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Towards Ontology Evolution in Physics

The Introduction of Two Ontology Repair Plans

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http://dream.inf.ed.ac.uk/projects/ontology_evolution



Abstract: Our research proposes to tackle the problem of automatically repairing inconsistent ontologies. We aim at developing mechanisms for automated evolution of ontologies to adapt to new circumstances and to make them better suited to the given task. If a conflict is detected between the original theory and new experimental evidence, a repair is required to resolve the inconsistency and to recover from failure. The rules for conflict diagnosis and transformation of the ontologies are composed together into *ontology repair plans*. The repair plans have been implemented in the GALILEO system and successfully evaluated on a diverse range of examples from the history of physics. Physics is an excellent domain for our work because it has good historical records of how physicists change their view on the world, which can be seen as ontology evolution.

The “Where’s my stuff?” Ontology Repair Plan

Suppose we have:

- An ontology O_t representing the current state of a physical theory and an ontology
- An ontology O_s representing some sensory information arising from an experiment
- O_t and O_s disagree over the value of some function *stuff* when it is applied to a vector of arguments \vec{s}

Trigger: If $stuff(\vec{s})$ has two different values in O_t and O_s then the following formula will be triggered:

$$O_t \vdash stuff(\vec{s}) = v_1, O_s \vdash stuff(\vec{s}) = v_2, O_t \vdash v_1 \neq v_2 \quad (1)$$

where $O \vdash \phi$ means that formula ϕ is a theorem of ontology O . Below we deal with the case where $v_1 > v_2$. The other case is symmetric, with the roles of O_t and O_s reversed.

Split Stuff: The repair is to split *stuff* into three new functions: visible stuff, invisible stuff and total stuff. Then we create a definition of invisible stuff in terms of total and visible stuff:

$$\forall \vec{s}: \vec{\tau}. stuff_{\sigma_{invis}}(\vec{s}) ::= stuff(\vec{s}) - stuff_{\sigma_{vis}}(\vec{s}) \quad (2)$$

Create New Axioms: Let $\nu(O_t)$ and $\nu(O_s)$ be the repaired ontologies. We calculate the axioms of the new ontologies in terms of those of the old as follows:

$$\begin{aligned} Ax(\nu(O_t)) &::= \{\forall \vec{s}: \vec{\tau}. stuff_{\sigma_{invis}}(\vec{s}) ::= stuff(\vec{s}) - stuff_{\sigma_{vis}}(\vec{s})\} \cup Ax(O_t) \\ Ax(\nu(O_s)) &::= \{\phi\{stuff/stuff_{\sigma_{vis}}\} \mid \phi \in Ax(O_s)\} \end{aligned}$$

Application to the Discovery of Latent Heat

Before Joseph Black discovered the concept of latent heat around 1750:

- The concepts of heat and temperature were conflated
- A paradox: as water is frozen, it is predicted to lose heat, but the temperature remains constant

Black had to *split* the concept of heat into energy and temperature.



The paradox faced by Black can be formalised as follows:

$$O_t \vdash Heat(H_2O, Start(Freeze)) = Heat(H_2O, Start(Freeze)) \quad (3)$$

$$O_s \vdash Heat(H_2O, Start(Freeze)) = Heat(H_2O, End(Freeze)) \quad (4)$$

$$O_t \vdash Heat(H_2O, Start(Freeze)) \neq Heat(H_2O, End(Freeze)) \quad (5)$$

where

- H_2O is the water being frozen
- *Freeze* is the time interval during which the freezing takes place
- *Start* returns the first moment of this period and *End* the last
- (3) comes from the reflexive law of equality;
- (4) comes from the observed constant temperature during freezing; and
- (5) is deduced from the then current theory that heat decreases strictly monotonically when objects are cooled.

The repair plan can be triggered with the following substitution:

$$\{Heat/stuff, \langle H_2O, Start(Freeze) \rangle / \vec{s}, Heat(H_2O, Start(Freeze)) / v_1, Heat(H_2O, End(Freeze)) / v_2\}$$

To effect the repair we will

- Define $\sigma_{vis} = \{Temp/stuff\}$
- Define $\sigma_{invis} = \{LHF/stuff\}$

where *LHF* can be read as the latent heat of fusion. These choices instantiate (2) to:

$$\forall o: obj, t: mom. LHF(o, t) ::= Heat(o, t) - Temp(o, t)$$

which is very close to what is required.

Since $Heat(H_2O, Start(Freeze))$ is greater than $Heat(H_2O, End(Freeze))$, the repaired triggering formulae are transformed to :

$$\begin{aligned} \nu(O_t) \vdash Heat(H_2O, Start(Freeze)) &= Heat(H_2O, Start(Freeze)) \\ \nu(O_s) \vdash Temp(H_2O, Start(Freeze)) &= Temp(H_2O, End(Freeze)) \end{aligned}$$

which breaks the derivation of the detected contradiction, as required.

The Inconstancy Ontology Repair Plan

Inconstancy works on ontologies set up as follows:

- Different sensory ontologies give distinct values for $stuff(\vec{s})$ in different circumstances
- Function $V(\vec{s}, \vec{b})$, where \vec{b} contains variables distinguishing among these circumstances, returns distinct values in each of these circumstances
- $stuff(\vec{s})$ does not depend on $V(\vec{s}, \vec{b})$

So, Inconstancy repairs ontologies by **adding** $V(\vec{s}, \vec{b})$ **as a new argument to** *stuff*.

stuff might, for instance, be the gravitational constant G and $V(\vec{s}, \vec{b})$ might be the acceleration of an orbiting star due to the gravity (Modified Newtonian Dynamics).