# Representing Mathematical Problems by means of Protégé OWL

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With the objective of improving Mathematical supervisory capacity of Computer Aided Systems, we are developing a system which makes use of an ontology for the representation of knowledge in Mathematics, with the purpose of making use of the same by means of specific applications (for example carrying out geometric demonstrations). The distributed architecture of our system is composed of a series of modules that work in different virtual machines. The system is structured in two main subsystems:

- A web server that controls communication with the users (professors or students) by means of corresponding editors that work on a standard browser.
- A system of knowledge, RAMSYS (Reasoning And Managing SYStem) that serves as: a database of problems, support for symbolic calculation and, the fundamental part, a module of representation of knowledge.

Communication between both modules uses the RIACA OM Library (ROML) [1]. This library is oriented to communication among applications by means of OpenMath, a standard language that is easily extended to represent mathematical concepts from a semantic point of view. On the other hand, the module that houses the part of representation of knowledge (the classes of mathematical objects and their relationships), and the logical verification of the student's actions, is based on the language OWL [2, 3]. As a consequence, beyond the semantic possibilities of representation that OpenMath offers us, by means of the use of ontology we can verify, from a logical point of view, the objects and the relationships among them that the student defines. These objects can be defined in an incorrect or incomplete way, but the system must be able to process this information in order to let the student know that he has made an error. In such situations OpenMath is not able to carry out the semantic confirmations needed. For example, if the student has defined *A* as a *point* but then later on tries to use it or to redefine it as a *straight line*; or the case where he might use an object not yet defined in a relationship, what should the system do in these circumstances?. Therefore, it is necessary to maintain the consistency of the knowledge base.

In order to check and maintain the consistency we make use of a module named BATMAN (Bivalent AnnoTation MANager). The OpenMath generated code associated with the student actions is translated into OWL code in order to make the annotations and corresponding verifications in the knowledge base. All the annotations are made dynamically by means of the *API Jena Semantic Web Framework* [4]. Each annotation requires that the integrity of the knowledge base be checked, so that all possible inconsistencies (for example, identifying a point with a straight line) can be avoided. In order to carry out this semantic verification we make use of the RACER [5] reasoner, which doesn't only preserve its integrity but also derives new facts from the knowledge base when necessary.

On the other hand, the system has to manage data from problems defined by the professors. These are defined in OWL using as a schema an ontology which has been created with Protégé. This tool allows users to construct domain ontologies, customize data entry forms, and enter data with a friendly and extensible interface. But because of the mathematical nature of the ontology, some components for formulae display are being developed to be integrated in Protégé's user interface and facilitate problem editing. The Protégé OWL plug-in DIG interface is used with RACER to validate problems checking ontology integrity but a problem needs to be validated from a mathematical point of view too. For that purpose an interface with the symbolic computation module is necessary.

Finally we must point that the ontology uses the taxonomy of defined symbols in OpenMath obtained from the project MONET [6]. This ontology is oriented to the description of mathematical services on the Web and in it the objects and the relationships among these are applied that the student defines.

## References

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