A Species Conservation Recommender System based on Knowledge Graph for Brown Bear Movement Prediction

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1 Introduction

In the context of Nature FIRST [1] research project we have constructed a knowledge graph (KG) for preserving biodiversity – *Nature First KG* [1] – that connects species, habitats and Natura2000 sites. The knowledge graph connects the data silos in various formats that are provided by different authorities such as EUNIS/EEA[2] and IUCN[3]. The connection between data under different authorities in the KG has been created using the so-called *crossovers*, namely SKOS `exactMatch` relations, whereas within EUNIS apart SKOS bespoke OWL relations have been used as well. The crossovers allow to traverse from one vocabulary context to another, i.e. from a EUNIS 2012 thesauri about habitat concepts to EUNIS 2021 concepts, maintaining the relationships despite that the habitats have undergone code and name changes. Referring to [1] as an example, "habitat *Subarctic and alpine dwarf Salix scrub* with code S21 in EUNIS ver. 2021 versus *Subarctic and alpine dwarf willow scrub* with code F2.1 in EUNIS ver. 2012". Such equivalence between concepts via `skos:exactMatch` can be used to infer statements about concepts and exploited similar to `owl:sameAs` reasoning, in which statements from the other concept can be taken into account. As another use case on the equivalence of habitats, we can mention for instance the mapping of local habitat codes to EUNIS classification system to ensure reporting in a consolidated form within EU. The Nature FIRST KG provides the necessary backbone that we can use for various use cases and applications that can be built on-top in order to exploit it for various querying and reasoning services. In the recent years there has been an increase of KG-based Recommender Systems that are used to provide the users not only explicit results, but also by traversing complex relationships in the graph. For such services, to name a few, either Datalog-based rules are used or path-based traversal where the connectivity of the graph is exploited[4]. In the context of Nature FIRST we are developing a KG-based recommmender system that is used to predict the brown bear (*Ursus Arctos*) movement for the purpose of avoiding human-wildlife conflicts by sending alerts to the nearby people. Herein, the crossovers between habitats are exploited in the context of (local) classification of habitats with respect to EUNIS in one of the field partners of Nature FIRST consortium in Stara Planina, Bulgaria.

[1] `www.naturefirst.info`

[2] European Nature Information System of the European Environment Agency (EUNIS/EEA), `https://eunis.eea.europa.eu/`

[3] The International Union for Conservation of Nature, `https://www.iucn.org/`

[4] For a practical overview on the topic, refer to the presentation in `https://cs.ulb.ac.be/conferences/ebiss2023/slides/EBISS2023_slides_AlbinAhmeti.pdf`

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2 Recommender System for Brown Bear Movement Prediction

We present our ongoing work on the recommender that predicts the movement of brown bears, leveraging knowledge from different sources:

1. the NF KG containing the knowledge on species, habitats, Natura 2000 providing the backbone and maintained in PoolParty Thesaurus manager;
2. geographic data stored in GeoServer that can provide different map layers and useful information on elevation, distance to roads;
3. habitat suitability index that provides useful data on how a habitat is preferred by species (brown bear) based on weights and maintained in PoolParty as a thesaurus;
4. observations on species, points of interests from rangers and other people using Sensing Clues' Cluey application that are exposed via Marklogic's SPARQL endpoint.

The NF KG has been extended with the modelling – *NF Ecological Model* – that extends the knowledge on brown bear and relevant habitats, species. This knowledge is currently refined by ingesting the knowledge via SPARQL endpoint on biotic interactions between species, specifically brown bear [5]. This modelling allows us to determine and reason on "query time" which species and habitats are relevant to brown bears in a given season and time. The data on 2. - 4. has been integrated using Python and calling the necessary APIs from Geoserver, queries to SPARQL endpoints producing the connected results in a graph, i.e. a species has been observed in a certain elevation, which is known to have a certain weight of preference for that particular species.

The integrated data allows us to compute the gradient (slope) on the observations with the respect to the grid points around the nearby spatial coordinates. The smallest slope distance w.r.t nearby points is a measure that will be used for recommender actions, which will be further refined and contextualised using consolidated knowledge on 'distance to river', 'distance to town' etc. in addition to elevation. Based on the gradient we can determine what could be the trajectory considering a point of interest for the brown bear. For the trajectory we are planning to use path-based queries that also consider the connectivity between graphs within the overarching NF KG.

Apart from the deductive capabilities that are being used, also the data from the collared brown bears gives us the GPS positions that we can leverage to understand their behaviour and habits, provides test scenarios for validation and gives us the necessary data to apply machine learning algorithms. Furthermore, the knowledge on priors (weights) and conditional probabilities can be validated or changed based on the feedback loop provided by the ML algorithms.

3 Conclusions & Future work

To conclude, in this talk we apply the techniques of Neuro-Symbolic AI, combining symbolic and probabilistic reasoning, and machine learning in order to predict the movement of brown bears, with the ultimate aim of mitigating the human-wildlife conflict. In the future we want to provide more contextualised knowledge on habitats and species that are relevant for the brown bear, and connect it with the corridors and habitats that are encoded in Geoserver map layers. The collared brown bear data in the region of Stara Planina will also allow us to evaluate our approach and provide a feedback mechanism for more informed recommendation actions. In the future, we also consider the interaction between multiple brown bear individuals as in the scenario of multi-agent systems, as well as agent-based simulation of brown bears simulating trajectories based on points of interest and associated weights respectively.

References

[1] Albin Ahmeti, Jan-Kees Schakel, Robert David, Artem Revenko: Towards preserving Biodiversity using Nature FIRST Knowledge Graph with Crossovers. ISWC 2023 Posters and Demos: 22nd International Semantic Web Conference, November 6–10, 2023, Athens, Greece.

[5] See GLOBI for ursus arctos biotic interactions, https://www.globalbioticinteractions.org/browse/?interactionType=ecologicallyRelatedTo&resultType=json&sourceTaxon=Ursus%20arctos