KNOWLEDGE REPRESENTATION WITH HOTT

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While the concept of Formal Ontology already secured its central role in Knowledge Representation (KR), *Formal Epistemology* presently remains a purely philosophical subject with no direct application in KR [5]. As a result, standard formal tools used in KR such as Description Logics (DL) and Web Ontology Language (OWL) lack any *epistemic* semantics, which is an obvious miss since these tools are supposed to help us to represent *knowledge*. Formal semantics qualifies as epistemic when it supports a formal distinction between true propositions, on the one hand, and propositions such that their truthness is *known* by an epistemic agent, on the other hand. Accordingly, an epistemic semantic of logical inferences requires that a given inference not only preserves the truthness of premises but also that the truth-preservation property of a given inference is made evident to an agent (which may put strong restrictions on admissible inferential structures). Since OWL and DL use the standard truth-condition logical semantics rather than a version of proof-theoretic semantics [4] OWL and DL do not formally distinguish between those truth-preserving inferences, which are epistemically admissible and those, which are not.

Even if the concept of knowledge remains a subject of wide philosophical controversy, the very idea that knowledge of a proposition should not be identified with this proposition itself is hardly controversial. According to an influential view, an agent *knows* that P just in case (i) P is true and (ii) she *justifiedly beliefs* that P. (This view constitutes the so-called JTB theory of knowledge). While the issue of human belief belongs to human psychology and is arguably beyond the scope of theoretical KR, the epistemically-laden concept of *justification* allows for a formal treatment [1] and fully belongs to its scope. The fact that standard KR architectures do not support justificatory procedures, on the practical side, means that a regular user of KR system typically is not in a position to judge whether the "knowledge" she obtains from this system is reliable or not unless she uses some external means and tools for checking it. The present proposal aims at integrating relevant justificatory procedures into the KR architecture itself.

A justificatory procedure related to certain propositional knowledge has its formal dual in the form of verification of the corresponding procedural knowledge aka knowledge-how, that is, knowledge how to perform a given procedure. In this case the epistemic goal is not

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to justify a proposition but to assure that an accomplished construction has some required properties (think of technological processes which certain desired outcomes). Since this difference in epistemic goals does not affect the basic semantics, our proposed approach applies to both these sorts of tasks.

We propose to use HoTT and its proof-theoretic semantics as a formal semantic framework for KR, which satisfies the above desiderata. The following features of HoTT motivate this choice.

(1) HoTT admits the constructive epistemically-laden proof-theoretic semantics intended by Martin-Löf's Type for MLTT [2].
(2) The new interpretation of equality in HoTT gives rise to the notion of cumulative h-hierarchy of types which, in particular, supports the distinction between propositional and higher-level types. This is the crucial feature of HoTT, which allows for representing objects (of various levels) and propositions "about" these objects within the same framework. Each such object serves as a witness/truth-maker for proposition obtained via the propositional truncation of type where the given object belongs.
(3) HoTT involves a system of formal rules, which are interpreted as logical rules at the propositional h-level and as rules for object-construction at all higher levels. This feature of HoTT, which is not available in the "flat" extensional MLTT, allows for representing various extra-logical procedures (such as material technological procedures) keeping track of the corresponding logical procedures at the propositional level of representation.

A simple example of using HoTT for representing the empirical knowledge of identity of Morning Star and Evening Star is given in my [3]. Here I interpret the observable trajectory of Venus as a path in the sense of HoTT. Other perspective applications of this approach may be less direct but the same geometrical intuition associated with HoTT can be useful in such cases too.

References

[1] S. Artemov and M. Fitting. *Justification Logic*. Cambridge University Press, 2019.
[2] Per Martin-Löf. *Intuitionistic type theory*, volume 1 of *Studies in Proof Theory*. Bibliopolis, 1984.
[3] A. Rodin. Venus Homotopically. *IfCoLog Journal of Logics and their Applications*, 4(4):1427–1446, 2017. Preprint: http://philsci-archive.pitt.edu/12116/.
[4] Peter Schroeder-Heister. Proof-theoretic semantics. In Edward N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, spring 2018 edition, 2018.
[5] Jonathan Weisberg. Formal epistemology. In Edward N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, winter 2017 edition, 2017.