ARTIFACT-CENTRIC SEMANTIC SOCIAL-COLLABORATIVE NETWORK IN AN ONLINE HEALTHCARE CONTEXT

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ABSTRACT

The emergence of Web 2.0 technologies and associated social networking systems opens up many possibilities for online collaboration. Several reference models, frameworks, tools and infrastructures have been proposed to support seamless communication between human entities in an online social environment. A few studies suggested social networks are not only constructed of connections between people, but are also mediated by shared objects, known as object-centred sociality. However, most developed social software systems limit themselves to human-centric social relationships. This may be due to the more difficult task of integrating heterogeneous elements of the network, compared to a network of people only. These additional resources or artefacts, such as physical objects, software entities, documents, etc., are active elements in a way that they may coordinate, cooperate, and even trigger collaborative work in a social environment, which is more difficult to understand and implement. Hence, it is essential to concentrate on exploring the artifact-centric social relations in a new generation of social-collaboration networks.

This paper explores the concept and characteristics of social software systems and emphasises the importance and role of objects and artifact-centric sociality. It also outlines the benefits of semantic representation of the social-collaborative network structure by extending existing social ontologies such as FOAF, SIOC, and DC that define additional concepts, properties and complex social relationship of humans, social objects and collaboration artefacts. The paper ends by demonstrating the effectiveness of its proposed approach by applying it to a large-scale social-collaborative healthcare service called GRiST within the United Kingdom.

KEYWORDS

Web 2.0, Social Network, Work Artifacts, Semantic Web, Ontology, Healthcare, GRiST.

1. INTRODUCTION

The emergence of Web 2.0 and associated social media technologies such as wikis, blogs, and social networks has dramatically changed the way to communicate and share information between people across communities (Chen, Hendry, & Huang, 2016). Social networks in particular build on Web 2.0 technology because it brings many opportunities for online collaboration. Collaboration within communities provides a powerful weapon for solving problems, building consensus, and helping in decision-making processes (Zaffar & Ghazawneh, 2012). Traditionally, email was the most-widely used method because of its flexibility and ease of use. The drawback of email is that people tend use it for a variety of purposes and often in a quasi-synchronous manner (Abbattista et al., 2008). It is not truly real-time and fails to meet the variety of collaboration and communication needs. On the other hand, traditional face-to-face communications amongst communities are limited by geographical location and resources (Soto et al., 2016). Online collaboration tools overcome these limitations by exploiting different kinds of activities that transgress time and distance (Samuel, 2015). Their processes are influenced by social and communication structures formed by the collaborators (Liptchinsky et al., 2014), and building relationships is fundamental to the success of

collaborations (Bergstrom et al., 1995). Socially-enabled collaboration empowers and encourages participation, conversation, openness, content creation and socialisation among a community of users (Gaál et al., 2015).

In this context, several reference models, frameworks, applications and infrastructures have been proposed to support seamless interaction and communication in a collaborative network environment. Sadly, most are wholly people-centric for sharing common interests, goals, and areas of expertise (Zaffar & Ghazawneh, 2012). For example, Facebook, LinkedIn, and YouTube, are dedicated to connecting friends and families, professional networking and media sharing (Arnaboldi et al., 2017). A few Web 2.0 based open social applications such as wikis, groupware, and google docs do include artefacts within their social context but not where both humans and objects are equally important entities within the integrated collaboration network. In general, current approaches do not pay much attention to artefact-centric relations, communication and collaboration in a context-based social network.

Object-centred sociality (Engeström, 2005) means social structures and interactions can be centred around objects (Marie & Gandon, 2011). People do not just connect to each other, they also connect through shared objects and work artefacts (Begel & Deline, 2009). For example, the relations between documents, software components, technical designs and other work artefacts should all influence the collaboration process (Liptchinsky et al., 2014). The problem is that existing collaboration modelling approaches do not recognise how objects and artefacts establish and maintain social relationships, how they are used and understood by people, or how they tie people together within a social network (Nansen et al., 2014).

Without consistent structures and semantics, it is impossible to capture the social phenomenon of human and artefact-centric social interconnections. One approach is to use Semantic Web based ontologies (Berners-Lee, Hendler, & Lassila, 2001) for linking concepts and properties together in the Web 2.0 era (Stan & Villarceaux, 2009). The ontology explicitly specifies the concepts and properties (object properties and data properties) and uses reasoning and inference mechanism to deduce new information through the rules (e.g., discover new relationships (Oellinger & Wennerberg, 2006). Additionally, services can take advantage of semantic reasoning capabilities to generate intelligent recommendations (Chen et al., 2016). Although some standard social ontologies (e.g., FOAF, SIOC, SKOS, DC) exist to define the social network structure, they are not capable of representing a network of objects or artefacts and their relationships with human entities.

The purpose of this paper is to explore the concept and characteristics of social software systems and distinguish to what extent they can promote online collaboration. It discusses the importance and role of artefact-centric sociality in a social-collaboration network. Benefits are described for generating semantic representations of object-centred social-collaborative network structures by extending existing social ontologies into. Finally, the applicability of the proposed approach is explored by applying it to a large-scale social-collaborative healthcare service called GRiST (https://www.egrist.org) within the United Kingdom.

The paper is organized as follows: Section II describes the background and motivation for the work. Section III explores related work and Section IV presents a new Semantic Social-Collaborative Network SSCN model. Section V proposes an extended ontology that is implemented within Section VI as a case study. Section VII discusses the findings and concludes with further research directions.

2. BACKGROUND AND MOTIVATION

Online healthcare is a prime example of social-enabled collaborative work where multiple people work together to provide care for patients in hospital or at home (Xiao, 2005). Healthcare provision is a set of activities that demands collaboration between, for example, physicians, nurses, managers, and patients (Christopoulou et al., 2017) to improve research, cost effectiveness, good management of resources, etc. (Benhiba et al., 2017). Using social media tools, physicians can reach their patients easily to update them with a therapeutic plan, to answer disease-related questions, or simply to provide advice or reminders (Lapointe, Ramaprasad, & Vedel, 2014). At the same time, health information systems are mediated by artifacts such as software modules and other resources that are usually spatially and functionally distributed (Christopoulou et al., 2017), which require a significant attention to define their social relationship and semantic representation in a collaborative environment. The motivation for this work is the development of a semantic social-collaborative network (SSCN) model, which will support communication and collaboration

between care communities, patients and medical artifacts. Furthermore, semantic web technologies will improve interoperability between people and resources in healthcare practice by using a shared ontology.

2.2 Web 2.0 and Social Software

A new generation of web-based and community-centred applications are usually given the label of social software (Lohmann et al., 2009). The core idea is often characterised as a subset of the Web 2.0, and its application to supporting collaboration in organizations is termed "Enterprise 2.0" (Koch, 2008).

Collaboration is the process of working together for people, groups and organizations in a sociable environment to systematically solve a problem that could not be solved by an individual alone (Bergstrom et al., 1995). Social media tools like wikis are becoming increasingly popular for managing knowledge and collaboration within enterprises (Zaffar & Ghazawneh, 2012) and social networking in general allows quick and easy communication methods between users for personal or professional purposes (Dey et al., 2018).

A social network is a social graph composed of users and other entities such as multimedia contents, humans, messages, places, events, etc. collectively called nodes. They are interrelated or connected by edges representing common social relationships such as friendship, following, likes, shares, etc., either directly or indirectly (Ghafoor & Niazi, 2016). Advanced social networks can be represented as graphs with nodes both for people and their work artefacts that are coordinated into collaborative tasks (Begel & Deline, 2009).

2.2.1 Objects and Artifacts in Social Network

The concept of object-centred sociality was introduced by Jyri Engeström (Engeström, 2005) to examine how the inclusion of shared objects can enhance online social networking between people and shared objects (Marie & Gandon, 2011). It encapsulates the idea that strong social relationships are built mainly when individuals are grouped together around a shared object, and it mediates the ties between them (Kaldoudi et al., 2011).

2.2.2 Semantic Social Network

The Semantic web is an extension of the current web, in which information is given defined meaning, enabling machines and users to cooperate (Berners-Lee et al., 2001). An ontology is a semantic web technology that formally and explicitly specifies entities, attributes and properties related to a domain (Obeid et al., 2018). In the conceptual model, entities are defined as Classes representing a collection of instances, Properties represent relations between classes, and Instances (also known as objects or individuals) are concrete members of a class.

A few researchers showed how social networks would benefit from utilising existing social ontologies such as FOAF, SIOC, SKOS, and DC (Erétéo et al., 2011). FOAF (Friend-Of-A-friend, http://www.foaf-project.org/) is the most popular ontology used for describing people, their relationships and social activities. SIOC (Semantically-Interlinked Online Communities, http://sioc-project.org) describes the most common elements present on Web of communities. The SKOS (Simple Knowledge Organization System) ontology (https://www.w3.org/2004/02/skos/) describes systems of organised knowledge, and DC (Dublin Core) metadata vocabularies (http://dublincore.org/) can be used to describe digital resources (video, images, web pages, etc.), as well as physical resources such as books or CDs, and objects like artworks. However, these ontologies are not capable of fulfilling all the requirements of a domain-specific context-aware social network structure.

3. RELATED WORK

Various definitions, characteristics and tools for online collaboration have been proposed that highlight how to use Web 2.0 technology to support knowledge sharing, communication and collaboration in organisations. Exter et al. (2012) explores its use in a higher-education context, including a review of the key strengths and weaknesses of Web 2.0 technology. Thelwall & Kousha (2015) investigated ResearchGate, a social network site for academics to create their own profiles, list their publications and interact with others. Also, in an academic context, Obeid et al. (2018) proposed an ontology-based recommendation system to assist students

in finding and selecting relevant universities and major subjects in their field of interest. Arif (2017) showed how the new online collaboration tools like Slack, Trello, and Asana, can serve as a means for focused communication and project collaboration both inside and outside academia. Wikipedia, though, is probably the most well-known online collaborative platforms for enabling users to view, create, edit, or remove articles on different topics (Zaffar & Ghazawneh, 2012). The social aspects of all these systems build trust in virtual teams and provide an important foundation for collaboration (Murthy & Lewis, 2015).

Nansen et al. (2014) extended social networks to include objects, which play a role in mediating human social relationships and have a social life of their own through the fact of their emergence, persistence, relations and death. Maamar, Buregio, & Sellami (2015) discuss how to design and develop collaborative enterprise applications using business and social artifacts. This paper continues this line of work by proposing a social-collaboration network that encompasses people and things as equal entities within a single system.

4. THE PROPOSED SEMANTIC SOCIAL-COLLABORATION NETWORK MODEL

The proposed Semantic Social-Collaborative Network (SSCN) is a generic web application model with ontology support that can be used to implement context-aware collaborative networks, where all kinds of participants, both human and artificial, will work together in a social and possibly distributed environment. To illustrate the system, a conceptual model of an SSCN has been proposed, which is comprised of three core subsystems: (i) a Social-Collaborative Network (SCN), (ii) a Recommender System (RS), and (iii) an Ontology Service Module (OSR) that together form the whole SSCN as shown in Figure 1.

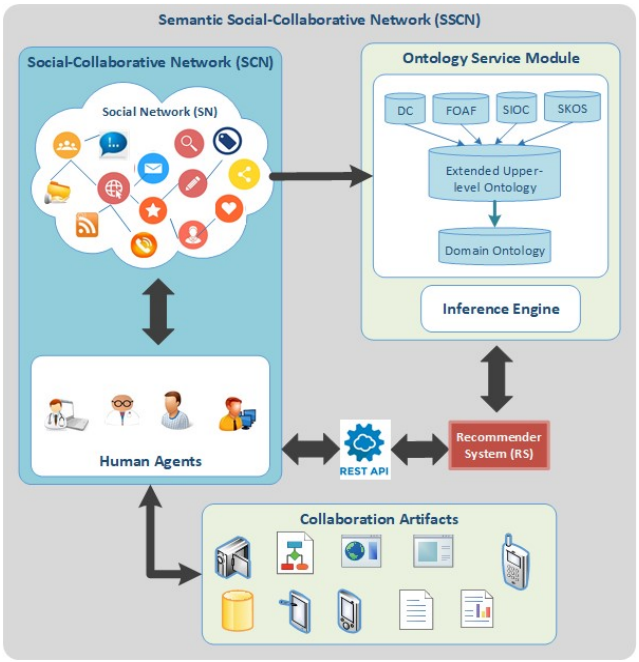

Figure 1: Semantic Social-Collaboration Network Model

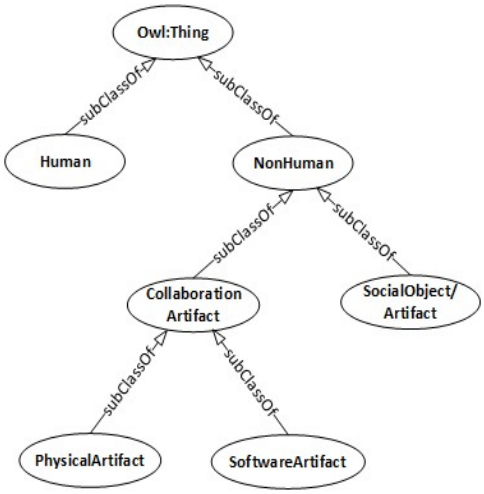

Figure2: Core Ontology Classes

The Social-Collaborative Network (SCN) is a subsystem of the SSCN and comprises of a Social Network (SN) environment and *Human Agents*. The SN maintains all kinds of social entities and properties and their interactions, communications and relationships. The *Human Agents* are the physical people who create and manage their social profile and maintain social connections like friendship, membership, sharing, follows,

etc., and who interact with social objects and collaboration artifacts. These artifacts are non-human entities, which can have a social existence and relations in the SN environment and are maintained by humans.

The Ontology Service Module (OSM) provides ontology management and inference services to the system, where an extended upper-level ontology and domain-specific ontology is linked with existing FOAF, SIOC, SKOS and DC. This ontology integration formally defines the whole SCN structure, concepts and properties, and updates the ontology as changes happen in the network. The Recommender System (RS) is an integrated third-party software module that can provide functionality to generate personalised or collaborative recommendations based upon the ontology inference and semantic similarity of user profiles, preferences, annotations, tags and interests. The RS can send and receive data from the SCN by a standard RESTful API but this paper will not focus on the low-level functionality or internal logic of the recommendation system.

5. EXTENDED ONTOLOGY MODELLING

The extended ontology model discusses a way to represent artifict-centric social-collaboration network data in a shared and machine-readable way. Its main objective is to capture additional non-human related concepts, properties and relations in the social-collaborative network while reducing the unintended modeling costs and human efforts. For the ease of development, we split our ontology model into a Core Ontology (CO), an extended upper-level Social-Collaboration Ontology (SCO). A separate Domain Ontology (DO) allows for a flexible interface and the ability to extend into any domain-specific system implementation.

5.1 Defining The "CoreOnto" Ontology

The "CoreOnto" ontology is illustrated in Figure 2. It defines a set of abstract concepts as the main building blocks for the representation of artifact-centric sociality discussed in this paper. It is a light-weight ontology consisting of minimal core concepts and relationships about human and non-human entities, user-generated social objects and collaborative artifacts that may be further deconstructed into physical artifacts and software artifacts.

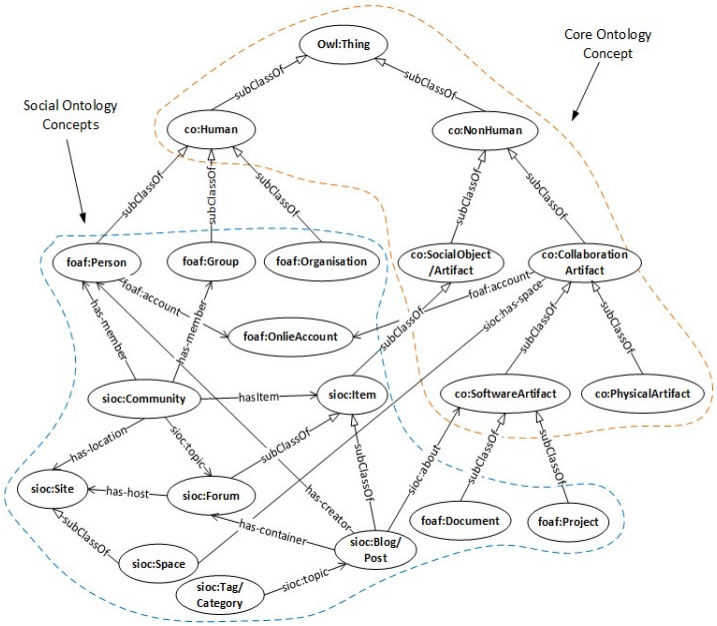

Figure 3: Extended Social-Collaboration Ontology

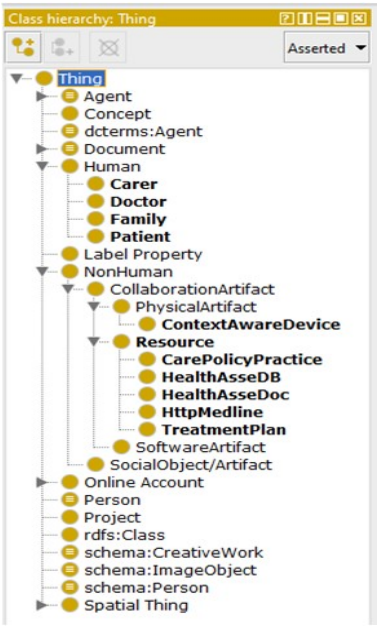

Figure 6: Ontology Implementation

5.2 Upper-level "SocialCollaborationOntology"

The extended upper-level "SocialCollaborationOntology", reuses the concepts and properties from the "CoreOnto" ontology as well as existing FOAF and SIOC ontologies as shown in Figure 3 and its implementation in Figure 4. This upper-level ontology is limited to a very abstract conceptualisation that can be shared across domain-level ontologies. In this ontology extension, we have reused a few concepts and properties to interlink both ontologies together based on our case requirements. However, the domain-level ontology may inherit additional concepts and properties from the upper-level ontology or may define new terms and properties according to domain-specific requirements.

6. USE CASE: GRiST HEALTHCARE SYSTEM

In In order to demonstrate the applicability of the proposed approach, we considered the GRiST (Galatean Risk and Safety Technology, www.egrist.org) web-based decision support software system. It provides expertise directly connecting older adults and their network of carer's such as family, friends, and clinical services to ensure they are safe, secure, and thriving (Buckingham et al., 2015). However, GRiST and many other similar online healthcare systems do not wholly encapsulate non-human participants (e.g., care artifacts and resources) and their interactions and communication, and neither are they semantically described.

This paper's proposed approach could fill the gap by implementing an extended social-collaborative care network of GRiST and its relevant extended ontology, which will semantically represent the additional concepts, properties and their relationships. It will make social links between resources, individuals and the community of practice in the social healthcare environment, which may improve care service and increased

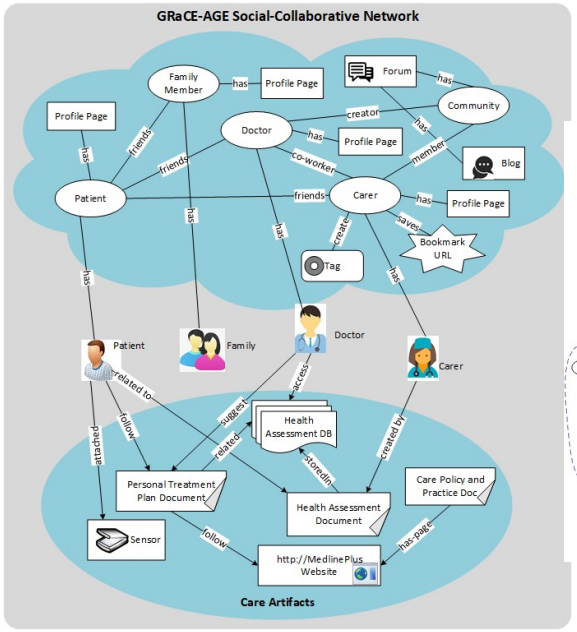

Figure 4: GRiST Social-Collaborative Healthcare Network

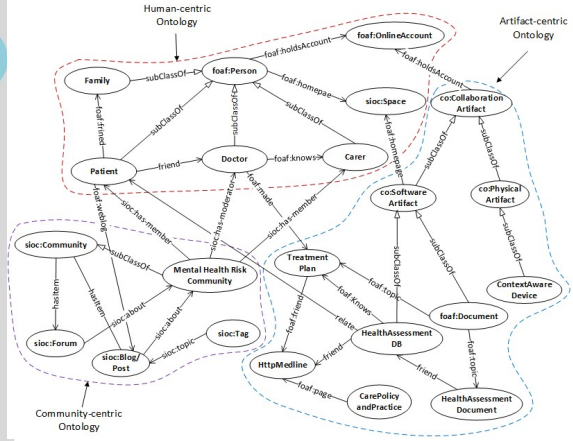

Figure5: GRiST Care-Network Ontology

transparency throughout the patient's care journey. The integrated Recommender Service may also improve suggested treatment plans based on the augmented information sources, such as posts and texts or suggest new contacts based on experiences of others going through similar difficulties. Figure 4 illustrates the semantic social-collaborative network in the context of GRiST's healthcare system with extended social relations involving non-human entities.

6.1 Scenario A - GRiST Social Connections and Communications

As shown in Figure 4, assume that a *Patient* is socially connected by friend relation with a *Doctor* and a *Carer* based on his/her care support team. This *Patient* is also connected with a *Family* member as a `friend` relation, and the *Doctor* and *Carer* are connected as a `co-worker`. The Recommender System may find relevant medical information based on the patient's health assessment record and suggest an additional care plan to the patient based on the inferred medical web resources (e.g. from the MedlinePlus Website).

Furthermore, the *Carer* may save a social *Bookmark* for the medical URL page about *Care Policy and Practice*, and may create a *Tag* for health information associated with the patient health condition. A social notification service may then send alerts to reach all connected members if required.

Patients may participate in a *Discussion Forum* about specific diseases or conditions, may `follow` particular medical treatments and procedures, and get advice on health-related topics. A discussion forum can have a moderator, such as a *Doctor* who creates a *Care Community* of practice for a particular type of health condition (e.g. mental health risk community) and allows access to others for joint discussions, posting comments or reviews, etc. Building this type of care community around a specific topic is a critical source of trusted information for patients and caregivers, where they can engage with other potential members, listen to each other's concerns and answer disease-related questions. The social communication, interaction, event notification and relationship discussed in Scenario A will be maintained by the social networking system, which is easy to implement.
implement.

6.2 Scenario B - Artifact-Centric Social Relations in GRiST

Figure 4 also illustrates in more detail the complex social connections and communication between human and artifacts in the care network. These healthcare resources or artifacts are created, accessed, and used in a variety of contexts, which deliver a distinctive aspect of socialisation in the care network. According to Scenario B, there may be different kinds of healthcare artifacts, including: the *HealthAssessmentDB* to store health data; a *HealthAssessmentDocument* related to individual patient's health assessment; a *PersonalTreatmentPlanDocument* created by a doctor according to the patient's health condition and assessment; the *http://MedlinePlusWeb* web resource that contains health information and other medical artifacts; and *Care Policy and Practice* documents describing the various types of health information. These artifacts may socially be connected to each other as well as with the human agent by the relation of friends, follows, storedIn, createdBy, suggests, etc. property relations. However, the limitation is that these non-human objects need human interaction to maintain their social existence and relationship and to keep track of changes in the network, which is difficult in a dynamically changing situation when the links and interactions grows.

6.3 Implementation

This section presents a prototype implementation of the GRiST care network ontology as shown in Figure 6 and demonstrates how to link it with the extended upper-level "SocialCollaborationOntology" that endorses knowledge integration within the social-collaborative care network. The ontologies were built and manually merged using the Prot'eg'e-5.5.0 ontology editor (https://protege.stanford.edu/products.php\#web-protege). Prot'eg'e is a free, open-source platform that provides a suite of tools to construct domain models and knowledge-based applications. The resulting ontology was tested by launching the inference engine on *RacerPro* to ensure consistency.

6.3.1 Interlinking Extended "SocialCollaborationOntology" with the GRiST Network

The purpose of interlinking the ontology with a care network is to illustrate how a domain ontology reuses concepts and properties from extended upper-level ontology to describe the domain in semantic hierarchies and relationships. It will help to deduce context information from user's profile, personal medical status and shared objects or resources using inference rules in dedicated collaborative context. The first step is to create

the mind map that describes the major concepts of GRiST domain and then adding the properties (slots) and features (facets) to the classes to describe the structure of the care network. The classes of "CareNetworkOntology" are then constructed and linked with upper-level "SocialCollaborationOntology" and "CoreOnto" ontology with appropriate object and data properties based on the care context scenarios. The resulting ontology forming a three-different type of sub-ontologies, including Human-centric ontology, Artifact-centric ontology and Community-centric ontology separated by dash lines as shown in Figure 5.

7. DISCUSSION AND CONCLUSION

Web 2.0 based social-collaboration platforms enable participation, communication and cooperation in working groups based on individual's activities (Gaál et al., 2015). In this work, we illustrate the advantage and applicability of social networking approach with artifact-centric interaction, communication and information sharing in a collaborative context. In practice, we have demonstrated how social networking features utilised and impacted the way health care network of participants (human, smart devices and care artifacts) does collaboration with regards to care support. We suggest that the social context plays an essential role in describing the situation in which human and collaborative artifacts engage and communicate. In addition, we argue the benefits of ontological representation of social-collaborative network structure by extending existing social ontologies such as FOAF, SIOC, and DC that define new concepts and complex social relationship of these entities. One of the limitations of this work is that the resources in the network need human agents to maintain their social existence, relation and communication with others. Managing and keep tracking of these larger numbers of resources is a complex task for a human agent even with the help of computational tools, because of their social context and relation may change constantly as network grows. Additionally, social networks employ event notification mechanisms to notify people for relevant changes. A typical notification policy is that when an event happens at a node, the event is reported to all nodes that are directly connected to the source node. However, propagating events without overwhelming people with relevant information or alerts is another research challenge (Begel & Deline, 2009).

Our prospective vision is that the next-generation social-collaborative system and its resources will be able to maintain their connection, communication and collaboration in an autonomous way to reduce management complexity and without human intervention.

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