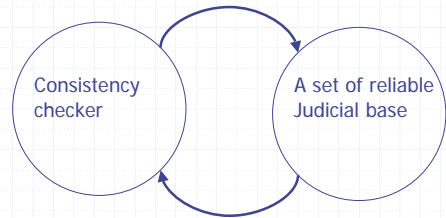


Inference from paraconsistent legal knowledge

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JAIST

For safe e-society



Inconsistency checker

- ◆ Influence on code change, revision, or update
- ◆ Necessity of logical consistency

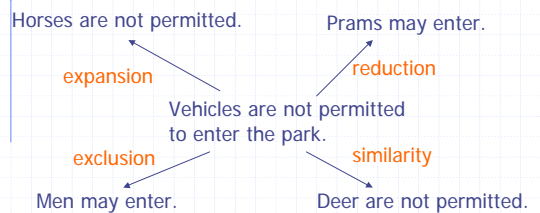
Legal reasoning, thus far

- ◆ Expert system based on First-order logic
- ◆ Rule-based reasoning
- ◆ Case-based reasoning
- ◆ Defeasible reasoning by multi-agents
- ◆ Similarity
- ◆ Event and temporal reasoning
- ◆ ...

Ex1: negative connective (\neg)

- ◆ 'Self-defence is tolerable.'
 $\forall x[act(x) \wedge selfdefence(x) \rightarrow tolerable(x)]$
- ◆ 'Self-defence would not be punished.'
 $\forall x[act(x) \wedge selfdefence(x) \rightarrow \neg crime(x)]$

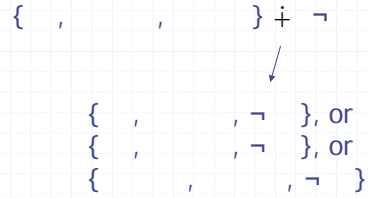
Ex2: revision



Nonmonotonic reasoning

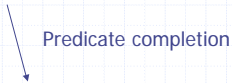
- ◆ Belief revision
 - expansion
 - revision
 - contraction
- ◆ Default logic
- ◆ Circumscription

Belief revision



Circumscription

$$\{ r(a), p(x) \rightarrow r(x), q(x) \rightarrow r(x) \}$$



$$r(x) \rightarrow p(x) \vee q(x) \vee (x = a)$$

'Vehicles are not permitted, exclusive of small and ones.'

$$vehicle(x) \rightarrow \neg permitted(x).$$

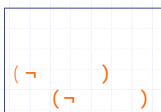
$$vehicle(x) \wedge light(x) \rightarrow permitted(x).$$

circumscription

$$permitted(x) \rightarrow \neg vehicle(x) \vee (vehicle(x) \wedge light(x))$$

Logic with paraconsistency

- ◆ Multiple concepts of negation
- ◆ Reasoning from an inconsistent knowledge
- ◆ Prover with paraconsistent logic



: vehicle
 : permitted
 : pram
 : light

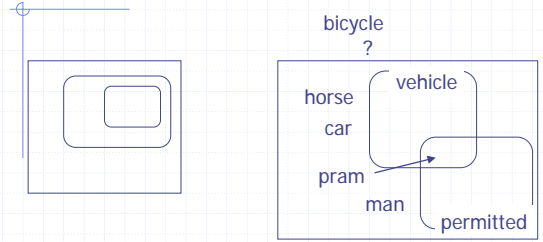
Minimal negation

Graded negation

$$\Delta \vdash \neg_{\varphi} \psi \text{ iff } \Delta \vdash \varphi \text{ and } \varphi \wedge \psi \vdash \perp$$

Minimal negation $\Delta \vdash \ominus_{\varphi} \chi$

$$\Delta \vdash \neg_{\varphi} \chi, \text{ and for any } \psi, \text{ if } \Delta \vdash \neg_{\psi} \chi \text{ and } \vdash \varphi \rightarrow \psi \text{ then } \psi \rightarrow \varphi$$



Maximal toleration

$$\Delta \vdash \circ_{\varphi} \psi \text{ iff } \Delta \vdash \varphi \text{ and } \varphi \wedge \psi \not\vdash \perp$$

Maximal toleration $\Delta \vdash \oplus_{\varphi} \chi$

$$\Delta \vdash \circ_{\varphi} \chi, \text{ and for all } \psi, \text{ if } \Delta \vdash \circ_{\psi} \chi \text{ and}$$

$$\vdash \psi \rightarrow \varphi \text{ then } \varphi \rightarrow \psi$$

In multiple MC(),

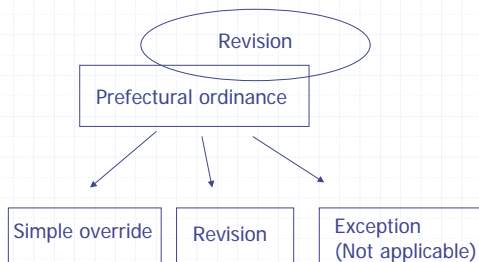
Absolute reject: for all,

$$\Delta^* \in MC(\Delta), \Delta^* \cup \{\chi\} \vdash \perp,$$

Possibly reject: there exists

$$\Delta^* \in MC(\Delta) \text{ that } \Delta^* \cup \{\chi\} \not\vdash \perp.$$

Ex3. Code revision



Summary

We admit:

- ◆ Multiple negations, and
- ◆ Knowledge-base may be inconsistent

But,

- ◆ Minimal negation,
- ◆ Maximal toleration, and
- ◆ Prover.