Aquaculture Knowledge Framework

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Abstract— **Despite to seem infinite, oceans have fragile ecosystems and limited resources. This way, aquaculture is an activity extremely important nowadays namely in the preservation and in the creation of a good alternative to fisheries. Moreover, aquaculture is extremely important to supply the population with food at a global level since fishing is not enough. In line with this, the authors propose an aquaculture knowledge framework to facilitate the development of information technologies solutions to improve the efficiency of the traditional aquaculture industry processes.**

I. Introduction

As vast as the world's oceans may seem, their resources are limited and their ecosystems fragile. Aquatic resources, although renewable, are not infinite and need to be properly managed, if their contribution to the nutritional, economic and social well being of the growing world's population is to be sustained [1].

Aquaculture, exists since ever, however it has had a greater impact in the last 50 years namely due to the fact of population growth. Thus, aquaculture is accomplished of others benefits such as: health benefits because eat fish are healthier and help fight cardiovascular disease, cancer, alzheimer's and many other major illnesses; economic benefits due to the increase of aquaculture farmers which origins new ways of develop and raise local/national economies moving the involved business chain such: researchers, breeders, fish food manufacturers, equipment manufacturers, marinas, storage facilities, processors, transportation and marketing companies as well as restaurants; and environmental benefits there are real advancements in all types of aquaculture systems. Especially for offshore systems, there are bio-security systems, cameras and surveillance infrastructure, as well as trained inspectors who ensure that farms are complying by environmentally safe practices. This helps to reduce diseases transfer in the waters and so on [2]. Accordingly to the population growing and to the reducing of natural and aquatic resources aquaculture is one of the solutions that contribute to the nutritional, economic and social well being of the growing world's population.

Thus, in this paper, the authors present a Knowledge Framework (KF) to be used by the aquaculture industry (farmers) and to demonstrate that such KF is essential to organize the semantics in the system to enable an harmonised communication between the business actors and as well to facilitate an effective knowledge transfer. Thus, in section II a study about aquaculture domain (e.g., definition, types, advantages and disadvantages) is presented. In section III, the proposed Aquaculture KF is introduced. Section IV presents the AquaSmart semantic referential and section V specifies the AquaSmart Knowledge Mechanisms. Conclusions and prospective work are analysed in section VI.

II. Aquaculture Domain

The word aquaculture it has its origin in mid of 19th century and its divided in two words "aqua" and "culture". The word "aqua" derives from the Latin and means "water" while the word "culture" derives from English on the pattern of words such as agriculture [2].

The term aquaculture refers to the cultivation of both marine and freshwater species and can range from land-based to open-ocean production [3]. Aquaculture also includes the production of ornamental fish for the aquarium trade, and growing plant species used in a range of food, pharmaceutical, nutritional, and biotechnology products [4].

Aquaculture is also mentioned as the farming of aquatic organisms such as fish, molluscs, crustaceans, aquatic plants, crocodiles, alligators, turtles, and amphibians [5]. Farming is the process that implies an intervention in the growth process to increase production, such as feeding, protection from predators, regular stocking, individual or corporate ownership of the stock being cultivated, etc. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of capture fisheries [6].

Aquaculture has any cultivating science has advantages and disadvantages not only to the aquaculture but also to the consumers and farmers. Thus, some of its advantages are presented in the following sentences.

Accordingly to the Food and Agriculture Organization (FAO), aquaculture has the highest production rate per area (hectare) in comparison with other cultivations, thus one cultivated hectare can produce more fish than any other animal. So, aquaculture is of great importance in the panorama of world food supply, mainly because it is possible to maintain a balanced and adequate diet to ensure that species develop in a healthy way, without altering its nutritional value [7].

Through aquaculture is achieved significantly increase the amount of fish produced compared to fishing, which contributes for a sustainable fish supply business. The explanation relates to artificially fertilizing eggs that lead to higher chance of fertilization, as in the wild only 10% of eggs are fertilized [8].

However, some of the aquaculture disadvantages are related to the rations and products used for this practice can harm the ecosystem if they are released into the environment without proper treatment. Other point is related to the fact that farmers use large quantities of low cost proteins for animal feed, producing high-cost products (e.g. shrimp) instead of bet in the production of other fish population, less costly, and sometimes use high doses of antibiotics leading to bioaccumulation in humans that consume it.

Additionally, farmers' management behaviours sometimes results in bad environmental impact as in the increase of the spread of invasive species [9], or due to low spatial equality and organisation leads to large wastes concentrated in one area, which can facilitate disease to spread, leading easy transmission from host to host [8].

To better understand the relevance of aquaculture, it is relevant to distinguish the three types of aquaculture. These correspond to the terms used for terrestrial agricultural production [9]. The three types of aquaculture are the following:

- Extensive aquaculture it uses craft techniques, the species are raised in tanks next to their natural habitat where they receive nutrients and the renewal of the waters is made depending on the tides. Low rearing density and little or no food input accomplished with low production levels also characterizes this type of aquaculture.
- Semi-intensive aquaculture uses little primitive techniques, it is made in tanks on shore or land, it uses industrial rations and the created species reach up to 1 year old. It represents an intermediate level of production.
- Intensive aquaculture uses technologically advanced techniques. The species are raised of in tanks where the water is renewed every hour through pumps. High density and total food input. The species are totally fed through rations. High production levels characterize this type of systems [9].

In any type of aquaculture it is necessary to improve the existent tools in a way that these ones can contribute to increase the production of the number of high quality of fishes in aquaculture and reducing the production costs at the same time. Thus, the authors will present in the next chapter a KF that can support the development of systems to help in such objective. The defined framework proposes the use of ontologies, which related features and mechanisms could be deployed as a tool in organizations for advanced aquaculture industry systems establishment that would facilitate the increase of production management efficiency.

III. Aquaculture Knowledge Framework

Knowledge is considered the key asset of modern organizations and industry. The aquaculture domain has a proper nomenclature and the knowledge associated with that economic activity that needs a proper type of knowledge structuring and management. That king of knowledge organization can be achieved by the development of a specific ontology-based framework aiming to support Aquaculture knowledge, research and operational activities. The authors propose a framework to be the foundation for the aquaculture knowledge organisation and representation (Figure 1). It specifies the aquaculture knowledge model in four main parts: the aquaculture glossary or thesaurus; the aquaculture domain ontology; the aquaculture training ontology; and the IT infrastructures ontology. The framework also establishes the principles for the knowledge use and management services establishment. It encloses three main parts: searching and reasoning mechanisms; semantic enrichment mechanisms; knowledge and lexicon management mechanisms.

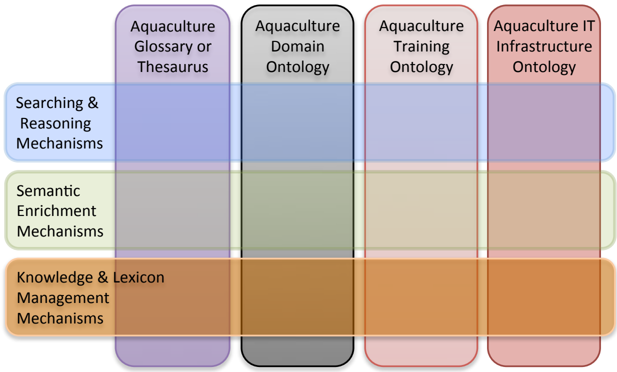

Figure 1. Aquaculture KF

When an information system intends to represent a domain knowledge needs to be aligned to the community that it represents. Consequently it is required to have a solution where community members could present their view on the domain and discuss it with their peers. Additionally, such knowledge must be available and maintained by all the involved actors.

Fundamentally, ontologies are used to improve communication between people and/or computers. By describing the intended meaning of "things" in a formal and unambiguous way, ontologies enhance the ability of both humans and computers to interoperate seamlessly and consequently facilitate the development of knowledge-based (and more intelligent) software applications.

A. Aquaculture Glossaries or Thesaurus

The main objective of a glossary or thesauri is to be a lexicon reference for a particular community. Thus, an aquaculture glossary or thesauri is such reference but for the aquaculture domain. This domain lexicon integrates terms and concepts with shared definitions (semantics) defined by domain experts. Due to such characteristics, these lexicon elements facilitate the semantic alignment between actors (systems or people) enabling interoperable communications. Additionally, a multi-language glossary that has mappings between the various languages concepts and synonyms outreaches a bigger community.

B. Aquaculture Domain Ontology

Ontologies allow key concepts and terms relevant to a given domain to be identified and defined in a structure able to express the knowledge of an organisation [10]. A good ontology model of any particular domain knowledge facilitate its understanding [11]. Additionally, Its recognised capacity to formally represent knowledge, to facilitate use and maintenance through semantic searching and reasoning, if integrated in a system could be handled for problem solving [12] contributing to such system computational intelligence increasing. Aquaculture domain ontology represents the knowledge in the domain in such way that if defined by domain experts with the support of knowledge engineers, will provide the necessary insights towards the improvement of the efficiency of the aquaculture production processes. Thus, it can enclose knowledge for representing fish diseases, aquaculture production equipment, water quality, etc.

C. Aquaculture Training Ontology

The aquaculture training ontology will be used to represent the training knowledge base facilitating the categorization of its elements and subsequently reasoning over it. It comprises the model to represent any training curriculum and it is composed by generic training elements as courses, modules, competences, skills, etc. Its main objective is to specify a training curriculum which, addressed by appropriate reasoning mechanisms, will be able to generate customizable training programmes. It should contribute to the skills and competencies development of the trainees as required for specific understanding and exploitation.

D. Aquaculture IT Infrastructure Ontology

In the context of any project a set of use cases are normally identified to describe required functionalities that can be provided through particular services. Thus, these services' can accomplishes or support particular business processes and applications. In order to allow future reuse or sharing of these services, an ontology to formalise such IT services or infrastructures in a kind of services UDDI are necessary. This framework will be supported through Semantic Web technologies by providing tools: (i) to define an information model (as an ontology), (ii) to semantically enrich and relate the modelled data and (iii) to query this information. This framework will essentially provide:

1. An information model that allows users to instantiate and catalogue information that describes the functionality and interface of modularized services;
2. A query interface, providing service filtering capabilities and access to the descriptions of individual services.

IV. THE AQUASMART SEMANTIC REFERENTIAL

The AquaSmart is an Innovation Action project that received support by the European Commission under the H2020 program. The purpose of AquaSmart project is through the usage of open and big data analysis along with a cloud infrastructure to promote the aquaculture industry. Thus, it intends to solve one of the main problems that aquaculture companies are facing nowadays, which is related to the fact that they cannot interpret the data they capture neither use others companies data. If they were able to do so, they would be able to dramatically improve the production in terms of feed conversion rate, cost, mortality, diseases, environment impact, etc.

In line to this objective, the AquaSmart consortium is developing a cloud based platform with a backend based on machine learning and data mining techniques to provide assistance to aquaculture managers in the decision making process. Such platform encloses big and open data analytics as a service to make more accurate estimations of the growth of the fish enabling a better view of the living inventory (biomass) that exist in a farm.

However, to accomplish such platform features authors also developed a set of mechanisms that instantiates the KF presented in the previous section. Such instantiation establishes the so-called AquaSmart Semantic Referential. It represents the foundation of both content-based information access and semantic interoperability over AquaSmart platform.

The AquaSmart semantic referential is the backbone for the technical developments which handle the semantic interoperability dimension. Such technical developments fit in the application areas presented in Figure 2. and can be described as follows:

- Aquaculture Glossary of terms - a glossary that contains terms and definitions of aquaculture domain, in a multilingual manner to accomplish a reference lexicon in the domain.

- Semantic Reasoning Mechanisms - services that make use of the knowledge contained in this semantic referential to apply reasoning techniques able of infer logical consequences from a set of asserted facts.

- Semantic Enrichment - services that use the semantic referential to enrich knowledge sources as documents or training courses.

- Knowledge Management - services that use appropriate semantic queries to retrieve or formalise knowledge from or to the semantic referential ontologies.

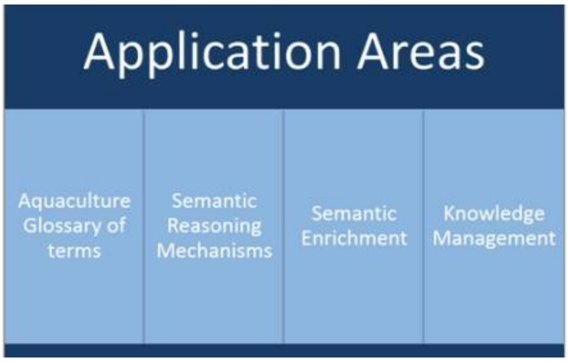

Figure 2. Application areas of the semantic referential

The creation of a semantic referential followed a method for designing and developing a domain ontology with inputs from knowledge experts, providing the necessary insights towards the improvement of the efficiency of the aquaculture production processes. Such experts, contributed with their knowledge about the aquaculture production, the actors involved, and the data generated during the production process [13].

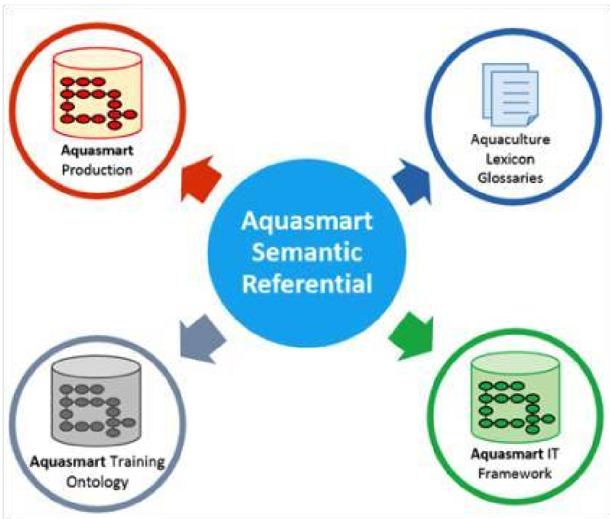

Figure 3. AquaSmart Knowledge Framework

In Figure 3. is presented the semantic referential with the four different modules as proposed by the Aquaculture KF: the AquaSmart Training Ontology; the AquaSmart Glossary; the AquaSmart IT Ontology; and the AquaSmart Production Ontology.

A. AquaSmart Production

In the AquaSmart context, knowledge experts are the end users (mainly fish farmers). The purpose of evolving such experts in the process is not only to provide input to the semantic referential, but to perform a quality review of the AquaSmart training courses. With the help of these experts, the main structure of the AquaSmart ontology was developed to accommodate all the important and necessary information that will support all the project services and functionalities. The Figure 4 shows the ontology with the structure proposed by the experts (i.e. Collector, Manager, Analyst, Administrator, Feeder, Diver, Vet, Biologist).

As depicted in Figure 4. the ontology is mainly separated in two concepts, the "Aquaculture Production Entities" and the "Grow Out Data Analysis". The first contains the all the aquaculture related entities, while the second one contains the key performance, the process and production related data.

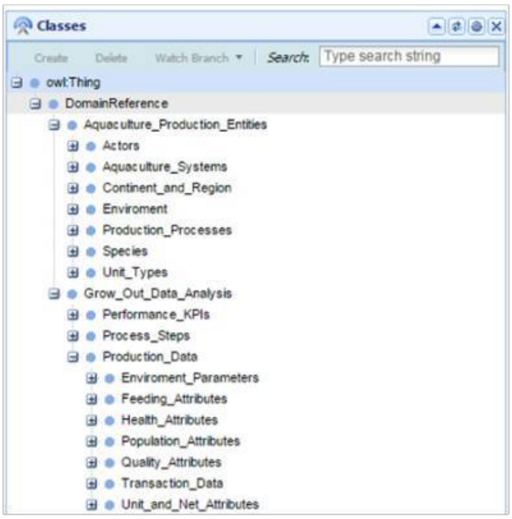

Figure 4. Domain Ontology

To make available fully interoperable multi-lingual data products and services this ontology establishes links with an aquaculture glossary that contains specific domain terms and their definitions. Such glossary integrates contents from the FAO glossary for aquaculture [14].

B. Aquaculture Lexicon Glossaries

From the AquaSmart perspective, the multilingual data generated within the aquaculture domain, can be exploited as a layer of services and resources by seamlessly adding (i) linguistic information for data and vocabularies in different languages, (ii) mappings between data with labels in different languages, and (iii) services to dynamically access and traverse linked data across different languages.

We envisage a multilingual aquaculture system where an end-user would query the "Aquaculture Open Data Cloud" in his/her own language, and would get the relevant data in that language. The glossary includes English, French, Greek, Hebraic, Spanish and Portuguese terms. Each term has properties, which defines it (Name, definition, related term, synonyms, subject area, translation, and image). Figure 5. shows an example of a glossary term.

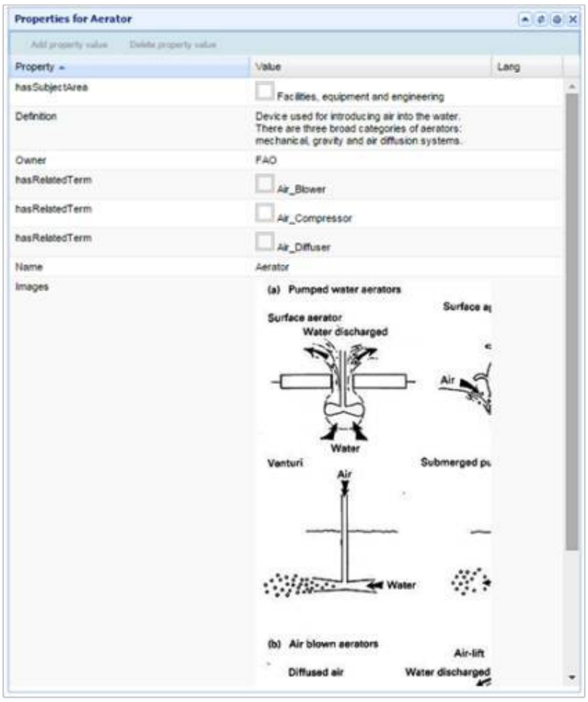

Figure 5. Glossary term

C. AquaSmart Training Ontology

The AquaSmart training ontology reflects the need to develop, organise and run courses to train "future users" about how to use the AquaSmart software, for instance, in extracting relevant patterns from aquaculture production data.

As an example, in this ontology model each learning *Module* has several concepts associated. The *Sources* concept contains information about the training materials sources used in the *Module*. *Contact* includes the contact information of the author of a *Module* or *Course* and *Keywords* contain a list of all relevant concepts needed for describing their contents. A *Course* belongs to a *Curriculum Main Area* that is divided by *Content Areas* and *Learning Levels*. Each *Module* and *Course* has a *Target Audience*, which are the ones that are recommended to attend to it. Such set of recommendations materials (*Courses* and *Modules*) can compose instances of pre-defined training *Programmes*.

D. AquaSmart Information Technology Framework

In the context of any project a set of use cases are normally identified to describe required functionalities that can be provided through particular services. Thus, such services can accomplish or support particular business processes and applications. In order to allow future reuse or sharing of such services, an ontology to formalise such IT services or infrastructures in a kind of services UDDI is necessary. This ontology component provides that. It encloses:

1. An information model that allows users to instantiate and catalogue information that describes the functionality and interface of modularized services;

2. A query interface, providing service filtering capabilities and access to the descriptions of individual services.

V. AQUASMART KNOWLEDGE MECHANISMS

Associated to the AquaSmart Semantic Referential presented it was developed a set of ontology related services that represent the various mechanisms defined in the also proposed Aquaculture KF. Thus, in the overall such services supply the system with: 1) searching & reasoning: 2) semantic enrichment; and 3) knowledge & lexicon management mechanisms.

These mechanisms provide users with the ability to query the semantic referential knowledge base for terms, potential partners and public results as new knowledge resulted from big data analysis.

There is a partner search functionality, which enables users of a searching functionality able to find companies in the aquaculture domain by determined criteria such as water temperature, type of fish produced, size of production, country, etc.

Since an ontology is not a static entity, this set o proposed mechanisms also include specific ontology management services to update its represented knowledge. Additionally, due to the multi-language nature of the stakeholders of AquaSmart the ontology interface integrates a translation service to translate newly added terms.

As a consequence of all these features, an ontology API was developed to allow the users to handle such provided services to interact with the proposed Semantic Referential. A User Interface (UI) will be also provided to ease these interactions, allowing the user to explore the full provided services functionalities. This same UI will communicate with the developed ontology API, and consequently such ontology API at other level will communicate with a FUSEKI API via HTTP. FUSEKI is a SPARQL server that can be used to communicate with the ontology in order to do particular reasoning by the mean of TDB RDF Datasets.

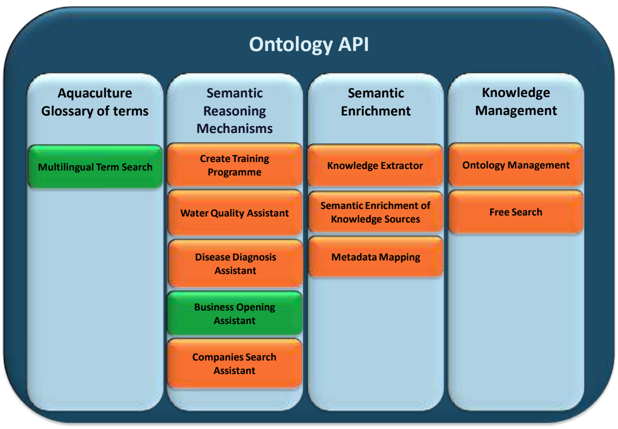

Figure 6. AquaSmart Knowledge Mechanisms

The proposed ontology API contains all the services categorized the four different modules presented on the semantic referential; the aquaculture glossary of terms, the semantic reasoning mechanisms, the semantic enrichment and the knowledge management (Figure 6.).

Each of the services provided are described in the following sub-sections.

1) *Aquaculture Glossary of terms*

The introduction of an innovative multilingual knowledge base capacity suitable for the Aquaculture sector, which would enable an end-user query the "Aquaculture Open Data Cloud" in his/her own language, and would get the relevant data in that language, could significantly improve semantic interoperability solutions and the formal knowledge representation in the sector, which could contribute for the competitiveness increase. Thus, one of the main components of the semantic referential is the Aquaculture glossary of terms. As explained before, the glossary contains information regarding terms related to the aquaculture domain.

a) *Multilingual Term Search*

The aquaculture glossary of terms UI allows the user to search for information regarding aquaculture terms making use of this glossary and the amount of information contained within. This UI uses the multilingual services, which extends the usability of the semantic referential component. This multilingual service searches locally at the AquaSmart semantic referential for information related to a specific aquaculture term in three different languages (English, French and Spanish). Additionally the multilingual service also integrates an extra translation functionality to integrate other languages supported by other external API (e.g. BING Translator, Google Translate) (Figure 7).

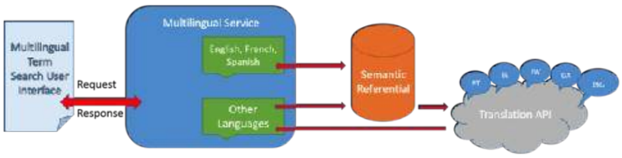

Figure 7. Multilingual service structure

Service description:

- Roles: user
- Parameters:
    - data – term to be searched
    - languages – original language and desired translation language
    - Returns: Translated term and all information (e.g. definition, images, etc.) regarding this term.

2) *Semantic Reasoning Mechanisms*

The semantic reasoning related services are services with the objective to provide specific information or knowledge to the user in order to facilitate and improve his work in relation to aquaculture business. In relation to this mechanism there are five proposed different services. However these can be more in the future. From these five there is one related to the training program and other four more specific to the particular business processes. The training service is a service that allows the creation of a training programme that meets the needs of the user. The other four services: water quality control assistant, disease diagnose assistant, business opening assistant and search for company assistant are services from which the user can ask for assistance. Based in the provided characteristics the services will then do some reasoning and narrow down the problem.

a) Create Training Programme

The system could establish orchestrations using the existent training modules and courses materials for the creation of customized training programmes.

Service description:

- Roles: user
- Parameters:
  - data – topics; keywords; trainee's profile; target audience; Roles and Competences; skills.
  - Returns: Customized Training Programme accordingly to the input data

b) Water Quality Assistant

The water quality includes all physical, chemical and biological characteristics that interact individually or collectively influence the performance of the fish growth. The Water Quality Control Parameters in aquaculture are usually the ones presented in the following table.

Table 1 Water Quality Parameters

PHYSICAL	***CHEMICAL***	***EXTERNAL STRUCTURE***
Temperature	*Ph*	*Algae*
Color	*alkalinity*	*sediments*
turbidity	*Toughness*	*Oils*
Visibility and transparency	*Dissolved oxygen*	
	Ammonia	
	Salinity	

There are other factors that also affect water quality and the result of fish farming. However the factors listed in Table 1 are the most critical and easier to monitor, and this can and should be done by the producer. This way the water quality control system aims to help the fish farmer to monitor the characteristics presented in Table 1, indicating possible adjustments parameter in order to maintain an aquatic environment suitable for productive development of aquaculture.

Service description:

- Roles: user
- Parameters:
  - data – Characteristics seen in the water (e.g. Table 1 values)
  - Returns: Possible problem regarding the input characteristics and a suggested solution.

c) Disease Diagnose Assistant

With the consolidation of aquaculture, new emerging technologies for intensive production and more diversity of fish species with potential for cultivation appear, however health problems or disease transmission problems may present obstacles at different stages of production. Thus, early diagnosis of diseases and the appropriate management constitutes a key factor for the success of the activity. In this sense the disease diagnostic assistant it is a computer system that aims to identify diseases in fish species based on physical and behavioural characteristics observed in the species and the environment in which are inserted, this includes water quality, presence of foreign matter to production environment as sediment or algae amongst other features. This service allows early diagnosis of disease and treatment suggestions. However the service does not aim to replace the veterinarian, but propose practical for immediate treatment and mortality containment, aiming to reduce the evolution and disease dissemination.

Service description:

- Roles: user
- Parameters:
  - data – Characteristics seen in the fishes (these are defined from existent concepts in the semantic referential)
  - Returns: Possible problem regarding the input characteristics and a suggested solution.

d) Business Opening Assistant

The opening of a new business within the aquaculture, involves criteria and requirements that could help to determine if it is an economically viable activity. These criteria are related to the location, climate, topography, water quality (salinity), distribution logistics and capture inputs. Through them, it is possible to determine what kind of fish are best suited to these conditions, what kind of equipment the entrepreneur will need to purchase and other valuable information. The service "Business opening assistant" aims to identify the best business approach taking into account specific criteria and requirements.

Service description:

- Roles: user
- Parameters:
  - data – Characteristics of the desired business (e.g. farm location)
  - Returns: Description of the possible business type and infrastructures needed

e) Companies Search Assistant

The service "Companies search assistant" aims to search and list companies that are active in the market. Such research is done by specific characteristics of the aquaculture sector, as fish species marketed, production volume, production site, among other features. This service will use the knowledge gathered by the semantic referential and then provide the user the companies that fulfil the characteristics chosen. This will help the user to access to open data that could help in his business.

Service description:

- Roles: user
- Parameters:
    - data – Characteristics of the desired company (e.g. fish species)
    - Returns: Full description of the company regarding the input characteristics.

3) *Semantic Enrichment of Knowledge Sources*

There are three kinds of services related to semantic enrichment; the first intends to formalise new knowledge resulted from data analytics executions; then one that establishes semantic alignments with the raw datasets concepts, and finally other that enriches the existent knowledge base (semantic referential) with the knowledge sources as documents.

a) *Knowledge Extractor*

The service that make use of the data analytics results will allow users not only to get a better understanding of the results obtained as also will allow for extract knowledge in order to enrich the ontology.

Service description:

- Roles: user
- Parameters:
    - data – dataset analysis results
    - Returns: Description of the results.

b) *Metadata Mapping*

This service uses raw datasets. These datasets are composed by a set of standardized columns along with some company-specific columns. These company-specific columns may not be properly identified if they are meant to be kept as a company private information.

The purpose of this service is to:

1. Allow the disambiguation of the role of each column in the dataset;
2. Check the consistency of the values used in each column (i.e. temperature values above 50ºC or inconsistent temporal values).

These functionalities will be supported by:

1. A set of unique semantic concepts defined in a semantic referential, that describe precisely the meaning of each possible column;
2. A set of rules that define the range of allowed values for each column.

This service exposes operations that allow:

1. The mapping of the information in each column header of a dataset to a specific semantic concept;
2. The creation of new semantic concept, if needed to describe a non-standardized column and/or a private column;
3. The checking of the value set used in a column and, consequently, the reporting of errors found in the data (outliers).

The concrete implementation of this service will be achieved through a domain specific ontology (which will include aquaculture specific terms) backed by an RDF Triple Store, for data persistence, management and interrogation. The following diagram (Figure 8) contains a high level architectural description of this service, which encompasses three main operations:

1. Search concepts allows searching through the available concepts in the ontology;
2. Select concept enables the association between a dataset column and a concept, allowing its identification and the verification of its values;
3. Create concept exposes the functionality of adding previously undefined concepts to the ontology.

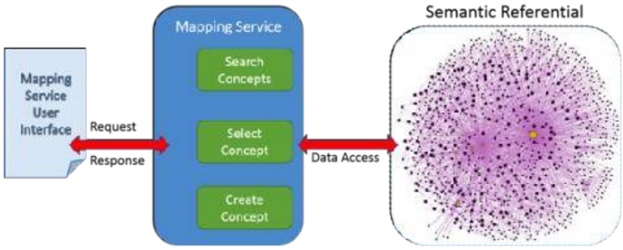

Figure 8. An high level description of the architecture of the metadata mapping service

Service description:

- Roles: user
- Parameters:
    - data – dataset upload
    - Returns: Full description of the dataset uploaded.

c) *Semantic Enrichment of Knowledge Sources*

This service supports the management (storing, indexing and retrieval) of aquaculture knowledge sources, using a formal representation method based on enriched Semantic Vectors. The method explores how traditional knowledge representations can be enriched through incorporation of implicit information derived from the complex relationships (semantic associations) modelled by domain ontologies with the addition of information presented in documents.

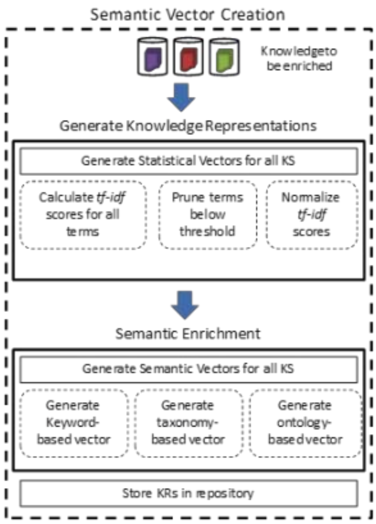

Figure 9. Overall approach for the semantic enrichment process

This service is responsible for enriching sources of non-structured information, combining with background knowledge available in the AquaSmart ontologies. The service can be composed into several steps as presented in the Figure 9. In the Document Analysis step, the tf-idf scores for all sources are calculated, next a procedure reduces the size of the statistical vector according to a certain relevance degree defined by the knowledge expert (Prune terms below threshold), after, another procedure normalizes the statistical vector after pruning the terms. Next, the semantic enrichment is performed by three different methods, responsible for the generation of the keyword, taxonomy and ontology-based vectors, respectively.

Service description:

- Roles: user
- Parameters:
  - data sources
  - Returns: semantic representations

4) Knowledge Management

Regarding knowledge management two services are being developed, one that allows ontology management, create/update/delete concepts; and other that allow free search within the ontology.

a) Ontology Management

Request an update to the ontology relating a concept or a relation.

Service description:

- Roles: ontology manager
- Parameters:
  - type – concept or relation
  - attributes – relation name, concept name
  - Returns: void (ontology is updated)

b) Free search

Submit a query to the ontology service. Incoming queries will be validated and subjected to limitations to prevent excessive resource utilisation. The ontology is queried and the response wrapped as a JSON message.

Service description:

- Roles: user
- Parameters:
  - data – search query
  - Returns: Information presented in the ontology related to the input query.

VI. Conclusions

The greatest innovation potential of this paper is the development of a KF for the aquaculture industry using a semantic layer in the form of the ontology service which will provide an open data service allowing interoperability between aquaculture companies. Openness of certain data was discussed while maintaining privacy and security for the owners of that data.

In conclusion, with an appropriate KF, aquaculture actors could benefit of advanced services to facilitate semantic interoperability and new knowledge formalization.

For future work it is intended to accomplish the others aquaculture knowledge mechanisms, represented in orange in Figure 6. during the second and last year of the project e.g., until end of January of 2017.

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