Ontology Reasoning, Justification and Argumentation

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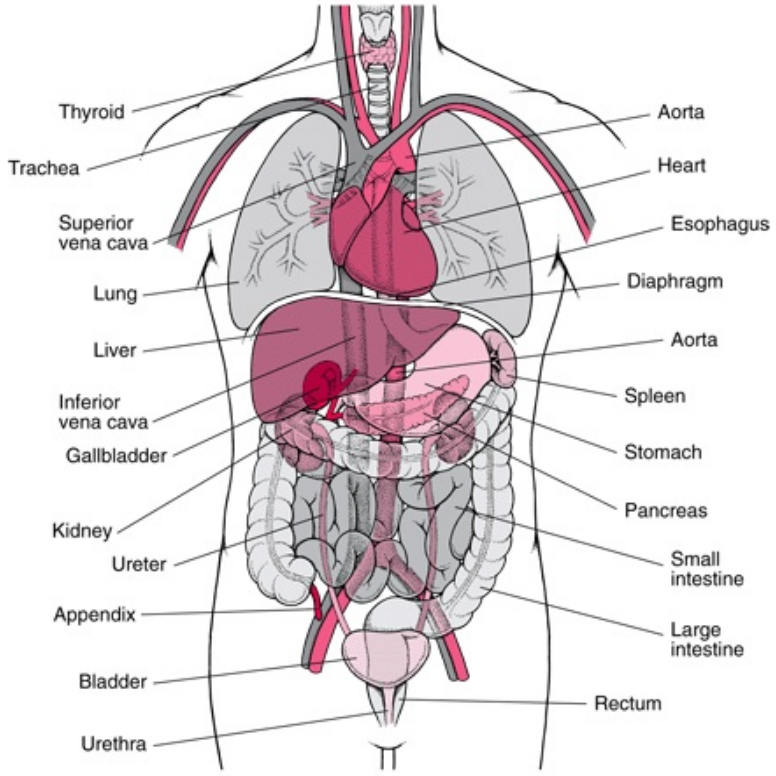
What is an Ontology?

A model of (some aspect of) the world

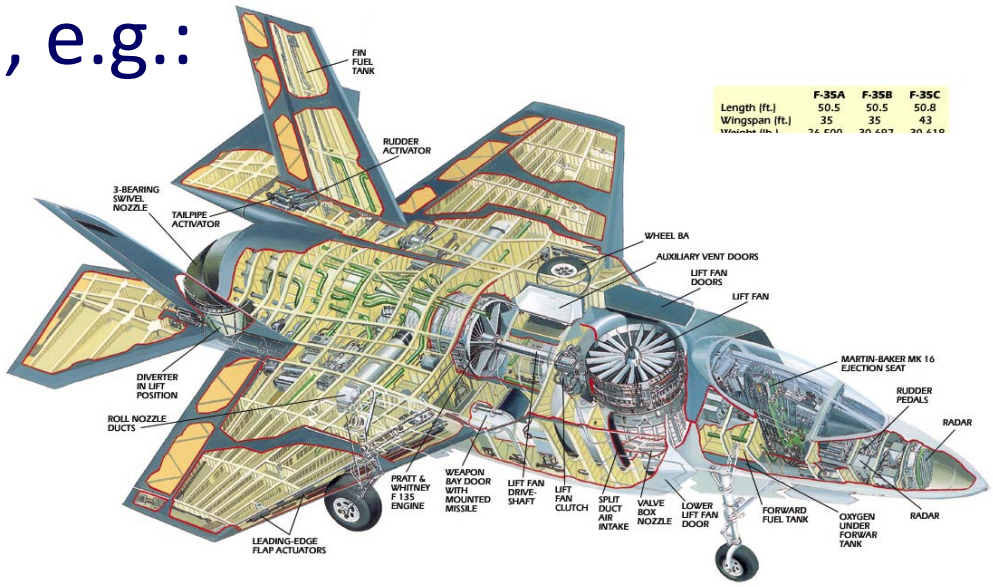
- Introduces **vocabulary** relevant to domain, e.g.
  - Anatomy



What is an Ontology?

A model of (some aspect of) the world

- Introduces **vocabulary** relevant to domain, e.g.:
  - Anatomy
  - Aerospace

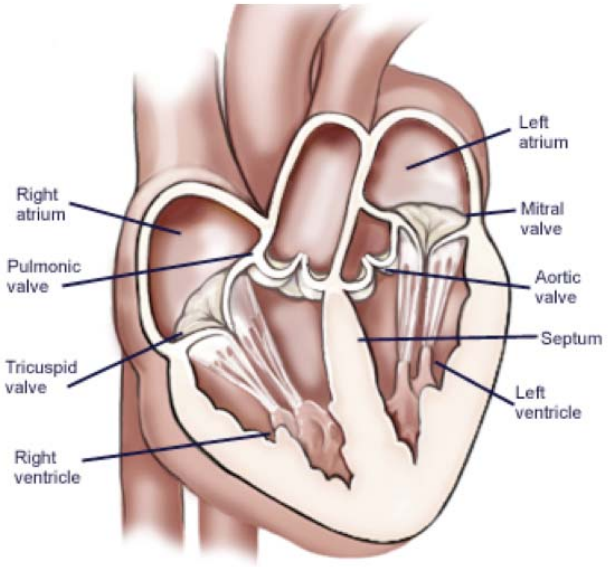


What is an Ontology?

A model of (some aspect of) the world

- Introduces **vocabulary** relevant to domain
- Specifies **meaning** (semantics) of terms

  Heart is a muscular organ that is part of the circulatory system



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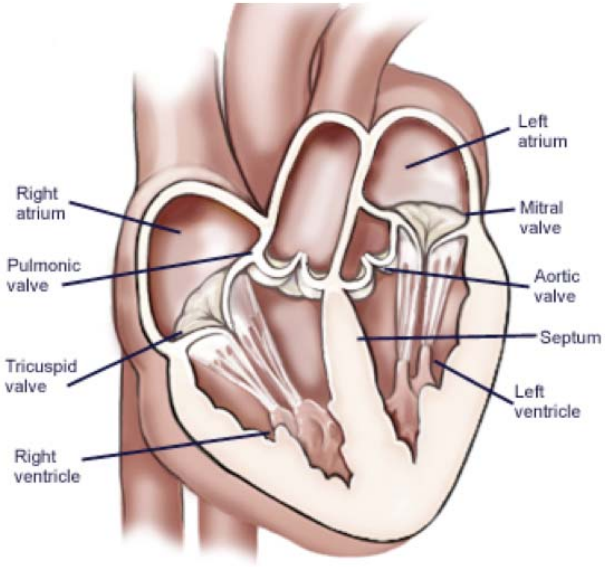


- **Formalised** using Description Logic / OWL

$$\text{Heart} \sqsubseteq \text{MuscularOrgan} \sqcap \exists \text{isPartOf}.\text{CirculatorySystem}$$

The DL Underpinning OWL2-DL

- $\mathcal{R}$ often used for $\mathcal{ALC}$ (**equivalent to $\mathcal{K}_{(m)}$**) extended with role chain inclusion axioms
  - following the notion introduced in $\mathcal{RIQ}$ [Horrocks and Sattler, 2003]
  - including transitive role axioms
- Additional letters indicate other extensions, e.g.:
  - $\mathcal{S}$ for role characteristics (e.g., reflexive and symmetric)
  - $\mathcal{O}$ for **nominals**/singleton classes
  - $\mathcal{I}$ for inverse roles
  - $\mathcal{Q}$ for qualified number restrictions
- role characteristics ($\mathcal{S}$) + $\mathcal{R}$ + nominals ($\mathcal{O}$) + inverse ($\mathcal{I}$) + qualified number restrictions($\mathcal{Q}$) = $\mathcal{SROIQ}$
- $\mathcal{SROIQ}$ **[Horrocks et al., 2006] is the basis for OWL2-DL**

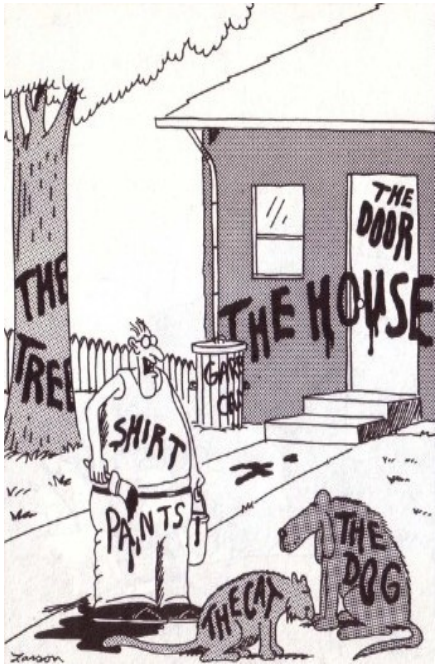
Web Ontology Language OWL

- W3C **recommendation(s)**
  - OWL2 (2009) provides expressive language OWL2-DL
  - and tractable profiles OWL2-EL, OWL2-QL and OWL2-RL
- Supported by **tools and infrastructure**
  - APIs (e.g., OWL API, Thea, OWLink)
  - Development environments
    (e.g., Protégé, Swoop, TopBraid Composer, Neon)
  - Reasoners & Information Systems
    (e.g., TrOWL [ESWC2010], Pellet, Racer, HermiT, …)

Ontology and Agreement

- Coherent **user-centric view** of domain
  - Help identify and resolve disagreements
  - Equivalent? Overlap? Disjoint?
- Towards ontology-based **agreement management**
  - Before reaching agreement: argumentation support
  - After reaching agreement: computing answers reflect the agreed schema & data, e.g.:

    "Patients suffering from Vascular Disease"



Now... *that* should clear up a few things around here

Reasoning

$$\begin{aligned}
\text{Heart} &\sqsubseteq \text{MuscularOrgan} \sqcap \\
&\quad \exists \text{isPartOf}.\text{CirculatorySystem} \\
\text{HeartDisease} &\equiv \text{Disease} \sqcap \\
&\quad \exists \text{affects}.\text{Heart} \\
\text{VascularDisease} &\equiv \text{Disease} \sqcap \\
&\quad \exists \text{affects}.(\exists \text{isPartOf}.\text{CirculatorySystem})
\end{aligned}$$

$$\begin{aligned}
\text{John} : \text{Patient} &\sqcap \\
&\exists \text{suffersFrom}.\text{HeartDisease}
\end{aligned}$$

Schema reasoning

- Subsumption checking: is HeartDisease a kind of VascularDisease?

Schema & data reasoning

- Instance checking: John suffersFrom VaascularDisease?

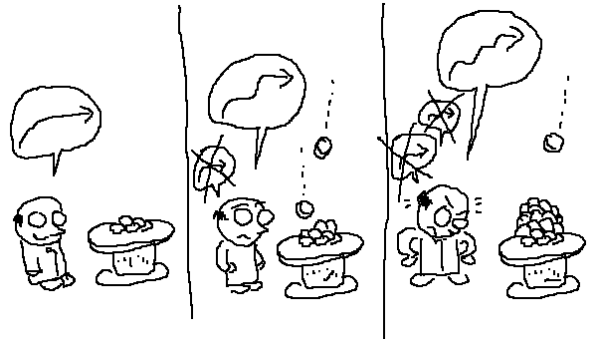
Inconsistency and Incoherency

- Inconsistent ontology [AAAI2006a]: ontology without a model
  - Example: {PhDStudent $\sqsubseteq$ Student,
    PhDStudent $\sqsubseteq$ Employee,
    Student $\sqsubseteq \neg$ Employee,
    PhDStudent(John)}
- Incoherent ontology [AAAI2006b]: ontology with at least one unsatisfiable concept
  - Example: {PhDStudent $\sqsubseteq$ Student,
    PhDStudent $\sqsubseteq$ Employee,
    Student $\sqsubseteq \neg$ Employee

Incoherent ontology can be consistent!

Justification

- Date back to diagnosis in AI
  - Is related to explanation
  - Was originally proposed to debug inconsistency
- Justification
  - Given an ontology O and an axiom ax
  - A justification is a minimal subset of O that imply ax
  - There could be multiple justifications



Example revisit

ax1 $\mathsf{Heart} \sqsubseteq \mathsf{MuscularOrgan} \sqcap \exists \mathsf{isPartOf}.\mathsf{CirculatorySystem}$

ax2 $\mathsf{HeartDisease} \equiv \mathsf{Disease} \sqcap \exists \mathsf{affects}.\mathsf{Heart}$

ax3 $\mathsf{VascularDisease} \equiv \mathsf{Disease} \sqcap \exists \mathsf{affects}.(\exists \mathsf{isPartOf}.\mathsf{CirculatorySystem})$

ax4 $\mathsf{John} : \mathsf{Patient} \sqcap \exists \mathsf{suffersFrom}.\mathsf{HeartDisease}$

Schema reasoning

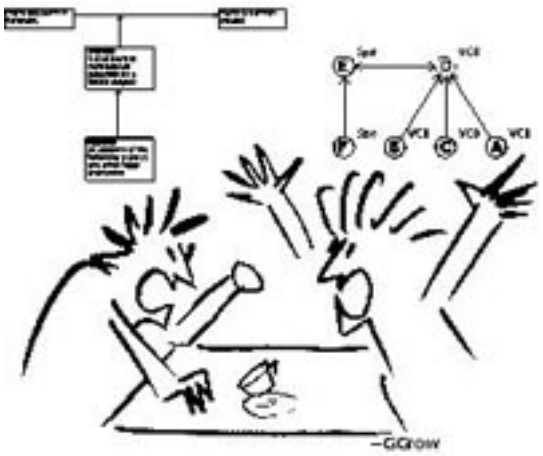
- Subsumption checking: is HeartDisease a kind of VascularDisease?
- 1 justification: {ax1,ax2,ax3}

Schema & data reasoning

- Instance checking: John suffersFrom VaascularDisease?
- 1 justification: {ax1,ax2,ax3,ax4}

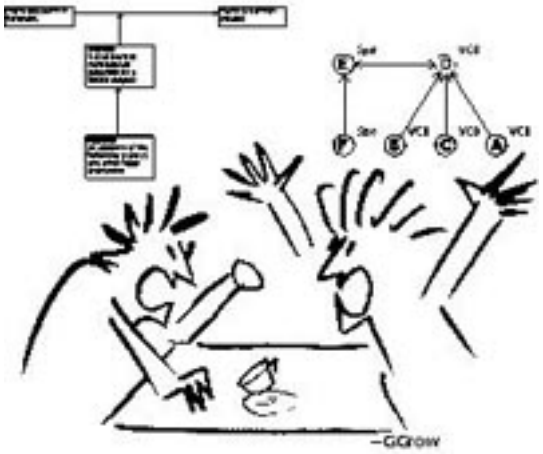
Ontology based Argumentation

- Informally, an argument is
  - a set of axioms
  - that can be used to prove some claim
- Given an ontology O, an argument is a pair <J, ax>
  - J is a justification of ax (w.r.t. O)
  - <J, ax> is called an argument of ax



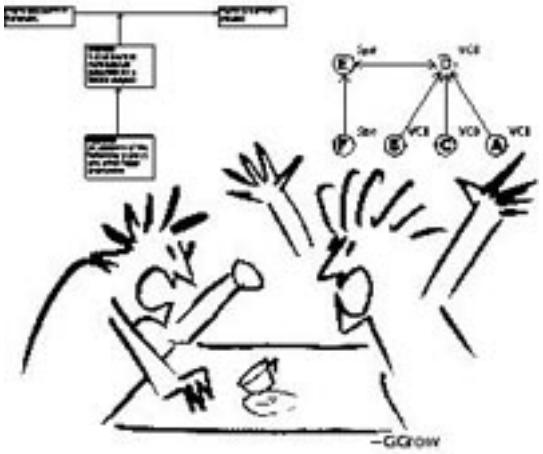
Ontology based Argumentation

- Ontology space OS
  - a set of ontologies O1, …, On
  - for agents A1, …, An
- Given two arguments <J1,ax1> (from O1) and <J2,ax2> (from O2)
  - <J1,ax1> is an undercut for <j2,ax2>
  - iff {ax1} U J2 is inconsistent or incoherent
- Example
  - <{A ⊑ B, B ⊑ C}, A ⊑ C>
  - <{A ⊑ ¬C}, A ⊑ ¬C >
  - undercut each other



Defeated and Undefeated

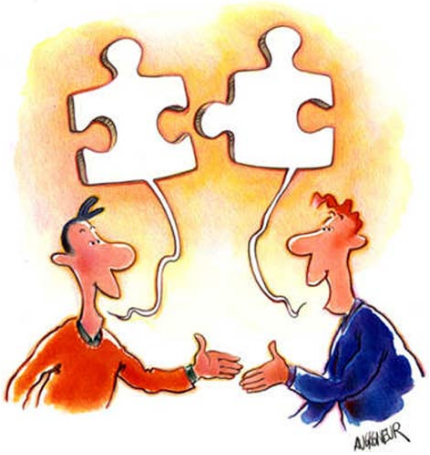
- Any argument with no undercuts is **undefeated**
- An argument is **undefeated**
  - if all the undercuts for it are defeated



- An argument is **defeated**
  - if there is a undercut to it that is undefeated.

Dialogical Argumentation

- A dialogue is a sequence of moves
- A move is a tuple of the form:
  - <ag, query, ax>: start a dialogue
  - <ag, posit, <J,ax>>: assert an argument for ax
  - <ag, concede, ax>: assert that ax is valid
  - <ag, close, ax>: made when no other moves possible



Elizabeth Black, Anthony Hunter and Jeff Z. Pan. **An Argument-based Approach to Using Multiple Ontologies**. In *Proc. of the 3rd International Conference on Scalable Uncertainty Management (SUM 2009)*. 2009.

Example: Dialogical Argumentation

- O1 = {¬D(a), D ⊑ A, A ⊑ ¬C}
- O2 = {D(a), D ⊑ C, D ⊑ E, E ⊑ ¬A}

$\langle 1, \textsf{query}, C(a) \rangle$

$\langle 2, \textsf{posit}, \langle \{D(a), D \sqsubseteq C\}, C(a) \rangle \rangle$

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$$\langle 1, \text{posit}, \langle \{D \sqsubseteq A, A \sqsubseteq \neg C\}, D \sqsubseteq \neg C\rangle\rangle$$

$$\langle \{D(a), D \sqsubseteq C\}, C(a)\rangle$$
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$$\langle \{D(a), D \sqsubseteq C\}, C(a)\rangle$$
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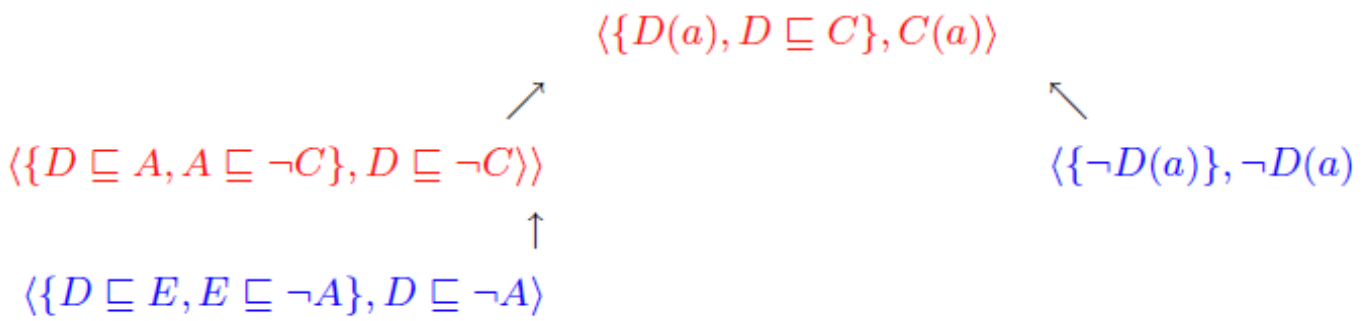
$\langle 1, \text{posit}, \langle\{\neg D(a)\}, \neg D(a)\rangle\rangle$



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$\langle 1, \text{posit}, \langle\{\neg D(a)\}, \neg D(a)\rangle\rangle$

$\langle 2, \text{close}, C(a)\rangle$

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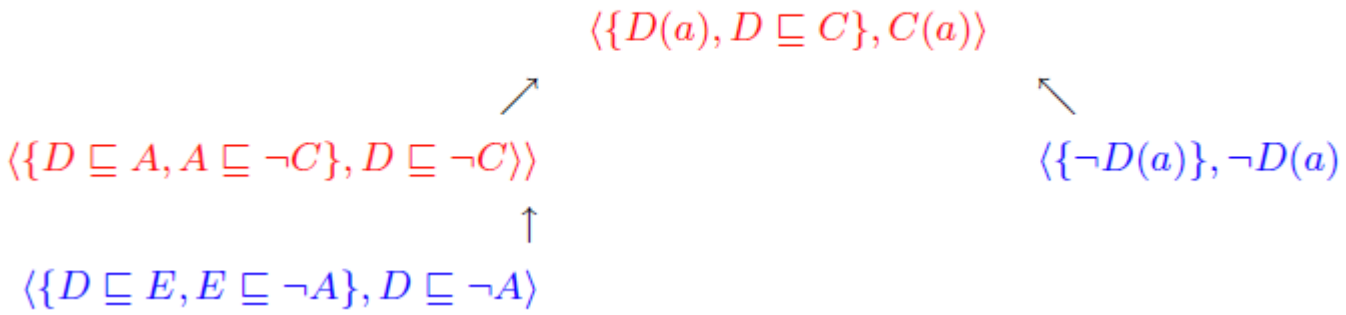

Conclusion

- Ontology based agreement management
  - help identify disagreement
  - support argumentation (such as dialogical argumentation)
  - check the consequence of the agreement by reasoning
- Scalable reasoning services required
  - Justification highly related to argument
  - TrOWL: Tractable OWL2 reasoning infrastructure (http://trowl.eu)

Elizabeth Black, Anthony Hunter and Jeff Z. Pan. **An Argument-based Approach to Using Multiple Ontologies**. In *Proc. of the 3rd International Conference on Scalable Uncertainty Management (SUM 2009)*. 2009.

Joey Lam, Jeff Z. Pan, Derek Sleeman and Wamberto Vasconcelos. **A Fine-Grained Approach to Resolving Unsatisfiable Ontologies**. In *Proc. of the 2006 IEEE/WIC/ACM International Conference on Web Intelligence (WI-2006)*, 428 - 434. 2006. (**Best Paper Award**)

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Thank you!

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TrOWL: http://trowl.eu/