Populating an Ontology for Climate Change and Its Impact on Marine Life

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Abstract: Climate change is a problem that the world currently faces and will continue to face for the coming years. It has brought about various changes to different ecosystems, including the marine ecosystems. There have been multiple studies on the subject matter, enough that it is very hard to find a structured collection of studies on the topic. However, one means of providing better structure to all the information is with the use of ontologies, formal representations of knowledge organized as concepts of a domain with its relationships defined. This paper discusses the development of an ontology population system that extracts data from scientific publications containing information about climate change and its impact on marine life and habitats. In this paper, we present initial findings after analyzing results of the automatic extraction to expected outputs from eighteen scientific papers.

Key Words: Ontology Population; Information Extraction; Climate Change; Marine Life

1. INTRODUCTION

Climate change has had various effects on the world, and it is a problem that the world will continue to face in the future. Due to climate change and various changes in our environment, people and other living organisms are forced to adapt. One of the most affected organisms are the marine organisms. According to Pankhurst and Munday (2011), seasonal changes in temperature have a significant effect on the reproduction and early life history stages of fishes. Because of the increase in temperature, there is also an elevation in atmospheric carbon dioxide which results in ocean acidification. This leads to the developmental stage for the growth of the larvae increasing, however it also causes the success rate for the Embryonic development and hatching to be lower. A study done by Madeira, et al. (2012) talks about thermal tolerance and potential impacts of climate change on coastal and estuarine organisms. The study states that there are differences in the changes observed depending on their habitat, geographic distribution, taxonomic groups and their temperature tolerance. Doney, et al. (2012) also studied the impact of climate change on marine ecosystems, where their research found that direct temperature and chemical effects brought by climate change caused alteration in organism physiology and behavior and population size, and population growth rates.

As can be seen in these research, their findings are published in different scientific venues and would usually present only a specific aspect of their work. Co-relating findings of different researchers and across different publications would be difficult due to the sheer volume of unstructured text.

To address this, we have come up with an ontology to capture the effects of climate change on marine creatures. An ontology consists of concepts and their relationships with one another (Gruber and Olsen, 1994). Ontologies find many uses like conceptual indexing, text categorization, query expansion, document clustering, and automatic summarization. Recognition of terms, discovery of relationships among the terms and declaration of concepts are the vital steps to creating an ontology.

Currently, there are existing ontologies on fish species and ontologies on implications of global climate change. But there are no ontologies that correlate the effects of climate change to the habitat with the organisms that exist in that habitat, which in turn, affects the behavior and physiology of the species/creatures living in the habitat.

In Section 2, we discuss our ontology to model the climate change as it affects the habitat and thus the marine creatures living there. Section 3 presents the modules involved in the extraction process using bootstrapping. Section 4 shows the performance of the automatic extraction vis a vis the reference data. Lastly, in Section 5, we present our conclusion and future work.

2. OUR MARINE CLIMATE CHANGE ONTOLOGY

The designed ontology was inspired by existing ontologies created for fishes (Ali, et al., 2017) and climate change related facts (Pileggi and Lamia, 2020). With insight from these existing ontologies, the marine climate change ontology was created. Listed below are the entities that were covered in this ontology along with their descriptions

1. Habitat represents the set of habitat names wherein different organisms may be found.
2. MarineOrganism represents the set of scientific names of marine organisms.
3. CommonName represents the set of common names of marine organisms.
4. Location represents the set of location names.
5. Genus represents the set of classification of the organism within a family.
6. Family represents the set of names of a family of organisms, usually in Latin, where an organism belongs to.
7. Effect represents the set of effects brought by climate change factors such as the temperature, water acidity, carbon dioxide level and salinity.
8. EffectValue represents the scale or value of an effect of climate change such as the temperature, water acidity, carbon dioxide level and salinity.
9. AffectedByFactor represents the set of factors such as the temperature, water acidity, carbon dioxide level and salinity which causes the changes brought by climate change.
10. FactorValue represents the scale or value of a factor of climate change.

Below are the corresponding relationships between the entities defined in the marine climate change ontology in Figure 1:

1. isLocatedIn relationship specifies where the habitat can be found. A specific example of this is isLocatedIn(coral reefs, Eastern Australia).
2. isAffectedBy relationship specifies which climate change affects this habitat. For example, isAffectedBy(mangroves, ocean acidification).
3. belongsToGenus relationship specifies what genus the organism belongs to. Example, belongsToGenus(Rhincodon typus, Rhincodon).
4. hasCommonName relationship specifies the different common names of the organism. An example is hasCommonName(Whale Shark, Rhincodon typus).
5. belongsToFamily relationship specifies what family the genus belongs to. An example of which is belongsToFamily(Gouramies, Badidae).
6. causedBy property relationship indicates which factors, such as temperature, water acidity, carbon dioxide level and salinity causes this effect of climate change to occur. An example of this is causedBy(ocean acidification, decrease in growth rate).
7. effectValueIs relationship specifies the scale or value of the effect of climate change. An example of this is effectValueis(species richness, lower)
8. factorValueIs relationship specifies the scale of value of the factor of climate change, such as changes in values in temperature, water acidity, carbon dioxide level and salinity. An example of this is effectValueis(saline, increase).

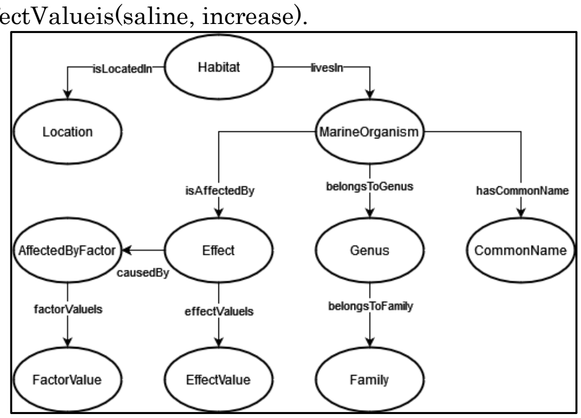


Fig. 1. Marine Climate Change Ontology Design

To give a better understanding of the ontology design, the entries to be stored for the marine organism, Milkfish, is seen in Figure 2. It should be noted that there can be multiple entries for the same relationship. For example, there can be many isAffectedBy() tuples that affect the habitat (and in effect, the marine creatures in that habitat).

To populate our ontology, we utilized

bootstrapping technique, as discussed in the next section, to extract data from scientific publications. We also implemented scripts with the use of APIs of Fishbase (Froese and Pauly, 2022) and Ocean Biodiversity Information System (OBIS, 2022) to extract data such as the species' scientific name, common names, family, and genus.

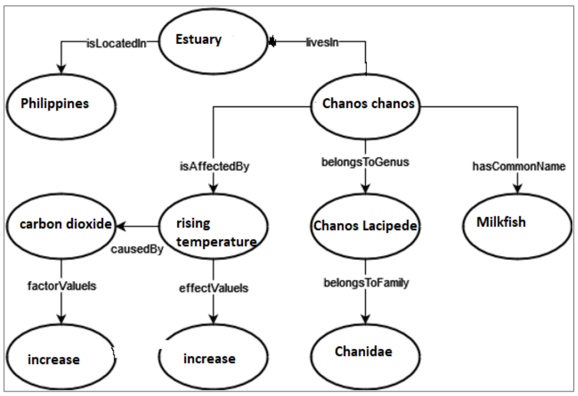


Fig. 2. Sample Marine Climate Change Ontology

3. ONTOLOGY POPULATION VIA BOOTSTRAPPING

This section focuses on the system design and implementation of information extraction with the use of a bootstrapping algorithm. Modules developed include the user interface, information retrieval, document processing, preprocessing module, and bootstrapping module, as seen in Figure 3.

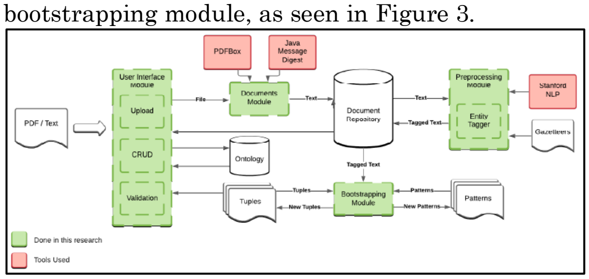
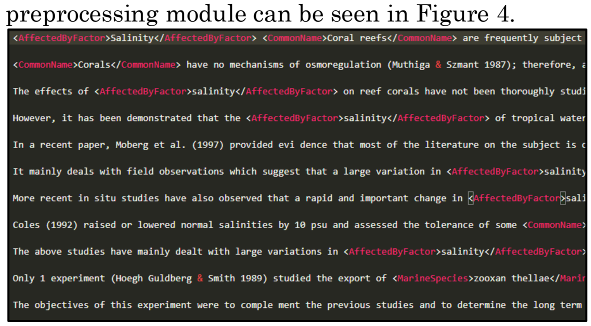


Fig. 3. System Architecture

3.1 Preprocessing of the Documents

Before any information extraction is done, the scientific documents must first go through the preprocessing module to prepare the document for extraction.

Each document is first converted to a text file. This removes the images, figures, and tables from the document, as the information is only taken from the text written. This is done with the use of a reusable library of Apache' PDFBox (https://pdfbox.apache.org/). After successfully converting the documents to text files, these now go through a cleaning module, where some unnecessary characters (like non-printable characters and new lines) are removed. Whitespaces and indentions are also fixed to remove any sentence or line breaks. Once the files have been cleaned, they are now split per line with the use of Regular Expressions, or RegEx. Each sentence is separated with a new line ("\n"), and once the file has been cleaned and prepared, the information is now tagged accordingly. All entities tagged are based on the classes from the designed marine climate change ontology. Entities were tagged with the use of gazetteers and lexicons by looking up an entity from the lists. An excerpt of the result of the preprocessing module can be seen in Figure 4.



```
<AffectedByFactor>Salinity</AffectedByFactor> <CommonName>Coral reefs</CommonName> are frequently subject

<CommonName>Corals</CommonName> have no mechanisms of osmoregulation (Muthiga & Szmant 1987); therefore, a

The effects of <AffectedByFactor>salinity</AffectedByFactor> on reef corals have not been thoroughly studi

However, it has been demonstrated that the <AffectedByFactor>salinity</AffectedByFactor> of tropical water

In a recent paper, Moberg et al. (1997) provided evi dence that most of the literature on the subject is c

It mainly deals with field observations which suggest that a large variation in <AffectedByFactor>salinity

More recent in situ studies have also observed that a rapid and important change in <AffectedByFactor>sali

Coles (1992) raised or lowered normal salinities by 10 psu and assessed the tolerance of some <CommonName>

The above studies have mainly dealt with large variations in <AffectedByFactor>salinity</AffectedByFactor>

Only 1 experiment (Hoegh Guldberg & Smith 1989) studied the export of <MarineSpecies>zooxan thellae</Marin

The objectives of this experiment were to comple ment the previous studies and to determine the long term
```

Fig. 4. Sample Output of the Preprocessing Module

3.2 Bootstrapping Module

Bootstrapping is a technique that uses the occurrence of seeds and scans the collection of unstructured documents to collect similar data (Batista, 2015). The seed tuples are two entities that have a relationship between one another. An example seed tuple is isLocatedIn(coral reefs, Eastern Australia). So, given a sample text "Coral reefs are found in Eastern Australia", we also have a seed pattern "X are found in Y". Using these seeds, we can now extract more data that follows the same pattern to populate the isLocatedIn() relationship in the ontology. Listing 1 outlines the algorithm to retrieve the pattern between the two entities. If the pattern matches the part of speech format of the algorithm, these entities are retrieved from the documents which are then validated by the user. The patterns stored and used then generate new patterns with the help of the WordNet API.

3.2.1 Add Relation

The Add Relation property searches the tagged documents for phrases that has relation to both seed entities. It reads the seed data that were populated from the ontology. If the sentence has both seed entities from the seed data, it is then stored within a TreeSet which is used for the bootstrapping.

```
Bootstrappping(){
  read the Tagged Documents;
  for every Tagged Documents:
    Read Seed Data;
    for every Seed Data:
        Retrieve TaggedDocumentPhrase from Tagged Documents;
        if seedoutput is not empty:
            run AddPreprocessingProperty(SeedOutput,
                                        TaggedDocumentPhrase);
        run AddRelationProperty(Seed Data,
                                TaggedDocumentPhrase);
        run POS Tagger Property(TaggedDocumentPhrase);
        run GenerateSeeds(TaggedDocumentPhrase)
        run AddCategoryProperty(seed relations)
        generate seedoutput;
        generate validationoutput;

}
```

Listing 1. Bootstrapping Process

3.2.2 Add Preprocessing

Add Preprocessing Property retrieves the generated seeds created from the bootstrapping module and seed entities found from the seed data. It searches for the tagged documents containing both the seed patterns and seed entities then stores it in a TreeSet that are used for the validation XML file.

3.2.3 POS Tagger

Before the phrases are saved as a pattern, the phrases are tagged based on their part of speech format using the Stanford POS Tagger to check whether the pattern is accepted by the bootstrapping algorithm which is V|VP|VW*P (Fader, et al, 2011). V|VP|VW*P was used as the format for the pattern so that the bootstrapping algorithm avoids extracting unrelated paired entities. V stands for verb, particule, and adverb. P stands for preposition, and particule. and lastly W stands for noun, adjective, adverb, pronoun, and determiner.

3.2.4 Generate Seed Pattern

With the use of the POS tagged patterns, synonyms of each word retrieved from WordNet are generated as shown in Listing 2 based on their part of speech. These newly generated patterns are used for the next batch of tagged documents, as it goes through not only the new tagged documents, but also the previously processed ones.

```
GenerateSeeds(){
  Retrieve the POSTaggedRelation from POS Tagger Property;
  Run the WordNet api;
  if the word is V:
    generate synonyms for V using WordNet;
    if the next is word is WP:
        generate synonyms for W using WordNet;
        generate synonyms for P using WordNet;
    else if the next word is P:
        generate synonyms for P using WordNet;
}
```

Listing 2. Generate Seed Pattern Pseudocode

3.2.5 Add Category

Add Category Property retrieves both matched entities extracted from the seed data or seed output to identify the relationship between the two entities. After the relationship has been found between the two, it saves the relationship for validation.

4. RESULTS AND FINDINGS

Eighteen (18) papers are used in the bootstrapping process to evaluate the system. The papers used are those that are freely available or those that the researchers were given consent to use. The Appendix lists the bibliographical reference to these. The papers are split into two sets, the first being the initial ten (10) documents retrieved by the proponents, and the additional eight (8) documents added later during the study. The first set is used to initialize the ontology and its data, while the second set is used to test the results of the initial run of the ontology and bootstrapping experiments. These form the first and second tests indicated later. Lastly, the third test is done with the same eight (8) documents again, to see if the bootstrapping has brought about positive changes to the results of the experiments.

The results from the bootstrapping are then compared to the same set of manually annotated papers so that it can be used for the computation of the metric scores: accuracy, precision, recall, and F-measure. The number of true positives (TP), false positives (FP), and false negatives (FN) were evaluated and used for computing the metric scores by comparing the referenced data with the results of the bootstrapping process. The reference data was a result of manual annotation that is validated by domain experts.

If the entity relation exists in both the referenced data and validation output, then it is counted as a TP. If the entity relation only exists in the validation output, then it is counted as FP. Lastly, if the entity relation only exists on the referenced data, then it is considered as a FN.

For the first test, the initial ten (10) papers were processed. These ten documents were used to initialize more seed data to be used. These same ten documents were also used to manually populate the ontology for the bootstrapping algorithm to generate initial seed patterns for the seed output. Only text after the abstract and before the references were included in the processing.

Table 1. First Test: Results per Article

Articles	Referenced	Retrieved	TP	FP	FN	Accuracy	Precision	Recall	F-measure
1	89	101	39	62	50	25.83	38.61	43.82	41.06
2	97	116	68	48	29	46.90	58.62	70.10	63.85
3	103	173	54	119	49	24.32	31.21	52.43	39.13
4	96	64	44	20	52	37.93	68.75	45.83	55.00
5	47	28	19	9	28	33.93	67.86	40.43	28.27
6	69	10	5	5	64	6.76	50.00	7.25	12.66
7	70	74	38	36	32	35.84	51.35	54.29	52.78
8	22	22	15	7	7	51.72	68.18	68.18	68.18
9	79	102	52	50	27	40.31	51.00	65.82	57.46
10	83	103	46	57	37	32.86	44.66	55.42	49.46
Total/Average	**675**	**793**	**380**	**413**	**375**	**33.64**	**53.02**	**50.36**	**46.79**

Out of the 793 entity relations extracted from the updated results seen in Table 1, 47.92% were true positives (TP) or the number of correct data that was retrieved, while 52.08% of the 793 entries were false positives (FP), meaning this was the number of relations that should not have been retrieved by the bootstrapping process.

On the second run, the additional eight documents were used. This is to determine whether the bootstrapping module can retrieve seed relations outside of the initial seed patterns by making use of the generated seed patterns found in the documents.

Out of the 872 entity relations retrieved from the results seen in Table 2, TP was 41.74%, while FP was at 58.26%.

Article 14 has the lowest precision, coming in at 28.48 with the number of retrieved data almost doubling the actual referenced data from the article. After further investigation, the issue of the details of the author and the publication appearing in the middle of the paper (resulting from automatic conversion of pdf file to text only) led to the tagging of unrelated data which had significant impact on the results.

On the third test, the same eight documents from the second test were used. This is to check if the bootstrapping done during the previous test would have relevant impact on future processing.

Table 2. Second Test: Results per Article

Articles	Referenced	Retrieved	TP	FP	FN	Accuracy	Precision	Recall	F-measure
11	152	244	93	151	59	30.69	38.11	61.18	46.96
12	83	156	68	88	15	39.77	43.59	81.93	56.90
13	28	15	13	2	15	43.33	86.67	46.43	60.47
14	80	151	43	108	37	23.24	28.48	53.75	37.23
15	79	128	52	76	27	33.55	40.63	65.82	50.24
16	105	86	32	54	73	20.13	37.21	30.48	33.51
17	96	64	44	20	52	37.93	68.75	45.83	55.00
18	46	28	19	9	27	34.55	67.86	41.30	51.35
Total/Average	**669**	**872**	**364**	**508**	**305**	**32.90**	**51.41**	**53.34**	**48.96**

Table 3. Third Test: Results per Article

Articles	Referenced	Retrieved	TP	FP	FN	Accuracy	Precision	Recall	F-measure
11	152	254	93	161	59	29.71	36.61	61.18	45.81
12	83	176	68	108	15	35.60	38.64	81.93	52.51
13	28	24	13	11	15	33.33	54.17	46.43	50.00
14	80	160	45	115	35	23.08	28.13	56.25	37.50
15	79	128	52	76	27	33.55	40.63	65.82	50.24
16	105	96	42	54	63	26.42	43.75	40.00	41.79
17	96	74	54	20	42	46.55	72.97	56.25	59.99
18	46	40	27	13	19	42.19	67.50	52.94	63.53
Total/Average	**669**	**942**	**394**	**558**	**275**	**30.09**	**47.8**	**57.60**	**50.17**

Out of the 942 entity relations retrieved from the results seen in Table 3, TP was 41.83%, while FP was 59.24%.

Article 17 presents the highest accuracy at 46.55 and precision of 72.97. The high precision was because the paper focuses on a basic habitat with common discussions on climate change which is covered by the appropriate seed data and gazetteers.

Article 14 has the lowest accuracy at 23.08, precision at 28.13, and F-measure at 37.50, again, due to details of the author and the publication appearing in the middle of the text.

A notable takeaway from this is that the number of the retrieved entities has increased compared to the previous test, however the results did not have a completely positive trend, with some articles having worse results during the third run. This is evident in Article 13, where it had some of the highest results during the second test, but now ending up with lower results, such as a lower accuracy at 33.33, precision at 54.17, recall at 46.43, and F-measure at 50. This is attributed to the additional entities retrieved, but all of which are false positives.

5. CONCLUSIONS

The current ontology population system can extract important information from the scientific publications using a bootstrapping algorithm to find possible patterns as to how the extraction of information from the papers will occur. The system currently excels at extracting relations between scientific names and common names since the relationship between the two entities are typically found accordingly in the databases referenced. The system however has lower metric scores when it comes to relationships between habitats and effects of climate change because there are less references of effects compared to those of other classes, which causes difficulty for the algorithm to learn and extract the necessary entities. Despite the high amount of FP, there is a reasonable number of TP to justify pursuing this technique in automatic ontology population. As the intention is for extracted data to be validated by expert users prior to adding [permanently] to the ontology, there is assurance that the data eventually for use by experts in the analysis will be accurate.

The system's current bootstrapping process generates seed patterns by extracting the valid phrases between two entities that will be used by the Wordnet API to generate new synonyms. The current findings on the bootstrapping process may help future researchers from the same field to search for ways to improve the bootstrapping process by considering other resources other than the Wordnet API and utilizing a threshold on extracting the patterns between the entities.

According to our expert consultants (whose profiles also fit our system's target users), this study has not been done before and could be of help to scientists in the field, as there has been difficulty in manually reviewing voluminous data prior to doing the actual analysis and correlations. The marine climate change ontology could serve as a public listing of marine creatures, habitats, and climate change effects felt.

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