1 INTRODUCTION

Ontology evolution and its automation are key factors for achieving software’s flexibility and adaptability. In the approach to automated ontology evolution adopted in the GALILEO project, progress in physics is modelled as a process of ontology evolution. An overview of the approach is provided in Section 2. Section 3 shows that the construction and the modification of qualitative causal models of experimental set-ups make it possible to gain information about the quantities that appear in an equation and contribute to creating the logical conditions for the equation to evolve.

2 ONTOLOGY REPAIR PLANS

In the framework of the GALILEO project a number of so-called Ontology Repair Plans (ORPs) are being developed and implemented in higher-order logic [1]. ORPs detect and resolve a contradiction between two or more ontologies. In ORPs developed thus far, one of the ontologies represents a theory while the second ontology represents a sensory or experimental set-up for that theory. When the sensory ontology generates a theorem that contradicts a theorem of the theoretical ontology, an ORP is triggered which amends the two ontologies according to the observations. The development of ORPs is inspired by cases in the history of physics. So far, a few ORPs have been developed from a number of development cases, which reflect common strategies used in physics to cope with contradictory evidence. One of the ORPs is called Where is my stuff? (WMS) and was inspired by the discovery of latent heat.

Until the second half of the 18th century, the chemical/physical notion of heat was conflated with the notion of temperature and it inspired by the discovery of latent heat.

Where is my stuff?

WMS’s logical infrastructure emulates part of the evolution from Equation 1 to Equation 2 and adds to Equation 1 a component for the heat transferred during phase transitions. The equation for such intermediary theory would be:

\[ Q = m \times \Delta T + m \times L \]  

where \( Q \) is the heat put into or taken out of the body, \( m \) is the mass of the body, \( \Delta T \) is the change in temperature, \( L \) is the specific latent heat required by a given substance during its phase transitions.

3 FROM THEORIES TO EXPERIMENTS

An aspect of the evolution of a physics theory that needs to be clarified is how the experimental set-up represented by the sensory ontology comes to produce evidence that contradicts the expectations of the theoretical ontology.

To this end a causal model of an experimental set-up for Equation 1 is discussed here. In particular, given the qualitative causal model shown in Figure 1, a new model is derived (Figure 2) based on principles 1 to 3 (see below). Running simulations on both models provides information (Figure 3) about the quantities that appear in the equation and create the conditions for the equation to evolve.

The causal models for Equation 1 are based on Qualitative Process Theory (QPT) [2], which allows to simulate the behaviour of a system through the explicit representation of causal relations between its quantities. The models and the results of the simulations were produced using a QTP-based tool called Garp3 (available on http://hcs.science.uva.nl/QRM/). In Garp3 terminology, a QPT model consists of a number of model fragments that describe their own sufficient or necessary conditions (in red resp. blue in the figures). Such fragments consist of entity types and relations between them, such as Container, Substance and Contains. Entities types have quantities, the value of which is a combination of their positive or negative magnitude on a qualitative scale and of a positive or negative times greater than the time required to raise a pound of water one degree in its temperature, both the ice and the water receiving the heat equally fast. This observation required to distinguish heat from temperature, thus ultimately change the very meaning of the quantity \( Q \). Equation 1 evolved into:

\[ Q = m \times \Delta T + m \times L \]  

The qualitative values for Temperature are named after phases. A phase Freeze,melt is included between points Frozen and Melted to reflect the state of knowledge at the time of Equation 1: it was believed that temperature would change during phase transitions, which requires an interval between the solid and the liquid phases.
In order to test Equation 1 against phase changes the process Heat_flow shown in Figure 1 needs to be modified into the process Melting, which includes as a precondition Heat_flow (which is grayed-out Figure 2). Melting is activated for Frozen < Temperature(Sub) < Melted and includes quantities for phases (Amount_of solid and Amount_of liquid) in order to observe Equation 1 at work during phase changes. These are phenomenological quantities, not included in the original equation, and their causal role in the modified model should be neutral from an energetic viewpoint, their insertion in the model should be based on the following three principles:

1. changes in their values should be direct effects of the cause quantity (i.e. Flow);
2. they should indirectly affect the effect quantity (i.e. Temperature);
3. they should exert an opposite indirect causal influence on the cause quantity with respect to the influence exerted on it by the effect quantity.

These changes to the process Heat_flow create an ambiguity in the model for the quantity Temperature, which during the process Melting is at the same time positively directly influenced by Flow and indirectly negatively proportional to it. Such ambiguity is reflected in the two alternative simulations produced by the modified model (Figure 3). The first simulation envisions an interruption of the temperature rise, whereas the second matches the prediction based on Equation 1. The very creation of the ambiguity through the modification steps 1 to 3 above sheds light on how the contradiction between the theoretical and the sensory ontology is generated.

REFERENCES