

The Ontology for Agents, Systems and Integration of Services: recent advancements of OASIS

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WOA 2022 : The 23rd Workshop 'From Objects to Agents'
1-3 September 2022

- Semantic web and ontology engineering have many applications in the realm of *(Multi-) Agent Systems*.
- Goals of Semantic Web applications range from agent representation to engineering and developing, from data sharing and reuse, to human-assistance.
- OASIS: An ontology of Agent, Systems, and Integration of Services (OASIS, in short) was introduced in 2019 with the aim of representing agents from a **behaviouristic** perspective.
- In 2022 OASIS has been adopted in many contexts and evolved since its first presentation.
- In this talk we explore OASIS, how it evolved and how it has been recently leveraged, in particular in the context of the NGI-ONTOCHAIN project (**ontochain.ngi.eu**)

Related work

- Semantic web has a long history in representing web artifacts.
- Semantic Web Services:
 - OWL-S (W3C, 2004), an ontology for describing web services and related information.
 - Semantic Web Services (Fensel et al. 2011), Web Services with semantically represented content.
- Semantic Web of Things and Internet of Things:
 - A. Ciortea et al., Repurposing manufacturing lines on the fly with multi-agent systems for the web of things, 2018.
 - W. Wang et al., A Comprehensive Ontology for Knowledge Representation in the Internet of Things, 2012.
- Semantic Agents:
 - J. Hendler, Agents and the semantic web, 2001.
 - M. Hadzic et al., Ontology-Based Multi-Agent Systems, 2014.
 - F. García-Sánchez, et al. Combining semantic web technologies with multi-agent systems for integrated access to biological resources, 2008.
 - D. Fritzsche et al., Ontologies within semantic interoperability ecosystems, 2017.
 - A. Freitas et. al., Applying ontologies to the development and execution of multi-agent systems, Web Intelligence, 2017.

OASIS leverages the behaviouristic approach to:

- provide operational semantics inspired by the Tropos methodology (Bresciani et al., 2004);
- model agent behaviours by decomposing them in the atomic and essential mental states (tasks, goals, ...);
- deliver a semantic representation system and communication protocol for agents and their commitments based on behaviours

where

- behaviours depict agent's capabilities and the related actions represent commitments history;
- behaviours are accessible so as they can be activated;
- behaviours are human-understandable, machine understandable, and implementation-independent;
- through behaviours, agents make available the set of operations that they are able to perform and the type of data required to execute these.

- OASIS is the ontological core of a (prototype of) domotic assistant based on that protocol (Cantone et al. 2019).
- OASIS is used to describe agent agreements (Ontological Smart Contracts) secured on Ethereum through IPFS (Cantone et al., 2022).
- OASIS is used to describe the Ethereum blockchain and the ERC721 standard protocol (Bella et al., 2022).
- OASIS models agents in the context of a blockchain oriented e-commerce developed within the NGI-ONTOCHAIN project (ontochain.ngi.eu) (Bella et al., 2021).

NGI-ONTOCHAIN funded the POC4COMMERCE project that

- describes the blockchain-oriented commerce domain with a behaviouristic vision of its essentials, i.e., commercial actors, offers, products, and tokens emitted on the Ethereum blockchain as digital witnesses of exchanged assets.
- leverages OASIS to represent ONTOCHAIN agents.
- is constituted by three ontologies
 - OC-Found (that includes OASIS) for agents (commercial participants, smart contracts).
 - OC-Commerce for commercial offerings, assets and activities.
 - OC-Ethereum for Ethereum smart contracts and related tokens (compliant with ERC20, ERC721, and ERC1155).
- a semantic search engine is built upon the stack to probe the blockchain-oriented marketplace.

OASIS represents agents

- (not mandatory) by modelling general abstract behaviours (called templates) from which concrete agent behaviours are drawn;
- by modelling concrete agent behaviours possibly, drawn by agent templates;
- modelling actions performed by agents, by associating them with the behaviours from which actions are drawn.

Other features:

- agent plans, i.e., requests that ask agents to perform an action associated with their behaviours.
- entrustment of agents, i.e., act of engaging agents to perform requested actions.
- restrictions or constraints on agent actions.

A version 2.0 is on-going.

OASIS: Ontological Core

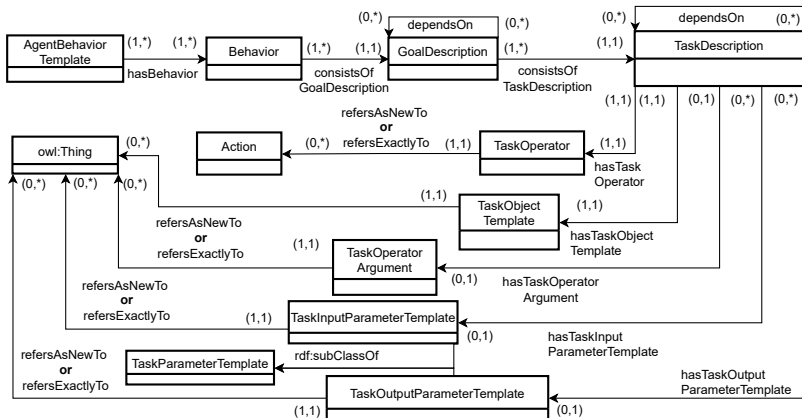


Figure 1: Agent template schema

OASIS: Ontological Core

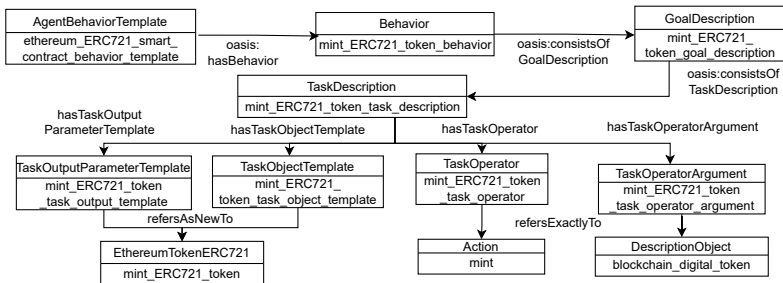


Figure 2: Agent template example

OASIS: Ontological Core

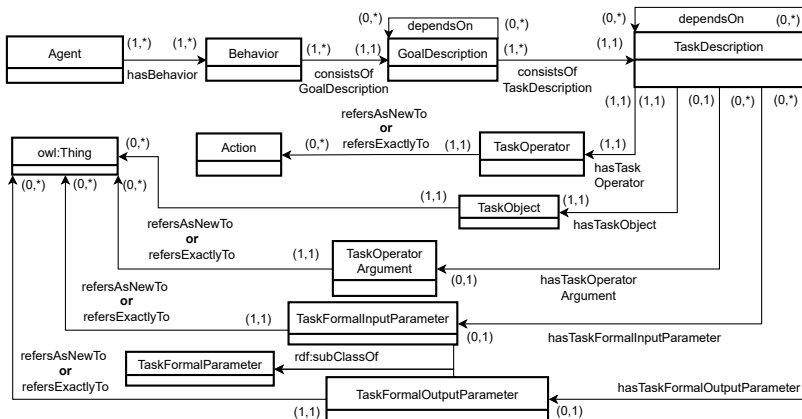


Figure 3: Agent behaviour schema

OASIS: Ontological Core

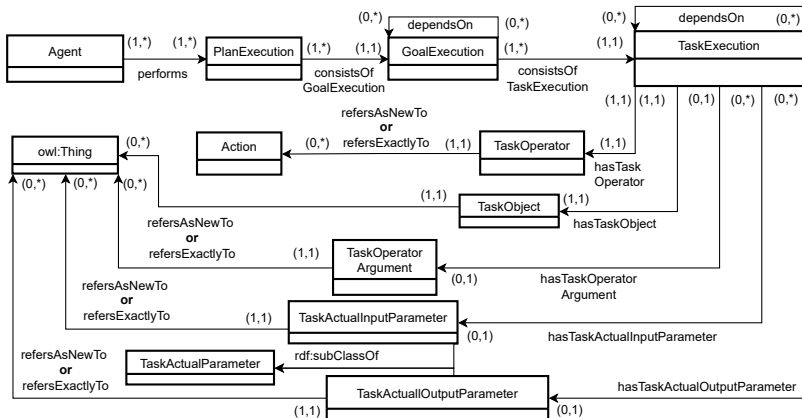


Figure 4: Agent action schema

OASIS: Ontological Core

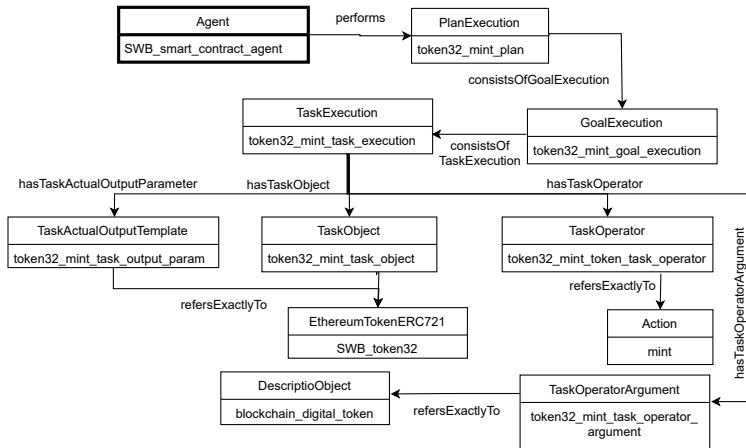


Figure 5: Agent action example

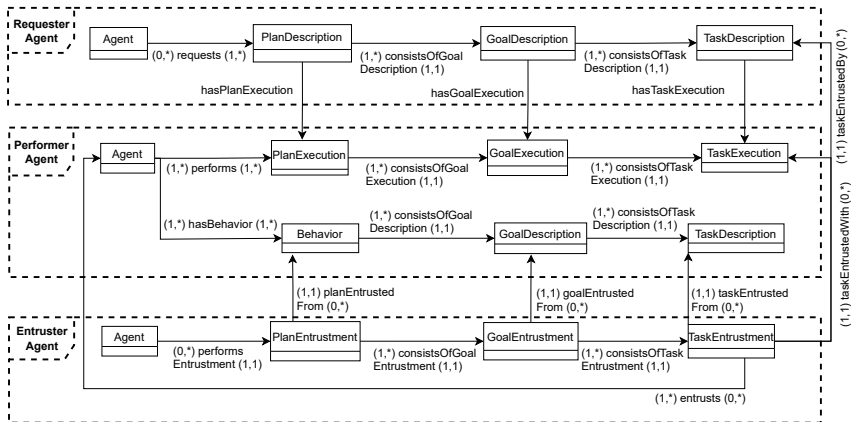


Figure 6: Agent entrustment schema

- OASIS is a foundational ontology for representing agents and commitments.
- OASIS adopts the behaviouristic and the related mentalistic notions.
- Here we focused on agents templates, concrete agents, agent commitments, agent entrustments.
- OASIS has been leveraged in many contexts, mainly in blockchain-oriented e-commerce.
- OASIS evolved as a consequence of its adoption in the POC4COMMERCE project (NGI-ONTOCHAIN) and in related contexts.

- OASIS version 2 is on-going.
- OASIS shall include meta-plans, namely, agent strategies designed to be achieved through plans.
- Conditionals shall be applied to represent security constraints for cybersecurity threat contexts, in particular for the purpose of semantically representing authentication and confidentiality properties for agents.
- Integration with frameworks for agent engineering shall be evaluated.

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- D. Fensel et al., Semantic Web Services, Springer, 2011.
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THANK YOU