nose and respiratory passages) and *mouth ulcer* (a health problem on the surface of the skin or mucous surface of the mouth) from the previous example aligned them as diseases. This categorization is represented in Table 3 above. This table also shows another example. *Cough* (a symptom involving sudden expulsion of air from lungs) and *coarse facial features* (symptoms related to the face) were identified as symptoms. This differentiation of the health problem helps in the facet

identification of the concepts and helps in the following steps of ordering and standardization.

Step 5: Term Standardization and Ordering – The natural language contains synonyms, and every concept can be in multiples. This step is to bring a standardized representation of the terms. When concepts are expressed in multiple terms, there is a need to choose one particular term that will fit the purpose of why the ontology is constructed. This is in alignment with the current best practices of reusing the existing vocabulary. Medical vocabularies, and thesauri such as the Unified Medical Language System (UMLS) (<https://www.nlm.nih.gov/research/umls/index.html>), SNOMEDCT (<https://www.snomed.org/>), etc. can be used. Besides these, there are vocabularies such as schema.org and Wikidata (https://www.wikidata.org/wiki/Wikidata:Main_Page) that were consulted for standardizing. For the concepts expressed in the previous step, i.e., *cold*, *mouth ulcer*, *coarse facial feature* and *cough*, there are multiple terms used for expressing them. These terms were replaced with common *cold*, *oral ulcer* and *coughing* following the UMLS. The *coarse facial feature* is already a standardized term. Similarly, for a person affected by some illness or disease, the terms are *patient*, *sufferer*, *sick person*, or even *client* in certain cases.

The term patient was chosen over the other terms because it is the term relevant within the domain as well as with the purpose of modeling, sticking with the Canon of Currency (Ranganathan 1937). Canon of Currency directs the users to use the term that is currently in use, the implication of which is that the terms that are 'in use' at the time of development will be added to the model. During the knowledge acquisition step, the terms were already collected from domain-specific literature (anonymized patient records and use cases). This eased the standardization since the terms were mostly domain specific and already standardized.

To have regularity in the ontology, we order the terms following some criteria. The ordering can be purpose-based, alphabetical, or chronological (Ranganathan 1937). The logic of the ordering disease followed by symptom was purpose-based. The idea was that the body gets affected by a disease

first and then the symptoms show up. Figure 9 illustrates a sample of the standardized terms with the examples mentioned in this step. The ordering of the concepts of symptom and disease shows that both these concepts represent some health problem.

Step 6: Knowledge Modelling and Formalization - This step reorganizes the knowledge produced in the previous step into entities, entity relationships, and their attributes and expresses them in a machine-processable format. Figure 10 shows the UML representation of the overall framework of ontology.

For formalizing and expressing the knowledge in a machine-processable format, we use OWL DL (Web Ontology Language Description logic) (Smith 2004). OWL is the language for describing and defining ontologies. OWL DL is a species of OWL that aids the users for maximum expressiv-

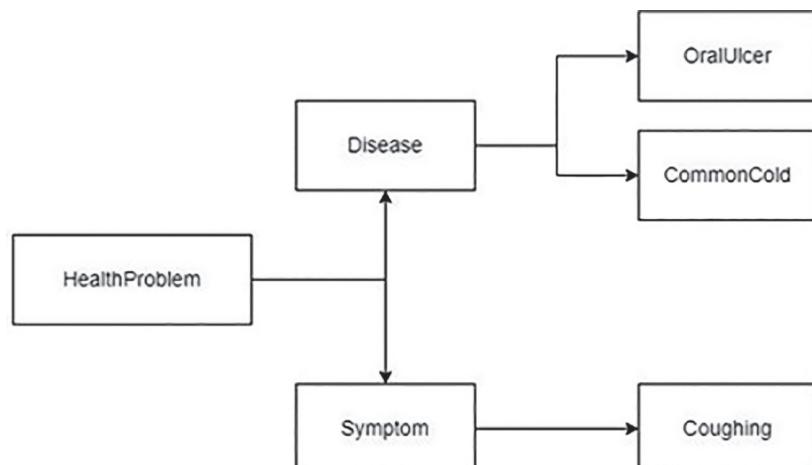


Figure 2. Standardization and Ordering of the concepts

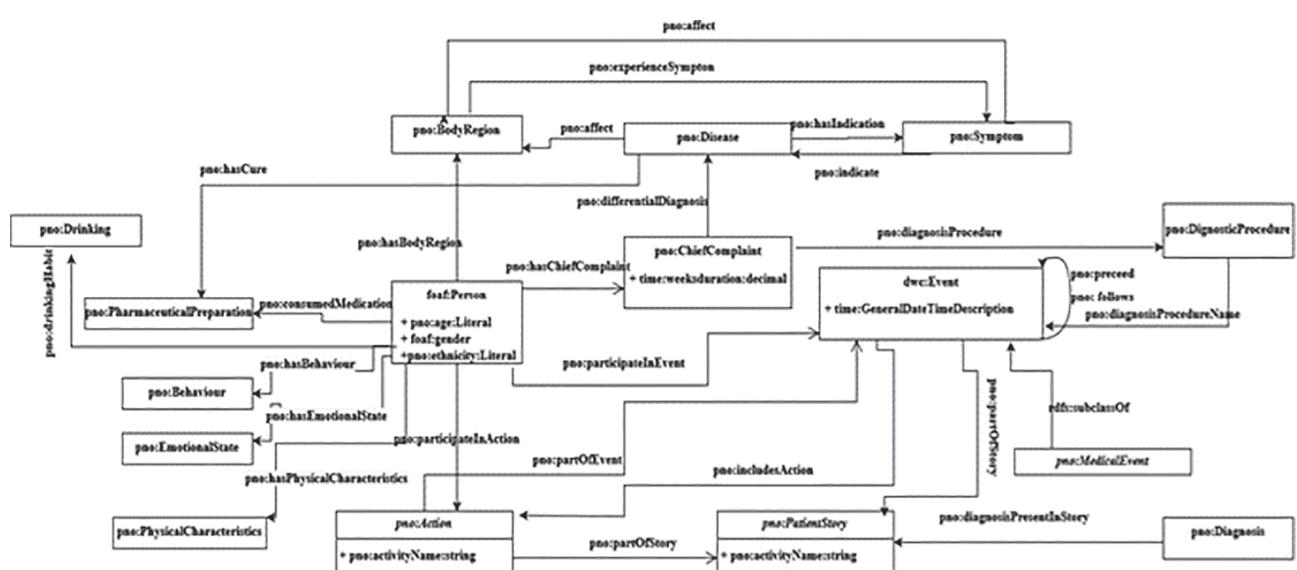


Figure 10. UMLS of the ontology

ity. We use Protégé ontology editor for the knowledge modeling and development of the ontology.

Figure 11 depicts a glimpse of class (a class is a group of individuals that belong together) and class hierarchies from ontology. MedicalStructure, details the medical aspect of the patient narration; StoryEntity details the elements of narration; DrammaticStrucure and DescriptionTemplate classes assist StoryEntity class in describing the narration. MedicalStructure has subclasses ChiefComplaint, HealthProblem and PharmaceuticalPreparation. HealthProblem has subclasses of Disease and Symptom which have instances, of oral ulcer and cough, respectively.

Entity relationship is the relationship between entities. Figure 12a is a screen grab of the object properties. Object property is the property that relates two individuals. For example, the property hasIndication links the Disease and Symptom. Similarly, the property performedBy connects the Action or Event class to the Agent (one who performs the action or event). Figure 12b shows the data properties. A data property connects individuals and the datatypes. For example, the properties duration(xsd:dateTimeStamp) and severity(xsd:literal) are attributes used for HealthProblem.

The current ontology consists of 52 classes, 42 object properties, and 18 data properties. Figure 13 provides a snap



Figure 11. The class hierarchy in the ontology



Figure 12a. Object property hierarchy



Figure 12b. Data property hierarchy

```

<?xml version="1.0"?>
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
  xmlns:base="http://www.isibang.ac.in/ns/OntoPaN"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  ontologyIRI="http://www.isibang.ac.in/ns/OntoPaN">

<Declaration>
  <Class IRI="#Agent"/>
</Declaration>
<Declaration>
  <Class IRI="#ChiefComplaint"/>
</Declaration>
<Declaration>
  <ObjectProperty IRI="#hasChiefComplaint"/>
</Declaration>
<Declaration>
  <ObjectProperty IRI="#hasIndication"/>
</Declaration>
<Declaration>
  <DataProperty IRI="#duration"/>
</Declaration>
<Declaration>
  <DataProperty IRI="#frequency"/>
</Declaration>
<Declaration>
  <NamedIndividual IRI="#Bilateral_knee_pain"/>
</Declaration>
<SubClassOf>
  <Class IRI="#Agent"/>
  <Class IRI="#StoryEntity"/>
</SubClassOf>
<SubClassOf>
  <Class IRI="#ChiefComplaint"/>
  <Class IRI="#MedicalStructure"/>
</SubClassOf>

```

Figure 13. A Snippet of the OWL code

shot of the ontology. The complete OWL file is available from <https://www.isibang.ac.in/ns/ontopan/index.html>.

Step 7: Evaluation – This step involves the evaluation of ontology. The purpose of the evaluation is to determine the quality of the developed ontology. The quality can be determined by verifying the constructed ontology for its logical consistency, its ability to retrieve answers to the query and its capability to support the knowledge representation of the domain. These types of evaluations were performed for the current ontology. This is detailed below.

Evaluation 1

To check for modelling errors, one can use ontology pitfall scanners such as OOPS! (Poveda-Villalón, et al 2014). The pitfalls identified and corrected are given in the figures below (Figure 14a and 14b respectively). The critical pitfall was the use of multiple domains and ranges for an individual property. This was rectified. The important pitfalls were missing disjoints, no license declaration missing domain and range for the properties, and wrong declaration of equivalent classes. The domain and range for the properties were added. The equivalent classes declaration was corrected. Other pitfalls, such as missing disjoints and no li-

cence will be corrected in the final version of the ontology. This is because, with more data for the ontology, the modelling can be perfected. Minor pitfalls were synonyms as classes, missing annotations, inverse relations, and inconsistent naming conventions in the ontology, which did not affect the overall concept of the ontology. These pitfalls highlight the best practices in the ontology development domain. Attempts were made to rectify these pitfalls as well. The scanner also produced some suggestions for declaring the transitive and symmetric properties. Also, the scanner erroneously suggests making the classes Event and Effect equivalent. These were ignored during the evaluation.

Evaluation 2

In addition, to evaluate the support for knowledge representation of an ontology, different use cases can be employed. The use case for the evaluation is given below.

Case 2: A patient is 24 years old, an African American male with a history of sickle cell reports to the ED with the chief complaint of bilateral knee pain with a history of 2 days. The pain began on Thursday at 4.00 am when the patient was working the night shift in the department store. The pain continued to increase from aching to 8/10. The pain didn't re-

OOPS! Ontology Pitfall Scanner!

OOPS! (Ontology Pitfall Scanner) helps you to detect some of the most common pitfalls appearing when developing ontologies. To try it, enter a URI or paste an OWL document into the text field above. A list of pitfalls and the elements of your ontology where they appear.

Scanner by URI:

Example: http://oops.linkeddata.es/example/svc_2009-05-09.rdf

Scanner by direct input:

```
<?xml version="1.0"?>
<rdf:RDF xmlns="http://www.isibang.ac.in/ns/OntoPaN"
  xmlns:base="http://www.isibang.ac.in/ns/OntoPaN"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:bfo="http://purl.obolibrary.org/obo/bfo/2.0/bfo.owl#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:foaf="http://xmlns.com/foaf/spec/#"
```

Uncheck this checkbox if you don't want us to keep a copy of your ontology.

Evaluation results

It is obvious that not all the pitfalls are equally important; their impact in the ontology will depend on multiple factors. For this reason, each pitfall has an importance level attached indicating how important it is. We have identified three levels:

- **Critical** (red): It is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, applicability, etc.
- **Important** (orange): Though not critical for ontology function, it is important to correct this type of pitfall.
- **Minor** (green): It is not really a problem, but by correcting it we will make the ontology nicer.

[Expand All] | [Collapse All]

Results for P02: Creating synonyms as classes.	1 case Minor
Results for P05: Missing annotations.	112 cases Minor
Results for P10: Missing disjointness.	ontology* Important
Results for P11: Missing domain or range in properties.	17 cases Important
Results for P13: Inverse relationships not explicitly declared.	28 cases Minor
Results for P19: Defining multiple domains or ranges in properties.	3 cases Critical
Results for P22: Using different naming conventions in the ontology.	ontology* Minor
Results for P30: Equivalent classes not explicitly declared.	1 case Important
Results for P41: No license declared.	ontology* Important

SUGGESTION: symmetric or transitive object properties. 1 case

Figure 14a. OOPS!Pitfall scanner result

Scanner by direct input:

```
<?xml version="1.0"?>
<rdf:RDF xmlns="http://www.isibang.ac.in/ns/OntoPaN"
  xmlns:base="http://www.isibang.ac.in/ns/OntoPaN"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:bfo="http://purl.obolibrary.org/obo/bfo/2.0/bfo.owl#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:foaf="http://xmlns.com/foaf/spec/#"
```

Uncheck this checkbox if you don't want us to keep a copy of your ontology.

Evaluation results

It is obvious that not all the pitfalls are equally important; their impact in the ontology will depend on multiple factors. For this reason, each pitfall has an importance level attached indicating how important it is. We have identified three levels:

- **Critical** (red): It is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, applicability, etc.
- **Important** (orange): Though not critical for ontology function, it is important to correct this type of pitfall.
- **Minor** (green): It is not really a problem, but by correcting it we will make the ontology nicer.

[Expand All] | [Collapse All]

Results for P05: Missing annotations.	109 cases Minor
Results for P10: Missing disjointness.	ontology* Important
Results for P13: Inverse relationships not explicitly declared.	25 cases Minor
Results for P22: Using different naming conventions in the ontology.	ontology* Minor
Results for P30: Equivalent classes not explicitly declared.	1 case Important

This pitfall consists in missing the definition of equivalent classes (owl:equivalentClass) in case of duplicated concepts. When an ontology reuses terms from other ontologies, classes that have the same meaning should be defined as equivalent in order to benefit the interoperability between both ontologies.

- The following classes might be equivalent:
 - <http://www.isibang.ac.in/ns/OntoPaN#Event>, <http://www.isibang.ac.in/ns/OntoPaN#Effect>

Results for P41: No license declared.	ontology* Important
SUGGESTION: symmetric or transitive object properties.	3 cases

The domain and range axioms are equal for each of the following object properties. Could they be symmetric or transitive?

- <http://purl.org/ontology/storyline/follows>
- <http://www.isibang.ac.in/ns/OntoPaN#orderedSequence>
- <http://www.isibang.ac.in/ns/OntoPaN#precedes>

Figure 14b. OOPS!Pitfall scanner result after rectification

duce with Percocet. The patient also experienced some chills and mild SOB. The pain was localized to the right knee.

Case 3: A 27-year-old male went to the dermatology clinic complaining of a rash on his back, arms, and hands that had appeared a week before. He had a history of obesity, ate a high-fat diet, and drank heavily. Physical examination revealed scattered pink-yellow papules on the upper back, extensor surfaces of the upper arms, and hand dorsa. The cause of the eruptive xanthomas was determined to be severe hypertriglyceridemia. Molluscum contagiosum, sebaceous hyperplasia, and widespread eruptive histiocytoma are among the possible diagnoses. However, eruptive xanthomas should be recognized in individuals with risk factors. The skin lesions disappeared after one month of fenofibrate therapy, which included abstaining from drinking, exercising, and eating a low-fat diet.

The data added via the use case helps in the creation of the knowledge base. The knowledge base consists of TBox (Terminological Box) (which consists of the concepts and their defining properties) and ABox (Assertional Box) (which contains the individuals and their property values) (Gruber

1993). From the use cases, the individuals were identified and fed into the framework. The framework was able to capture the details for cases 2 and 3. The screenshot in Figure 15 shows the modeling of use case 2. From the figure, you can observe that the Agent is described with the object properties that connect the agent to the symptom, chief complaint, the events performed, and Medication consumed. The depiction of use cases validates the ontology's expressivity.

Evaluation 3

Another method of evaluating the ontology is to perform a set of SPARQL queries. We use case scenarios (Cases 2 and 3) to perform the SPARQL query. Competency Questions (CQ) are generated from the use cases. Some CQs are: What was the primary reason for visiting the hospital? What were the symptoms of the case presented?

CQ derived from both the use cases (cases 2 and 3) is listed in column 'Competency Questions' of Table 4. The CQ has to be translated into machine-understandable language. Here

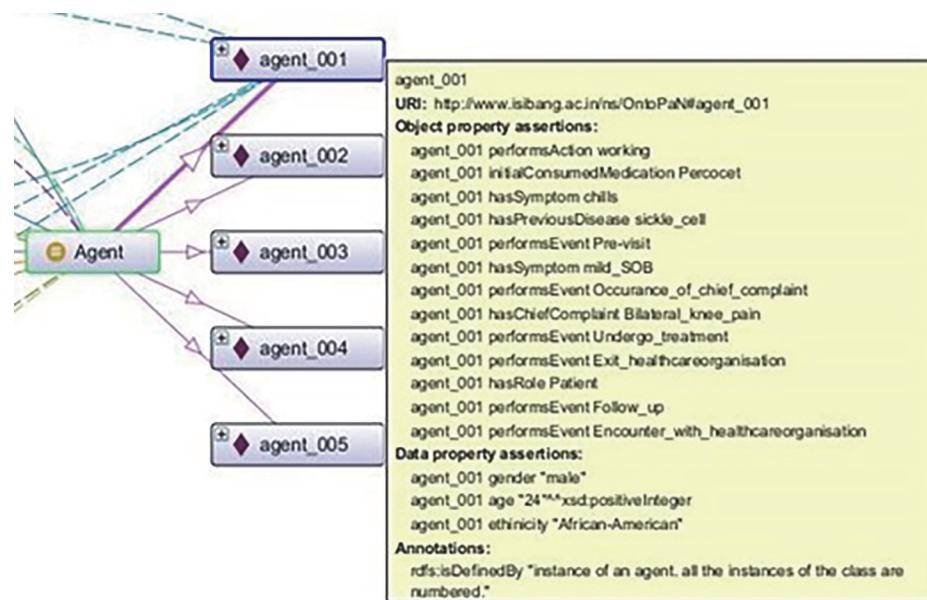


Figure 15. The screenshot of the use case 2

PREFIX <u>rdf</u> : < http://www.w3.org/1999/02/22-rdf-syntax-ns# >
PREFIX <u>owl</u> : < http://www.w3.org/2002/07/owl# >
PREFIX <u>rdfs</u> : < http://www.w3.org/2000/01/rdf-schema# >
PREFIX <u>xsd</u> : < http://www.w3.org/2001/XMLSchema# >
PREFIX <u>pno</u> : < http://www.isibang.ac.in/ns/PNO # >

Table 4. Prefixes of SPARQL Query

we use SPARQL (Prud'hommeaux and Seaborne 2008). The column 'SPARQL Query' in Table 5 is the corresponding translation of CQ. The SPARQL Query results are listed in Table 5 under the column 'SPARQL Query Result.' Every SPARQL Query starts with the following prefixes. These prefixes contain the internal (such as <http://www.w3.org/1999/02/22-rdf-syntax-ns>, <http://www.w3.org/2002/07/owl>) and external URLs (<http://www.isibang.ac.in/ns/PNO>) which abbreviate the URLs.

For example, CQ '*What was the primary reason for visiting the hospital?*' is used to identify the reason for visiting the hospital. In the ontology, the object property `hasChiefComplaint` shows the relation between the Agent and the

reason for visiting the hospital. We use the SELECT query form for extracting the values and WHERE clause for matching the graph pattern to the data graph i.e., triples (`?Agent` and `?ChiefComplaint`) to the object property (`hasChiefComplaint`). The results appear in tabular format. For convenience of representing them, we have the result of the triples queried `{?Agent, ?ChiefComplaint}` represented as `{agent_001, bilateral_knee_pain}` and `{agent_002, shortness_of_breath}` in Table 5.

Screenshots of the queries (Figures 16 and 17) are listed below.

Sl No.	Competency Questions	SPARQL Query	SPARQL Query Result
1	<i>What was the primary reason for visiting the hospital?</i>	<pre>SELECT ?Agent ?ChiefComplaint WHERE { ?Agent a:hasChiefComplaint ?ChiefComplaint }</pre>	<pre>{agent_001,Bilateral_knee_pain} {agent_002,Shortness_of_breath} {agent_007,Rash}</pre>
2	<i>What events does the agent perform?</i>	<pre>SELECT ?Agent ?Event WHERE { ?Agent a:participateInEvent ?Event }</pre>	<pre>{agent_001,Exit_healthcareorganisation} {agent_001,Encounter_with_healthcareorganisation} {agent_001,Follow_up} {agent_001,Pre-visit} {agent_004,Exit_healthcareorganisation} {agent_004,Encounter_with_healthcareorganisation} {agent_001,Visit_healthcareorganisation} {agent_001,Pre-visit} {agent_007,Pre-visit} {agent_007,Occurrence_of_chief_complaint} {agent_007,Encounter_with_healthcareorganisation} {agent_007,Undergo_treatment} {agent_007,Exit_healthcareorganisation}</pre>
3	<i>What were the activities that the patient was involved in during the occurrence of the chief complaint?</i>	<pre>SELECT ?Agent ?Action ?ActionType WHERE { {?Action a:actionType ?ActionType} UNION {?Agent a:performsAction ?Action} }</pre>	<pre>{agent_001,working,Action_during_chief_complaint} {agent_004,sleeping,Action_during_chief_complaint}</pre>
4	<i>What are the events and the associated actions in the story of the patient?</i>	<pre>SELECT ?Story ?Event ?Action WHERE { {?Story a:hasEvent ?Event} UNION {?Event a:partOfEvent ?Action}</pre>	<pre>{patientstory1,action009,Encounter_with_healthcareorganisation}</pre>

Table 5. The natural language and SPARQL queries for the ontology evaluation

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX pto: <http://www.isibang.ac.in/ns/PTO#>

SELECT ?Agent ?ChiefComplaint
WHERE { ?Agent <http://www.isibang.ac.in/ns/OntoPaN#hasChiefComplaint> ?ChiefComplaint }

```

Figure 16. Screenshots of CQ1 executed via SPARQL

Agent	Event
agent_001	Occurrence_of_chief_complaint
agent_004	Encounter_with_healthcareorganisation
agent_001	Undergo_treatment
agent_001	Follow_up
agent_004	Visit_healthcareorganisation
agent_004	Previsit
agent_001	Encounter_with_healthcareorganisation
agent_001	Previsit
agent_004	Exit_healthcareorganisation
agent_001	Exit_healthcareorganisation
agent_007	Previsit
agent_007	Occurrence_of_chief_complaint
agent_007	Encounter_with_healthcareorganisation
agent_007	Undergo_treatment
agent_007	Exit_healthcareorganisation

Figure 17. Screenshots of CQ2 executed via SPARQL

4. Discussion and Conclusion

The patient's narrative provides medically relevant information. This information is preserved in the EHRs' notes area but is otherwise misapplied. Despite the significance of narration in medicine, few narrative ontology models for medicine have been identified. The objective of this study was to create an ontology for patient narratives. The ontology aids in the capture of patient narration data. The framework development process contributed to identifying the common elements of narrative for modeling narrative information. These elements act as a framework for modeling narrative across various domains. They can act as the skeletal structures for capturing narrative across domains. The model is significant because it is: (i) helpful in finding the relationships between the causes of the diseases and the associated environmental factors; and (ii) is utilized as a training resource for novice healthcare professionals.

The current framework includes the class StoryEntity which details the narrative features. This class is connected

to the MedicalStructure class to record medically significant data for inclusion in the clinical narration. Agents were associated with each Event (like doctors, caretakers, patients, etc.). This complex modeling was simplified by constructing Event instances such as "Encounter with healthcare-organization," "Visit healthcare-organization," etc. DescriptionTemplate, DrammaticStructure, StoryEntity, and MedicalStructure are now the model's top-level classes. These top-level classes are modules that encapsulate the narrative in a medical setting with a narrative-like description.

The future of the work is envisioned to automate the data population and capture. The terms from the narrative records will be extracted and populated in the model using the widely available technologies of NLP, annotations and data integration. Further study on the model will include expert feedback on its usability and feasibility in the real world. This will be done by interviewing experts in the medical domain. Further, in the future, the framework will be published as a knowledge graph for community use to record the narrations.

Endnotes

1. See Damiano and Lieto 2013; Winer 2014; Bartalesi et al 2016; Khan et al. 2016; Adel et al. 2019; Karami and Rahimi 2019.

References

Adel, Ebtsam, Shaker El-Sappagh, Sherif Barakat, and Mohammed Elmogy. 2019. "Ontology-Based Electronic Health Record Semantic Interoperability: A Survey". In *U-Healthcare Monitoring Systems*, edited by Nilanjan Dey, Amira Shour, and Simon Fong. Advances in Ubiquitous Sensing Applications for Healthcare, vol. 1. 315-352. Academic Press.

Barber, Sarah and Carlos J. Moreno-Leguizamón. 2017. "Can Narrative Medicine Education Contribute to The Delivery of Compassionate Care? A Review of The Literature". *Medical Humanities* 43, no.3: 199–203. <https://doi.org/10.1136/medhum-2017-011242>

Barry, Peter. 2009. *Beginning Theory: An Introduction to Literary and Cultural Theory*. Manchester, UK: Manchester University Press.

Bartalesi, Valentina, Carlo Meghini, and Daniele Metilli. 2016. Steps Towards a Formal Ontology of Narratives Based on Narratology. Paper presented at the Workshop on Computational Models of Narrative, July 2016 at Kraków, Poland. <https://doi.org/10.4230/OASIcs.CMN.2016.4>

Branch, Frank, Theresa Arias, Jolene Kennah, Rebekah Phillips, Travis Windleharth, and Jin Ha Lee. 2017. "Representing Transmedia Fictional Worlds Through Ontology". *Journal of the Association for Information Science and Technology* 68, no.12: 2771-2782. <https://doi.org/10.1002/asi.23886>

Cappuccio, Antonietta, Alessandro Sanduzzi Zamparelli, Massimo Verga, Stefano Nardini, Alessandro Policreti, Pasquale Alberto Porpiglia, Silvia Napolitano, and Maria Giulia Marini. 2018. "Narrative Medicine Educational Project to Improve the Care of Patients With Chronic Obstructive Pulmonary Disease". *ERJ Open Research* 4, no.2. <https://doi.org/10.1183/23120541.00155-2017>

Cappuccio, Antonietta, Silvia Napolitano, Francesco Menzella, Guido Pellegrini, Alessandro Policreti, Girolamp Pelaia, Pasquale Alberto Porpiglia Maria Guida Marini, , and Sound Group. 2019. "Use of Narrative Medicine to Identify Key Factors for Effective Doctor-Patient Relationships in Severe Asthma". *Multidisciplinary Respiratory Medicine* 14, no.1. <https://doi.org/10.1186/s40248-019-0190-7>

Case Western Reserve University. Kurt Vonnegut Lecture| Shape of Story [Video]. YouTube. (2016, November 29)

Caswell, David A. 2015. "Structured Narratives as a Framework for Journalism: A Work In Progress". Paper Presented At 6th Workshop on Computational Models Of Narrative, 2015, at Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik.<https://doi.org/10.4230/OASIcs.CMN.2015.39>

Charon, Rita, Sayantani DasGupta, Nellie Hermann, Craig Irvine, Eric R. Marcus, Edgar Rivera Colsn, Danielle Spencer, and Maura Spiegel, eds. 2017. *The Principles and Practice of Narrative Medicine*. New York: Oxford University Press.

Ciotti, Silvia, Fortunato Bianconi, Vincenzo Saraceni, Maria Chiara Vulpiani, Giuseppe Rinonapoli, Auro Caraffa, and Mauro Zampolini. 2018. "Narrative Medicine in Amyotrophic Lateral Sclerosis and a Rehabilitation Project Based on International Classification of Functioning, Disability and Health". *American Journal of Physical Medicine and Rehabilitation* 97. no.11: 832–838. <https://doi.org/10.1097/PHM.0000000000000978>

Damiano, R., and Antonio Lieto. 2013. "Ontological Representations of Narratives: A Case Study on Stories and Actions". Paper presented at CMN'13 Computational Models of Narratives Satellite Workshop of the 35th Meeting of the Cognitive Science Society (CogSci) at Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik. <https://doi.org/10.4230/OASIcs.CMN.2013.76>

Damiano, Rossana, Vincenzo Lombardo, and Antonio Pizzo. 2019. "The Ontology of Drama". *Applied Ontology* 14, no.1: 77-198. <https://doi.org/10.3233/AO-190204>

Dick, Richard S., Elaine B. Steen, and Don E. Detmer, eds. 1997. *The Computer-Based Patient Record: An Essential Technology for Health Care*. Washington, DC: The National Academies Press.

Dosani, Sabina. 2021. "The Value and Benefit of Narrative Medicine For Psychiatric Practice". *BJP Psych Bulletin* 45, no.5: 274–276. <https://doi.org/10.1192/bjb.2020.45>

Dutta, Biswanath. 2017. Examining the Interrelatedness Between Ontologies and Linked Data. *Library Hi Tech* 35, no.2: 312-331. <https://doi.org/10.1108/LHT-10-2016-0107>

Dutta, Biswanath., Usashi Chatterjee, and Devika P. Madalli. 2015. "YAMO: Yet another Methodology for Large-Scale Faceted Ontology Construction". *Journal of Knowledge Management* 19, no.1: 6-24.

Ehrlinger, Lisa, and Wolfram Wöß. 2016. "Towards a Definition of Knowledge Graphs". Paper presented at SEMANTiCS (Posters, Demos, SuCESS) 48, no.2: 1-4. url: <https://ceur-ws.org/Vol-1695/>

Fernández, Mariano, Asunción Gómez-Pérez, and Natalia Juristo. 1997. METHONTOLOGY: From Ontological Art Towards Ontological Engineering. In *Proceedings of the AAAI-97 Spring Symposium Series*.

Freytag, Gustav. 1900. *Freytag's Technique of the Drama, An Exposition of Dramatic Composition and Art*. An Authorized Translation from the Sixth German Edition by Elias J. MacEwan, M.A. 3rd ed. Chicago: Scott, Foresman and Company.

Gómez-Pérez, Asunción, Mariano Fernández-López, and Oscar Corcho. 2004. *Ontological Engineering: With Examples from the Areas of Knowledge Management, e-Commerce and the Semantic Web*. Advanced Information and Knowledge Processing: Springer.

Greimas, Algirdas Julien. 1973. *Actants, Actors, and Figures. On Meaning: Selected Writings in Semiotic Theory*. Translated by Paul J. Perron and Frank H. Collins. Theory and History of Literature, Minneapolis: University of Minnesota.

Gruber, Thomas R. 1993. "A Translation Approach to Portable Ontology Specifications". *Knowledge Acquisition* 5, no.2: 199-220. <https://doi.org/10.1006/knac.1993.1008>

Gruber, Thomas R. 1995. "Toward Principles for The Design of Ontologies Used for Knowledge Sharing?" *International Journal of Human-Computer Studies* 43, no.5-6: 907-928. <https://doi.org/10.1006/ijhc.1995.1081>

Gruninger, Michael, and Mark S. Fox. 1995. "Methodology for the Design and Evaluation of Ontologies". Paper presented at Workshop on Basic Ontological Issues in Knowledge Sharing, IJCAI-95, Montreal. <https://www.eil.utoronto.ca/wp-content/uploads/enterprise-modeling/papers/gruninger-ijcai95.pdf>

Herbert, Louis. 2019. *An Introduction to Applied Semiotics: Tools for Text and Image Analysis*. Routledge.

Huang, Yung-Kai, Yi-Tzu Chen, and Yu-Chao Chang. 2021. "Initiating Narrative Medicine into Dental Education: Opportunity, Change, And Challenge". *Journal of the Formosan Medical Association* 120, no.12: 2191-2194. <https://doi.org/10.1016/J.JFMA.2021.06.008>

Jing, Xia, Stephen Kay, Nicholas Hardiker, and Tom Marley. 2007. "Ontology-Based Knowledge Base Model Construction-OntoKBCF." *Studies in Health Technology and Informatics* 129, no.1: 785. <https://pubmed.ncbi.nlm.nih.gov/17911824/>

Karami, Mahtab, and Azin Rahimi. 2019. "Semantic Web Technologies for Sharing Clinical Information in Health Care Systems". *Acta Informatica Medica*, 27, no.1: 4. <https://doi.org/10.5455/aim.2019.27.4.7>

Khan, Anas Fahad, Andrea Bellandi, Giulia Benotto, Francesca Frontini, Emiliano Giovannetti, and Marianne Rebou. 2016. "Leveraging a Narrative Ontology to Query a Literary Text". Paper presented at Workshop on Computational Models of Narrative at Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl. <https://doi.org/10.4230/OASIcs.CMN.2016.10>

King, Brandy E., Kathy Reinold, eds. 2008. *Finding the Concept, Not Just the Word: A Librarian's Guide to Ontologies and Semantics*. Elsevier Ltd. <https://doi.org/10.1533/9781780631721>

Klarer, Mario. 2013. *An Introduction to Literary Studies*. Devon: Routledge.

Labov, William, and Joshua Waletsky. 1967. "Narrative Analysis: Oral Versions of Personal Experience". In *Essays in The Verbal and Visual Arts: Proceedings Of The 1966 Annual Spring Meeting Of The American Ethnological Society, Seattle, WA*, edited by June Helm, 12-44. American Ethnological Society. <https://www.ling.upenn.edu/~rnoyer/courses/103/narrative.pdf>

Lemogne, Cédric, Céline Buffel du Vaure, Nicolas Hoertel, Annie Catu-Pinault, Frédéric Limosin, Christian Ghassrossian, Claire Le Jeunne, and Philippe Jaury. 2020. "Balint Groups and Narrative Medicine Compared to a Control Condition in Promoting Students' Empathy". *BMC Medical Education* 20, no.1. <https://doi.org/10.1186/s12909-020-02316-w>

Mohanti, Bidhu Kalyan. 2021. "Lessons from Narrative Medicine: Cancer Care Will Improve with Narrative Oncology". *Indian Journal of Cancer* 58, no.4: 615-618. https://doi.org/10.4103/ijc.IJC_809_20

Mulholland, Paul, Trevor Collins, and Zdenek Zdrahal. 2004. "Story Fountain." IUI'04. In *Proceedings of the 9th International Conference on Intelligent User Interface, 13 - 16 January Funchal, Madeira, Portugal*. New York: ACM, 62-9. <https://doi.org/10.1145/964442.964455>

Muneeb, Aeman, Hena Jawaid, Natasha Khalid, and Asad Mian. 2017. "The Art of Healing Through Narrative Medicine in Clinical Practice: A Reflection". *The Permanente Journal* 21: 17-013. <https://doi.org/10.7812/TPP/17-013>

Murphy, John W., Jung Min Choi, and Martin Cadeiras. 2017. "The Role of Clinical Records in Narrative Medicine: A Discourse of Message". *The Permanente Journal* 20, no.2: 103-108. <https://doi.org/10.7812/TPP/15-101>

Nakasone, Arturo and Mitsuru Ishizuka. 2006. "Storytelling Ontology Model Using RST." 2006. In *IEEE/WIC/ACM International Conference on Intelligent Agent Technology 18-22 December 2006 Hong Kong, China*. IEEE, 163-9. <https://doi.org/10.1109/iat.2006.114>

Noy, Natalya F., and Deborah L. McGuinness. 2001. "Ontology Development 101: A Guide to Creating Your First Ontology". *Knowledge Systems Laboratory* 32. https://protege.stanford.edu/publications/ontology_development/ontology101.pdf

Ogbuji, Chimezie. 2011. "A Framework Ontology for Computer-Based Patient Record Systems". In *Proceeding of the ICBO: International Conference on Biomedical*

Ontology 28-30 July 2011 Buffalo, NY, USA. <https://ceur-ws.org/Vol-833/paper28.pdf>

Peinado, Federico, Pablo Gervás and Belén Díaz-agudo. 2004. "A Description Logic Ontology for Fairy Tale Generation." In *Fourth International Conference on Language Resources and Evaluation: Workshop on Language Resources for Linguistic Creativity LREC, Portugal*, edited by Maria Teresa Lino, Maria Francisca Xavier, Fátima Ferreira, Rute Costa, and Raquel Silva, vol. 4. Lisbon: European Language Resources Association (ELRA), 56–61.

Pinto, H. Sofia, Steffen Staab, and Christopher Dr. Tempich, C. 2004. "DILIGENT: Towards A Fine-Grained Methodology for Distributed, Loosely-Controlled And Evolving Engineering Of Ontologies". In *Proceedings of the 16th European Conference on Artificial Intelligence (ECAI 2004)*, 22-27 August 2004 Valencia, Spain, August, 393–397.

Poveda-Villalón, María, Asunción Gómez-Pérez, and Mari Carmen Suárez-Figueroa. 2014. "OOPS! (Ontology Pitfall Scanner!): An On-Line Tool for Ontology Evaluation". *International Journal on Semantic Web and Information Systems (IJSWIS)* 10, no.2: 7-34.

Propp, Vladímir. 2009. *Morphology of the Folktale*. Texas: University of Texas Press.

Prud'hommeaux, Eric, and Andy Seaborne. 2008. *SPARQL Query Language for RDF*. Available at <https://www.w3.org/TR/rdf-sparql-query/>

Ragusa, Letizia, Antonio Crinò, Graziano Grugni, Luigi Reale, Alessandra Fiorencis, Maria Rosaria Licenziati, Maria Felicia Faienza, Małgorzata Wasniewska, Maurizio Delvecchio, Adriana Franzese, Irene Rutigliano, Paola Fusilli, Domenico Corica, Giuseppina Campana, Donatella Greco, Mariangela Chiarito, Michele Sacco, Silvia Toscano, and Maria Giulia Marin. 2020. "Caring And Living With Prader-Willi Syndrome In Italy: Integrating Children, Adults And Parents' Experiences Through A Multicentre Narrative Medicine Research". *BMJ Open* 10, no.8. <https://doi.org/10.1136/bmjopen-2019-036502>

Ranganathan, Shiyali Ramamrita. 1937. *Prolegomena to Library Classification*. Madras Library Association, Madras.

Robertson, Colin and Gareth Clegg, eds. 2016. *Storytelling in Medicine: How Narrative Can Improve Practice*. CRC Press.

Sameh S. El-Atawy and Mohamed E. Khalefa. 2016. "Building an Ontology-Based Electronic Health Record System". In *Proceedings of the 2nd Africa and Middle East Conference on Software Engineering (AMECSE '16) 28 – 29 May 2016 Cairo, Egypt*. Association for Computing Machinery, New York, NY, USA, 40–45. <https://doi.org/10.1145/2944165.2944172>

Sinha, Prashant Kumar, and Biswanath Dutta. 2020. "A Systematic Analysis of Flood Ontologies: A Parametric Approach". *Knowledge Organization* 47, no.2: 138-159. <https://doi.org/10.5771/0943-7444-2020-2-138>.

Smith, Michael K. 2004. "Owl Web Ontology Language Guide". Available at <http://www.w3.org/TR/owl-guide/>.

Stewart, Moira and Debra Roter, eds. 1989. *Communicating with Medical Patients*. Sage Publications.

Suárez-Figueroa, Mari Carmen, Asunción Gómez-Pérez, and Mariano Fernández-López. 2015. "The NeOn Methodology Framework: A Scenario-Based Methodology for Ontology Development". *Applied Ontology* 10, no.2: 107–145. <https://doi.org/10.3233/ao-150145>

Sure, York, Steffen Staab, and Rudi Studer. 2004 "On-to-Knowledge Methodology (OTKM)". *Handbook on Ontologies. International Handbooks on Information Systems*, edited by Steffen Staab and Rudi Studer, 117-132. Berlin, Heidelberg: Springer.

Swartjes, Ivo, and Mariët Theune. 2006. "A Fabula Model for Emergent Narrative". In *Technologies for Interactive Digital Storytelling and Entertainment. TIDSE 2006. Lecture Notes in Computer Science*, edited by Stefan Göbel, Rainer Malkewitz, and Ido Iurgel. Berlin: Springer. https://doi.org/10.1007/11944577_5

Uschold, Mike, and Martin King. 1995. "Towards a Methodology for Building Ontologies". Paper presented at Workshop on Basic Ontological Issues in Knowledge Sharing held in conjunction with IJCAI-95. Edinburgh: Artificial Intelligence Applications Institute, University of Edinburgh.

Varadarajan, Udaya, and Biswanath Dutta. 2021. "Towards Development of Knowledge Graph for Narrative Information in Medicine". In *Proceedings of the Third Iberoamerican Conference and Second Indo-American Conference, KGSWC 2021, Kingsville, Texas, USA, 22–24 November 2021*, edited by Boris Villazón-Terrazas, Fernando Ortiz-Rodríguez, Sanju Tiwari, Ayush Goyal, M Jabbar, 290-307. Springer, Cham.

Varadarajan, Udaya, and Biswanath Dutta. 2022. "Models for Narrative Information: A Study". *Knowledge Organization* 49, no.3:172-191. <https://doi.org/10.5771/0943-7444-2022-3-172>.

Varadarajan, Udaya, Bagchi, Mayukh, Tiwari, Amit, and Satija, M. P. 2023. "GOMME: A Generic Ontology Modelling Methodology for Epics". *Journal of Information Science Theory & Practice (JISTaP)* 11, no.1.

Ware, Carolyn E. 2017. "Personal Experience Narratives in Veterinary Medicine". *Narrative Culture* 4, no.2: 201–21. <https://doi.org/10.13110/narrcult.4.2.0201>

Wesley Tiffany, Diana Hamer, and George Karam. 2018. "Implementing A Narrative Medicine Curriculum During the Internship Year: An Internal Medicine Residency

Program Experience". *The Permanente Journal* 22, no. 2:17-187. <https://doi.org/10.7812/TPP/17-187>

Winer, Dov. 2014. "Review of Ontology Based Storytelling Devices". In *Language, Culture, Computation. Computing of the Humanities, Law, and Narratives. Lecture Notes in Computer Science*, edited by Nachum Dershowitz and Ephraim Nissan, 394-406. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-45324-3_12.

Yang, Ningxi, Han Xiao, Yingnan Cao, Shiyue Li, Hong Yan, and Yifang Wang. 2018. "Does Narrative Medicine Education Improve Nursing Students' Empathic Abilities and Academic Achievement? A Randomised Controlled Trial". *Journal of International Medical Research* 46 no.8, 3306–3317. <https://doi.org/10.1177/0300060518781476>

Yeh, J.-h. 2017. "StoryTeller: an Event-based Story Ontology Composition System for Biographical History". In *Proceedings of the International Conference on Applied System Innovation (ICASI), Sapporo, Japan, 13-17 May, 2017*. IEEE, 1934-1937. <https://doi.org/10.1109/ICASI.2017.7988448>

Yehia, Engy, Hussein Boshnak, Sayed AbdelGaber, Amany Abdo, and Doaa S Elzanfaly. 2019. "Ontology-Based Clinical Information Extraction from Physician's Free-Text Notes". *Journal of Biomedical Informatics* 98: 103276. <https://doi.org/10.1016/j.jbi.2019.103276>

Zaharias, Georges. 2018. "What Is Narrative-Based Medicine? Narrative-Based Medicine 1". *Canadian Family Physician* 64, no.3: 176–180. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5851389/>

Zhang, Yin, Bin Pi, Xianlin Xu, Ying Li, Xiangfan Chen, and Ningxi Yang. 2020. "Influence of Narrative Medicine-Based Health Education Combined with an Online Patient Mutual Assistance Group on The Health of Patients with Inflammatory Bowel Disease And Arthritis". *Psychology Research and Behavior Management* 13: 1–10. <https://doi.org/10.2147/PRBM.S213587>