International Knowledge Graph Reasoning Challenge (IKGRC)
Application Sheet

*Submit a PDF file containing the contents of this application sheet by e-mail.
(Any software can be used to create the sheet)

Contact: **kgrc@knowledge-graph.jp**

- Applicants to Main and Tool Tracks must describe all the information from 1 to 3.
- Applicants to Idea Track must describe at least information 1 and 2.
- There is no limit to the number of pages, so please add more pages as needed.

1. Information about the applicants

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2. Explanation of the reasoning and estimation process

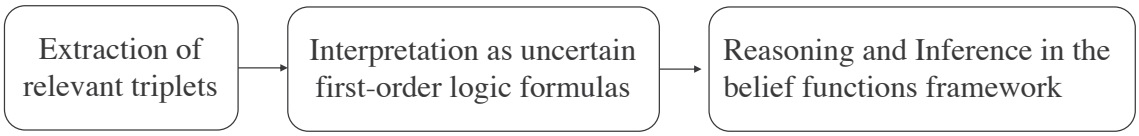
- Explain key points using the results, e.g., program logs. The format is free in the case of Idea Track.
(Please explain clearly with diagrams, etc.)

The proposed idea is to conduct reasoning and inference over knowledge graphs in the framework of the belief functions [1,2], which permits handling pieces of information affected by aleatoric and/or epistemic uncertainties.

First, the relevant triplets in the graph are extracted and interpreted as uncertain first-order logic formulas, i.e., first-order logic formula ϕ associated with an interval of the probability of ϕ, [belief of ϕ, plausibility of ϕ]. To do so, the uncertainties associated with each formula should be made explicit. One could use external knowledge such as "If the witness knows the person he/she saw, then he/she is right with a probability p" (aleatoric uncertainty). Concerning the consideration of epistemic uncertainty, we could take advantage of an external ontology to capture the level of precision of an object or a subject.

Then, first-order logic formulas are manipulated in a belief functions based-frameworks called framework Uncertain Logic Processing proposed in [3]. Thus, classical logic-based technics, such as the satisfiability (SAT) problem, can be generalized to the presence of uncertainty. Moreover, inference tools of the belief functions theory can be mobilized. For instance, computing the degree of conflict could be used to identify which sources, e.g., characters, are the most in conflict with the others or inconsistent with the facts.

The idea is summarised by the following diagram:



Let us, for example, consider the mystery of Abbey Grange and assume one tries to identify the number of criminals. Then relevant triplets include the following:

- Criminal include old man and two people (Statement of Lady Brackenstall)
- Three_of_glass have color_of_wine (Situation)
- Two_of_glass clean (Situation)
- Criminal and Maid gangUp (Thought)

Using contextual information, the triplet should be interpreted as first-order uncertain logic formulas. Let us reformulate these pieces of evidence in the belief function framework and define three masses functions for each information source, namely m1 for « statement of Lady Brackenstall », m2 for « Situation » and m2 for « Thought ». From the statement, the number of criminals is 3, thus $m1(\{3\}) = 1$. From the situation, we note weak evidence for the hypothesis of 3 persons and stronger evidence towards the hypothesis of only one criminal, thus we could reasonably set $m2(\{3\}) = 0.2$ and $m2(\{1\}) = 0.8$. Form the thought, we can interpret that there are at least two criminals, thus $m3(\{2,3\}) = 1$. We then can derive first-order uncertain logic formulas for each sources:

Logic formula φ	Uncertainty [Bel(φ),Pl(φ)]	Source
« criminal is one person »	[0,0]	Statement of Lady Brackenstall
« criminal is one person »	[0.8,0.8]	Situation
« criminal is one person »	[0,0]	Thought
« criminal is two persons »	[0,0]	Statement of Lady Brackenstall
« criminal is two persons »	[0,0]	Situation
« criminal is two persons »	[0,1]	Thought
« criminal is three persons »	[1,1]	Statement of Lady Brackenstall
« criminal is three persons »	[0.2,0.2]	Situation
« criminal is three persons »	[0,1]	Thought

We can then compute the degree of conflict, say between « Statement of Lady Brackenstall » and « Situation » as the amount of conflict between m1 and m2: 0.8. And no conflict between « Statement of Lady Brackenstall » and « Thought ».

- Range of knowledge graphs used (Scene ID)

Scenes #036, #151, #188, #141 in « Abbey Grange »

- Description of external knowledge added for reasoning
  (If the added knowledge is publicly available on the Web, include the URL of where to obtain it. It is not mandatory to make the additional knowledge publicly available.)

Specific external information has not been decided for this work.

- Performance information
  (machine specs, run time, memory, etc.)

Implementations of this idea have yet to be done.

- References
  (e.g., author's website and related papers, if any)

[1] G. Shafer, A mathematical theory of evidence, vol. 42. Princeton university press, 1976.
[2] P. Smets and R. Kennes, "The transferable belief model," Artificial intelligence, vol. 66, no. 2, pp. 191–234, 1994.
[3] R. C. Nunez, M. N. Murthi, K. Premaratne, M. Scheutz, and O. Bueno, "Uncertain logic processing: logic-based inference and reasoning using dempster–shafer models," International Journal of Approximate Reasoning, vol. 95, pp. 1–21, 2018.