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IDOMEN: An Extension of Infectious Disease Ontology for MENingitis

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Abstract

In sub-Saharan African countries the prevention and control of epidemic diseases requires the improvement of the surveillance system for these diseases. Biomedical ontologies are a growing field that can improve health information systems. Indeed biomedical ontologies allow semantic support, data integration, automated reasoning. We are building a meningitis ontology to assist filtering messages relevant to meningitis domain on social media in order to predict a possible epidemic. Indeed, the messages filtered are used for data and event extraction that serve as input for a meningitis surveillance system. In this paper we focused on the modeling and formalization of different perspectives of the meningitis disease such as biological perspective, clinical perspective, epidemiological and public health perspective. This paper presents the three modules in the global Infection Disease Ontology for Meningitis (IDOMEN) and at the end, we illustrate a case of reasoning with our ontology.

Keywords: Knowledge, Infectious Diseases, Meningitis

Introduction

Meningococcal meningitis is an infectious disease that causes an inflammation of the meninges surrounding the brain and the spinal cord [1]. It is due to a gram negative bacteria called neisseria meningitidis. Our work focuses only on meningitis, called meningococcal meningitis.

Since two decades the situation of meningitis is not clearly under control. Nearly one million of meningitis suspected cases and over 100 000 meningitis death are reported in the *African meningitis belt* [2] made up of 26 countries from western Senegal to eastern Ethiopia, via Mali, Burkina Faso, Niger, Chad, Nigeria and other countries.

Unfortunately, in the sub-Saharan countries in general there is no real-time data collection tools for the meningitis surveillance systems. Therefore, the risk analysis for early detection of the meningitis epidemic is delayed.

In this work we propose an approach of early detection of epidemics based on social networks analysis. Our approach is justified by the fact that the work of [3] shows how social media analysis can improve better health monitoring in terms of availability of information for risk analysis and patient support. As stated in social media analysis, health monitoring is conducted through 3 main steps: data collection, semantic analysis, and results sharing with users or decision makers. In this work we use the social media platform Twitter as data source to improve early detection of meningitis epidemic risk in Burkina Faso. We are interested in Twitter because of it increasing use Africa. Indeed, in, the report 2015 “How Africa Tweets”, Portland Communications analyzed 1.6 billion tweets from Africa during this year. They show that African people adopt more and more social media. At December 2017 Internet users in Burkina Faso exceeded to 3 million, with internet growth more than 36 percent.

However, the tremendous of stream of data generated by social media requires filtering while collecting data. It requires the use of a domain-controlled vocabulary to assist data filtering. A domain ontology for meningitis could act as better candidate for this task since ontologies provide at first a domain terminology and secondly axioms describing relations across terms. Our ontology for meningitis is built as an extension of infectious diseases ontology (IDO) [4]. As existing domain ontologies extending IDO, the meningitis ontology is called IDOMEN as Infectious Disease Ontology of/for MENingitis. The scopes of IDOMEN cover the classic views on the disease such as the biologic aspect, clinical aspect, and public health aspect.

In the following of this paper we first present the global architecture of IDOMEN in Methods. Then we highlight the knowledge modeling and formalization of the different meningitis aspects covered by our ontology in the Results.

Finally, we conclude and draw the perspectives of our work.

Methods

Ontologies define a set of basic terms and relations which exist in the vocabulary of a given domain, as well as the rules and axioms that apply on these ones. Gruber has given a fairly comprehensive of "what is an ontology" : « An ontology is a formal, explicit specification of a shared conceptualization ». Depending on the level of abstraction and the object of conceptualization we distinguish three kinds of ontologies :

- The **top level** (upper-level) **ontologies** are characterized by ontologies that model universals, general knowledge;
- The **core ontologies** or generic ontologies describe generic knowledge that are not specific to one domain but are common to several domains ;
- The **domain ontologies** represent knowledge from a specific domain.

The IDOMEN is designed as domain specific ontology since it represents knowledge of the meningitis disease domain.

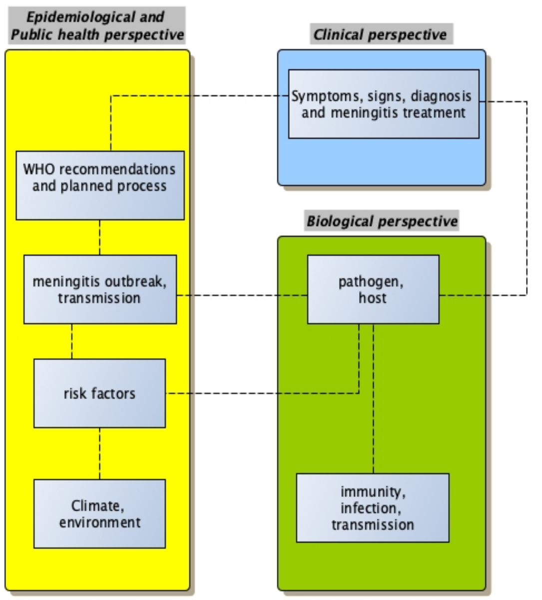

Figure 1 – Modular perspectives design of IDOMEN

The goal of IDOMEN is to assist extracting data and events from text messages published in social media, and to allow data integration, domain knowledge sharing and efficient communication between actors within the epidemiological surveillance system [10]. Therefore, to satisfy these requirements, the scope of IDOMEN covers the disease aspects related to the biology, clinical manifestation and care, public health, prevention and control, biomedical research, and epidemiological studies.

The different aspects have been packaged in three modular

perspectives that are biological perspective, clinical perspective, epidemiological perspective and public health perspectives (figure 1) :

- The **biological perspective** focuses on biology and microbiology of organisms implied in the disease course. In this perspective we model immunity, virulence factors, pathogen and host biology, etc. ;
- The **clinical perspective** focuses on clinical manifestations (signs, symptoms), complementary examination (laboratory test, laboratory findings, etc.), diagnosis, treatment, etc. ;
- The **epidemiological and public health perspective** focuses on topics related to the disease spread/outbreak such as risk factor, transmission, climate, environnement, etc. ; and deals with standard strategies of preventing or fighting against meningitis outbreaks.

This organization of the knowledge allows us to design our ontology in modular perspectives. Modularity makes it possible to build ontologies of large or small sizes and offers the possibility of easily reusing existing ontological resources. In the field of biomedical ontologies the reuse of existing ontological components is a best practice that is strongly encouraged.

This leads to the principles of the Open Biomedical Ontologies (OBO) Consortium [6] which are best practices and recommendations that promote interoperability. There are many biomedical ontology repositories containing ontology of different types and level of abstraction that can be freely reused. IDOMEN is designed and built upon this principle.

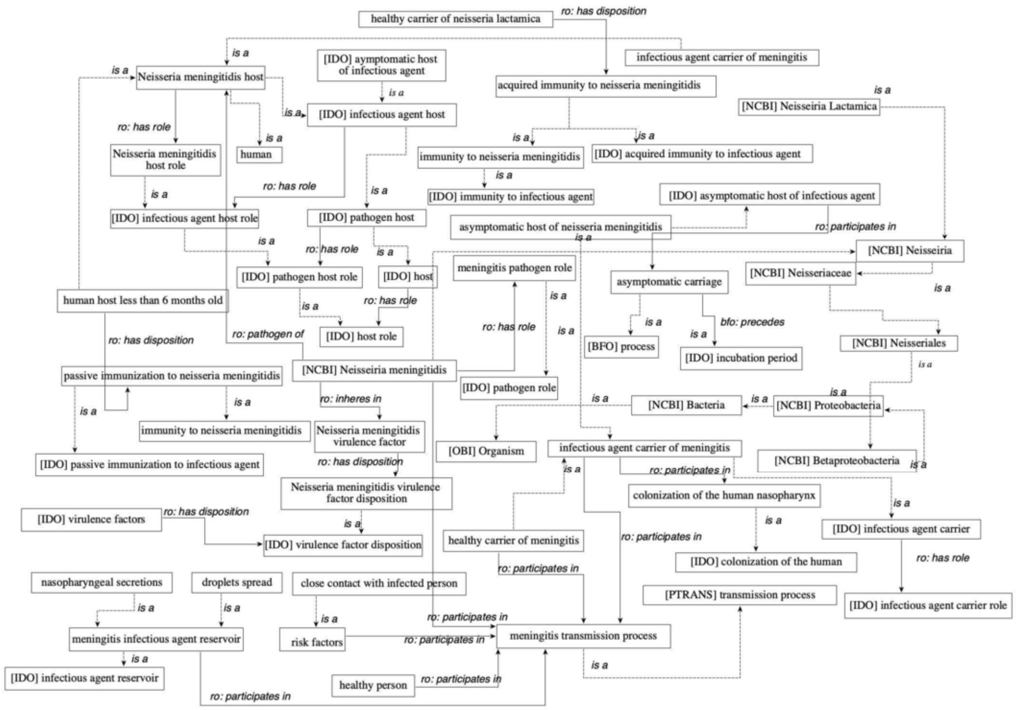

Figure 2– Conceptual model of the biological perspective of the meningitis disease

Results

Modeling biological perspective in IDOMEN

Pathogen and host

In figure 2, we present the knowledge modeling of the pathogen agent of meningococcal meningitis called *Neisseria meningitidis.* We use the classification of NCBI Taxonomy to provide a classification of the organism *neisseria meningitidis* in IDOMEN. The species *Neisseria meningitidis* in the taxonomic classification of NCBI is of the genus

Neisseria, and the *Neisseria* are from family of the *Neisseriaceae*. In the Figure 2 this is represented by *"[NCBI]Neisseria meningitidis"* is a *"[NCBI]Neisseria"*, followed by the relation *"[NCBI]Neisseria"* is a *"[NCBI]Neisseriaceae"*. Browsing further in the hierarchy of the NCBI Taxonomy, we found that *Neisseria Meningitidis* is also a subclass of *Proteobacteria*. *Proteobacteria* is a phylum of bacteria consisting of the purple bacteria *"[NCBI]Proteobacteria"* is a *"[NCBI]Bacteria"*. Bacteria is an organism. *Neisseria meningitidis* being the pathogen agent of meningitis, it plays a *"pathogenic role"* (*"meningitis pathogen role"*) in the human body : *"meningitis pathogen role"* ***is a*** *"[IDO]pathogen role"*. Thus, we have *"[NCBI]Neisseria meningitidis"* ***bearer of*** *"Meningitidis pathogen role"*. *Neisseria meningitidis* has the capability under specific conditions to trigger a pathogenic process, we say that it has a *"pathogenic disposition"*. A disposition is an intrinsic attribute of an entity that allows it to trigger itself a specific process or processes when particular conditions are satisfied : *"[NCBI]Neisseria meningitidis"* ***has disposition*** *"[IDO]pathogenic disposition"*.

Pathogenesis

The pathogenesis of meningitis refers to the process or processes responsible for triggering and developing meningitis. The pathogenesis of meningitis occurs in three (03) sequences that are: transmission, acquisition, colonization.

There are two (02) modes of transmission of meningococcal. The aerosol mode and the contaminated secretions one. A person who caught the pathogen agent Neisseria meningitidis but who has not any manifestations (symptom and sign) of the meningitis is called *"healthy carrier of meningitis"*. We translate this by *"healthy carrier of meningitis"* **is a** *"infectious agent carrier of meningitis"*. *"Asymptomatic carriage"* is a process during which the infected person develops no symptomatic manifestation of meningitis. This state of fact is described by 3 relations: : *"healthy carrier of meningitis"* ***is a*** *"[IDO]asymptomatic host of neisseria meningitidis"*. *"[IDO]asymptomatic host of neisseria meningitidis"* ***is a*** *"[IDO]asymptomatic host of infectious agent"*. "[IDO]asymptomatic host of infectious agent" **participates in** "asymptomatic carriage" and "asymptomatic carriage" **is a** "[BFO]process". This process asymptomatic carriage precedes the phase of colonization in the nasopharynx, what is transcribed by these two relations *"asymptomatic carriage"* precedes *"[IDO]incubation period"* and *"infectious agent carrier of meningitis"* ***participates in*** *"colonization of the human nasopharynx"*.

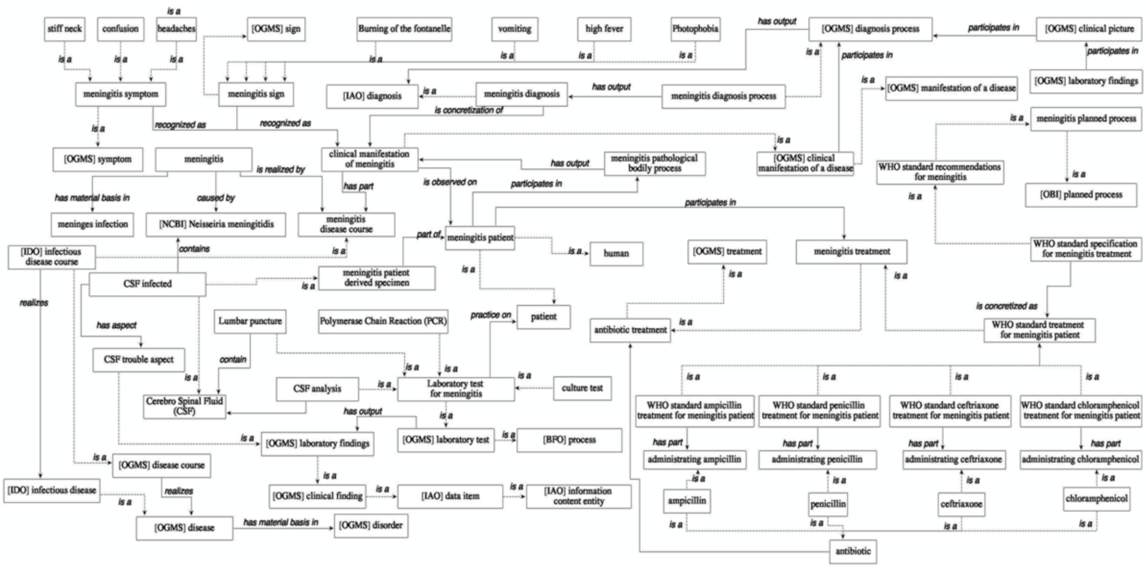

Figure 3– Conceptual model of the clinical perspective of the meningitis disease

Modeling clinical perspective in IDOMEN

Signs and symptoms

Meningitis symptoms and signs are clinical features of meningitis. The most common symptoms of acute meningitis are high fever, headache, stiff neck, vomiting, irritability or confusion, photophobia (sensitivity to light), Kerning signs, lethargy seizures. *"meningitis symptom"* and *"meningitis sign"* are perceived or noticed on patient. They are formalized as follow *"meningitis sign"* is a *"[OGMS]sign"* and *"meningitis symptom"* is a *"[OGMS] symptom"* by reusing existing concepts in OGMS. For instance, we can also infer the following relations *"headaches" is a "meningitis symptom"*, *"headaches" is a "meningitis symptom"*, *"photophobia" is a "meningitis sign"*, *"Kernig sign" is a "meningitis sign"*.

Meningitis patient is a patient presenting clinical manifestations of meningitis. "Meningitis patient" is a subclass of *"patient"* and a *"clinical manifestation of meningitis"* ***is a*** *"[OGMS]manifestation of a disease"*. Therefore *"meningitis symptoms"* ***recognized as*** *"clinical manifestations of meningitis"* and *"meningitis signs"* ***recognized as*** *"clinical manifestation of meningitis"*.

Diagnosis

The first step in the diagnosis consists mainly in the recognition of clinical manifestations.

In terms of diagnosis, *"meningitis diagnosis" is concretization of "clinical manifestation of meningitis"*, *"meningitis diagnosis" is a "[IAO]diagnosis". "meningitis diagnosis process" is a "[OGMS]diagnosis process"*. and *"meningitis diagnosis process" has output "meningitis diagnosis"*.

After seeing clinical signs, we can perform a CSF sample to further the diagnosis. In case of the observation of CSF (“*CSF analysis”*) reveals a cloudy or purulent appearance after macroscopic examination, this indicates a probable case of bacterial meningitis. CSF analysis can be extended by other laboratory tests such as Polymerase Chain reaction, antibiogram, etc., used to diagnose meningitis are organized in class called "Laboratory test for meningitis".

Finally, only the detection of the bacterial agent in the CSF at the laboratory level makes it possible to effectively define a *confirmed case of meningitis*.

"Laboratory test for meningitis" is a *"[OGMS]Laboratory test"*. The results of the laboratory tests are subclasses of *"[OGMS]Laboratory findings"*.

Treatment

Meningitis is a disease whose evolution is very fast in the patient, which necessitates a quick diagnosis in order to start the treatment. The different treatments for meningitis are specified in WHO standard protocols called "*WHO standard specifications for meningitis treatment*". Here are some treatments recorded in the standard protocol: "*WHO standard ampicillin treatment for patient meningitis*", "*WHO standard penicillin treatment for patient meningitis*", "*standard WHO ceftriaxone treatment for patient meningitis*", *"WHO standard chloramphenicol treatment for patient meningitis*". All of these different treatments are based on antibiotic administration [7], so we have for example "*WHO standard ampicillin treatment for meningitis patient*" ***has part*** "*ampicillin*" and "*ampicillin*" ***is a*** "*antibiotic*".

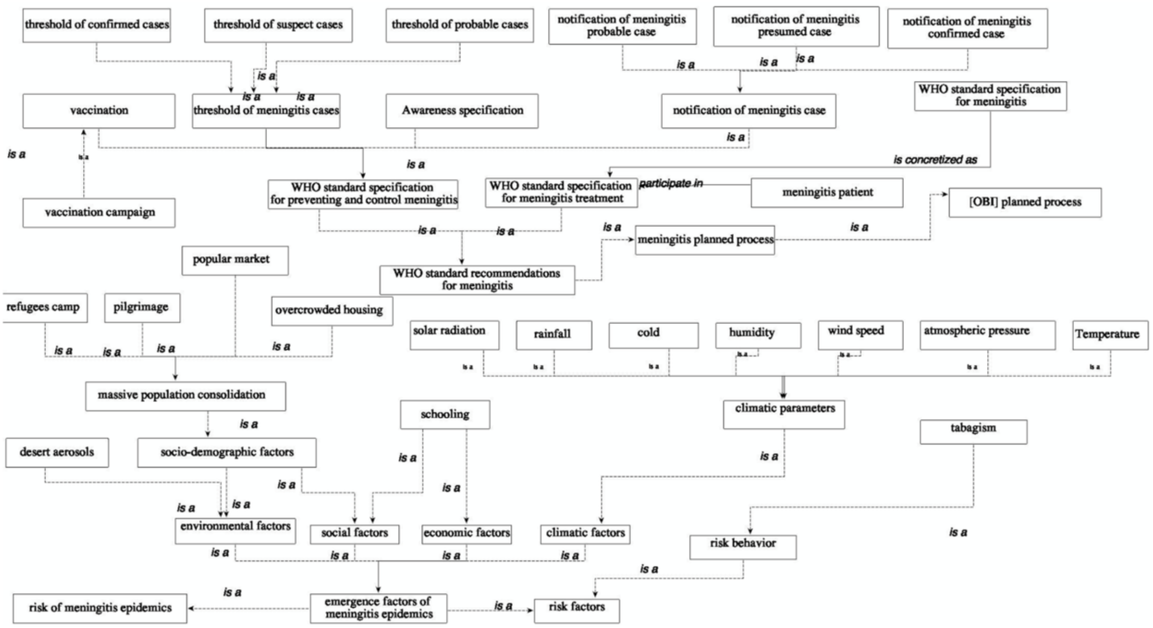

Figure 4– Conceptual model of the epidemiological and public health perspective of the meningitis disease

Modeling epidemiological and public health perspective in IDOMEN

In the figure 4, we describe different aspects related to disease spread/outbreak such as surveillance, prevention, epidemic emergence factors (risk behaviours, climate and environment).

Prevention

The prevention and control of meningitis is based on vaccination, vaccination campaigns and awareness : *"vaccination"*, *"vaccination campaigns"* and *"awareness"* are subclass of *"WHO standard specifications for preventing and control meningitis". "WHO standard specifications for preventing and control meningitis"* ***is a*** *"meningitis planned process"*. *"meningitis planned process"* ***is a*** *"[OBI]planned process"*. To control and prevent the occurrence of an outbreak there is a mechanism called *"cases notification"* consisting in systematically notifying the different cases encountered in health facilities (*"presumed case of meningitis"*, the *"probable case of meningitis"* and the *"confirmed case of meningitis"*). We have represented this notification mechanism in IDOMEN as follow *"presumed case of meningitis notification"* ***is a*** *"meningitis case notification”*, *"probable case of meningitis notification"* ***is a*** *"meningitis case notification”*, *"confirmed case of meningitis notification"* ***is a*** *"meningitis case notification”.* As soon as one of the thresholds (*"threshold of presumed cases"*, *"threshold of probable cases"* and *"threshold of confirmed cases"*) are reached an alert that corresponds to the level of the situation is launched in order to bring appropriate measures.

Epidemic emergence factors

The recurrence of meningitis outbreaks is linked to a complex combination of several factors of kinds economic, social, climatic and environmental [8] [9]. We defined a class *"meningitis epidemic emergence factors*" which is a parent classes of following subclasses *"environmental factors*", *"social factors*", *"economic factors*", *"climatic factors*". The population dynamics (movements of populations and communities) are considered to be factors influencing the intensity of meningitis epidemics in the African meningitis belt : *"massive population consolidation" is a "socio-demographic factors"*. *"socio-demographic factors*" is a subclass of *"environmental factors*" and *"social factors*". For example of *"massive population consolidation"* in the meningitis belt we have : *"pilgrimage", "popular market"*, *"refugees camp"* and *"overcrowded housing"*. The "climatic parameters" are : *"atmospheric pressure", "wind speed" , "humidity", "cold", "rainfall" and "solar radiation"*.

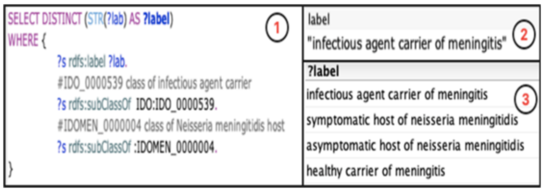

Figure 5– Use case reasoning

Conclusions

In this first stage of the IDOMEN ontology building, we provided formalization in OWL2 using the Protege editor which also allows us to experiment reasoning use cases on the ontology. For example, the Figure 5 presents (1) a SPARQL query about ***"Which are the infectious agent carriers that also are Neisseria Meningitidis hosts ?"***, (2) the result without launched inference engine, and (3) the results by activating the reasoner FaCT++ 1.6.5 engine in the Protégé editor. This explains that we obtain more complete results by deductive inferences on classes and subclasses. In the case of our query the deduction is based on the transitivity properties from the classes inheritance.

In this work we modeled the knowledge relating to the biological perspective, clinical, epidemiological and public health perspectives of the meningitis disease. A usable version is available for download at https://github.com/cedricbere/IDOMEN/blob/master/Ontology/idomen.owl.

Our future work will focus on validating and evaluating the ontology before using for filtering on social media.

Acknowledgements

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