

A Contextual Approach to Detection of Conflicting Ontologies

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Overview

- Ontologies can only be partial theories about the world, so they may encode distinct knowledge.
- A same situation can be described and represented differently in different ontologies.
- Example: A car moves at 1cm/s at t_2
 - $Ax(\mathcal{O}_1) ::= \{velocity(car, t_2) = 1cm/s\}$
 - $Ax(\mathcal{O}_2) ::= \{position(car, t_1) = 0cm, position(car, t_2) = 1cm\}$
 - $velocity(car, t_1) = 1cm/s$ cannot be deduced from \mathcal{O}_2 .
- To automate ontology evolution (in physics), detection of conflicting ontologies must be mechanised.
- Formalise ontologies as contexts and adopt ideas from McCarthy.



Outline

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The Bouncing-ball Case Study



- Suppose a bouncy ball is suspended above ground and a student believes the total energy (TE) relates to the kinetic (KE) and the potential (PE) energies by:

$$TE(p, t) = KE(p, t) + PE(p, t)$$

- Initial PE is > 0 J, initial KE is 0J, thus initial TE is > 0 J.



The Paradox



- Leads to paradox when the ball hits the ground and begins to rebound:
 - Final PE observed is $= 0J$ and final KE observed is $= 0J$, thus final TE is $= 0J$.
 - By the conservation of energy, initial TE is equal to final TE.
 - Initial TE is $> 0J$, but final TE is $0J$.
- Paradox arises from the idealisation of the ball as a particle without extent.



Ontological Representation

- Let there be two locally consistent ontologies, O_t (theory) and O_s (sensory).
- O_t contains the predictive theory, e.g., physics laws, definitions.
- O_s contains raw observed data, e.g., positions in photos, spectral densities.
- Physics laws are usually defined in resp. to physical properties and not to aspects of the experiment.



Axioms of O_t

- Ontologies are higher-order logic, but we adopt some ideas from description logic (loosely).

TBox

$$\begin{aligned} \text{Ax}(\mathcal{T}(O_t)) ::= & \{ \forall p:Part, t_i, t_j:Mom. TE(p, t_i) = TE(p, t_j), \\ & \forall p:Part, t:Mom. TE(p, t) = KE(p, t) + PE(p, t), \\ & \forall p:Part, t:Mom. KE(p, t) ::= \frac{Mass(p, t) \cdot Vel(p, t)^2}{2}, \\ & \forall p:Part, t:Mom. PE(p, t) ::= Mass(p, t) \cdot G \cdot Height(p, t) \} \end{aligned}$$

ABox

$$\begin{aligned} \text{Ax}(\mathcal{A}(O_t)) ::= & \{ Vel(Ball, Start(Drop)) = 0, \\ & Height(Ball, Start(Drop)) > 0 \} \end{aligned}$$

Axioms of O_s

ABox

$$Ax(\mathcal{A}(O_s)) ::= \{ \text{Posn}(\text{Ball}, \text{Photo}(\text{Ball}, \text{End}(\text{Drop}) - \Delta)) = 0, \\ \text{Posn}(\text{Ball}, \text{Photo}(\text{Ball}, \text{End}(\text{Drop}))) = 0, \dots \}$$

where $\text{Posn}(\text{Ball}, \text{Photo}) = p$ means that the position of the ball Ball in the photograph Photo is at position p .

- Cannot relate the terms in O_t to those in O_s or vice versa.



Lifting Axioms

- Lifting axioms relate the truths in different contexts.
 - Terms from one context can be translated into another context.
- Let O_t and O_s be individual contexts.
- Introduce a new ontology O_b for connecting O_t with O_s .

Axioms of O_b

$$\begin{aligned}
 \text{Ax}(O_b) ::= \{ & \\
 \forall p:\text{Part}, t:\text{Mom. } O_t.\text{Height}(p, t) ::= & O_s.\text{Posn}(p, O_s.\text{Photo}(p, t)), \\
 \forall p:\text{Part}, t:\text{Mom. } O_t.\text{Vel}(p, t) ::= & \\
 \frac{(O_s.\text{Posn}(p, O_s.\text{Photo}(p, t - \Delta)) - O_s.\text{Posn}(p, O_s.\text{Photo}(p, t)))}{(t - (t - \Delta))}, & \\
 \dots \} &
 \end{aligned}$$



The “Where’s My Stuff” Ontology Repair Plan

- The “Where’s My Stuff” (WMS) ontology repair plan
 - Triggered by conflict between predicted and observed returned values

Trigger

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



Contextual Trigger for WMS

Trigger

$$O_t \vdash \text{stuff}(\vec{s}) = v_1 \quad (1)$$

$$O_s \vdash \text{stuff}(\vec{s}) = v_2 \quad (2)$$

$$\text{if: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(\mathcal{T}(O_s)) \cup Ax(O_t)) \not\vdash \perp \quad (3)$$

$$\text{then: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(\mathcal{T}(O_s)) \cup Ax(O_t)) \vdash \text{stuff}(\vec{s}) = v_3$$

$$\text{else: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(O_t)) \vdash \text{stuff}(\vec{s}) = v_3$$

$$\text{if: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(O_s) \cup Ax(\mathcal{T}(O_t))) \not\vdash \perp \quad (4)$$

$$\text{then: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(O_s) \cup Ax(\mathcal{T}(O_t))) \vdash \text{stuff}(\vec{s}) = v_4$$

$$\text{else: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(O_s)) \vdash \text{stuff}(\vec{s}) = v_4$$

where $\text{decntxt}(\phi)$ de-contextualises the formula ϕ such that every term in ϕ is considered to reside in the same context, e.g., $\text{decntxt}(o_1.f = o_2.g)$ gives $f = g$.

- Satisfy (1), (2), and $v_1 > v_2$ (Non-contextual WMS)
- Satisfy (1), (4), and $v_1 > v_4$
- Satisfy (2), (3), and $v_2 > v_3$
- Satisfy (3), (4), and $v_3 > v_4$

Application to the Bouncing-ball Case Study

Trigger Satisfied

$$O_t \vdash \text{stuff}(\vec{s}) = v_1 \quad (1)$$

$$\text{if: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(O_s) \cup Ax(\mathcal{T}(O_t))) \not\vdash \perp \quad (4)$$

$$\text{then: } Th(\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} \cup Ax(O_s) \cup Ax(\mathcal{T}(O_t))) \vdash \text{stuff}(\vec{s}) = v_4$$

$$\{\text{decntxt}(\phi) \mid \phi \in Ax(O_b)\} ::= \left\{ \forall p:Part, t:Mom. \text{Vel}(p, t) = \frac{\text{Posn}(p, \text{Photo}(p, t - \Delta)) - \text{Posn}(p, \text{Photo}(p, t))}{\Delta} \dots \right\}$$

Substitution

$$\{\text{stuff} / TE, \vec{s} / \langle Ball, \text{End}(\text{Drop}) \rangle, v_1 / x. x > 0, v_4 / 0\}$$



Conclusion

- In heterogeneous environments, ontologies may not share a common language.
- Treat each ontology as an individual context and design lifting axioms.
- Detection of conflicting ontologies can make use of lifting axioms to translate terms across contexts.
 - Higher generality but higher complexity as well.
- Need for evolution of lifting axioms?



Thank you!

Questions?

