

MAPPING THE HUMAN BODY

Buffalo, NY

April 17, 2005

The Body Region Connection Calculus *Analyzing anatomical ontologies with the RCC-8 model*



Songmao Zhang
Olivier Bodenreider

Lister Hill National Center
for Biomedical Communications
Bethesda, Maryland - USA

Outline

- ◆ Objectives
- ◆ RCC8
- ◆ Anatomical relations in the FMA
- ◆ Mapping anatomical relations to FMA
- ◆ Results
- ◆ Discussion
- ◆ Conclusions



Objectives

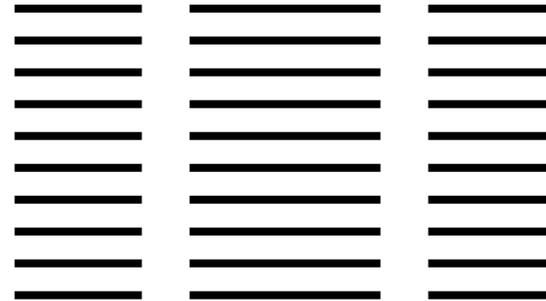
- ◆ To investigate consistency in the FMA
- ◆ Complementary to ontological analyses such as:
 - Zhang S, Bodenreider O.
Law and order: Assessing and enforcing compliance with ontological modeling principles.
Computers in Biology and Medicine 2005:(in press).
- ◆ Focus on anatomical relations
 - Assigned manually
 - Little enforcement possible in Protégé



General idea Overview



Anatomical relations

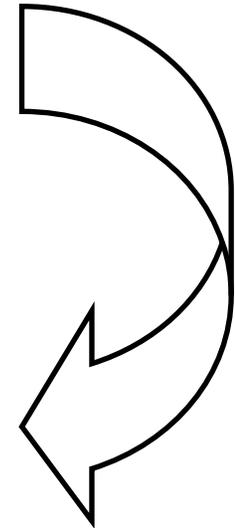


RCC-8 relations

RCC-8
consistency?

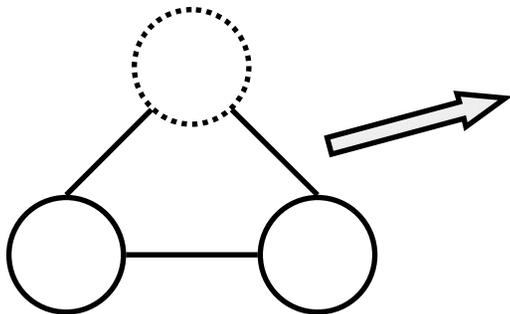
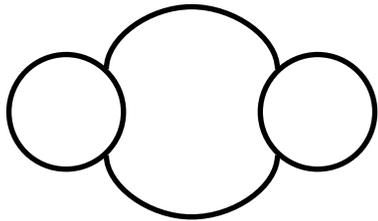
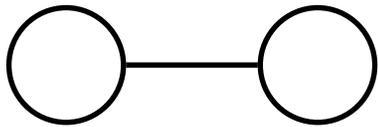


	DC	EC	PO	TPP	NT PP	TP Pi	NT TPi	EQ
DC	*	*	*	*	*	*	*	*
EC	*	*	*	*	*	*	*	*
PO	*	*	*	*	*	*	*	*
TPP	*	*	*	*	*	*	*	*
NTPP	*	*	*	*	*	*	*	*
TPPi	*	*	*	*	*	*	*	*
NTPPi	*	*	*	*	*	*	*	*
EQ	*	*	*	*	*	*	*	*

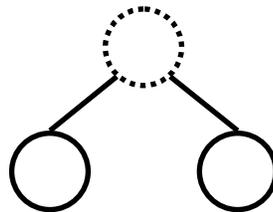
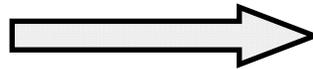
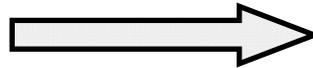


General idea Details

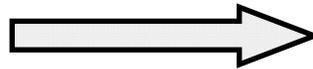
FMA



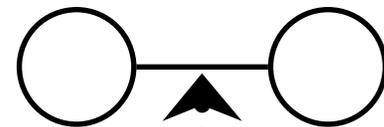
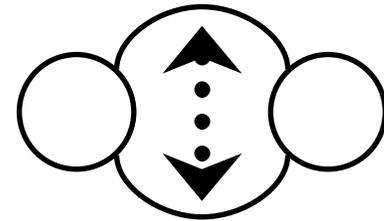
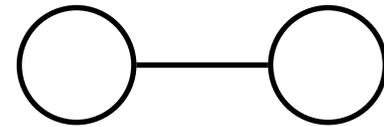
FMA-RCC
conversion rules



Entity	EC	PC	TOP	RTOP	RTOP	RTOP	RTOP	RTOP
EC	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
PC	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
TOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000



RCC



Foundational Model of Anatomy

- ◆ Dec. 2, 2004
- ◆ 71,202 classes
- ◆ 220 slots
 - 7 *part_of* slots
 - 81 slots for associative relations (*branch of, contains*)
- ◆ 101,200 partitive relations
- ◆ 33,685 associative relations

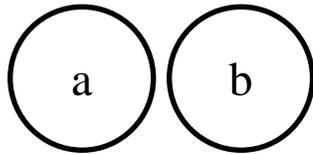


Region Connection Calculus (RCC)

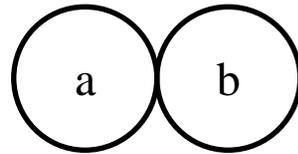
- ◆ Axiomatic theory of spatial relations
- ◆ Spatial reasoning
- ◆ 8 topological relations (JEPD)
 - DC Disconnection
 - EC External Connection
 - PO Partial Overlap
 - TPP Tangential Proper Part (+ inverse)
 - NTPP Non-Tangential Proper Part (+ inverse)
 - EQ Equality



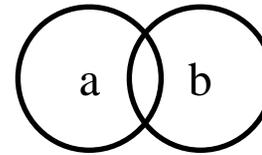
RCC 8 topological relations



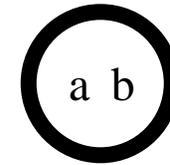
Disconnection



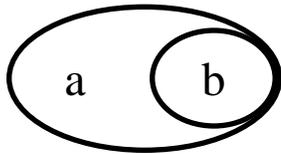
External
Connection



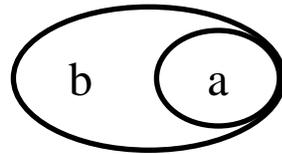
Partial
Overlap



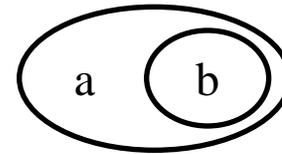
Equality



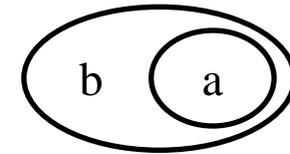
Tangential
Proper Part



Tangential
Proper Part (inv)



Non-Tangential
Proper Part



Non-Tangential
Proper Part (inv)

Composition table for the 8 RCC relations

$R1(a,b) \backslash R2(b,c)$	DC	EC	PO	TPP	NTPP	TPPi	NTPPi	EQ
DC	\top	DR,PO,PP	DR,PO,PP	DR,PO,PP	DR,PO,PP	DC	DC	DC
EC	DR,PO,PPi	DR,PO TPP,TPi	DR,PO,PP	EC,PO,PP	PO,PP	DR	DC	EC
PO	DR,PO,PPi	DR,PO,PPi	\top	PO,PP	PO,PP	DR,PO,PPi	DR,PO PPi	PO
TPP	DC	DR	DR,PO,PP	PP	NTPP	DR,PO TPP,TPi	DR,PO PPi	TPP
NTPP	DC	DC	DR,PO,PP	NTPP	NTPP	DR,PO,PP	\top	NTPP
TPPi	DR,PO,PPi	EC,PO,PPi	PO,PPi	PO,TPP,TPi	PO,PP	PPi	NTPPi	TPPi
NTPPi	DR,PO,PPi	PO,PPi	PO,PPi	PO,PPi	O	NTPPi	NTPPi	NTPPi
EQ	DC	EC	PO	TPP	NTPP	TPPi	NTPPi	EQ

[Bennett, 1997]



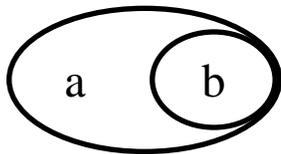
Mapping FMA relations to RCC (1)

part of
general part of
constitutional part of
systemic part of
clinical part of
regional part of
2D part of
custom paratomy of

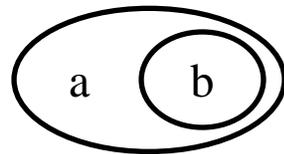
TPP \vee NTPP

part
general part
constitutional part
systemic part
clinical part
regional part
2D part
custom paratomy

TPPi \vee NTPPi



Tangential
Proper Part



Non-Tangential
Proper Part

attributed part
attributed constitutional part
attributed regional part

TPPi \vee NTPPi

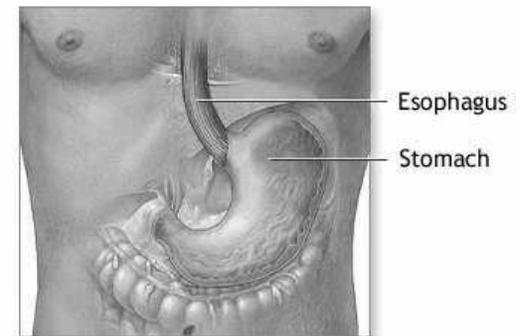
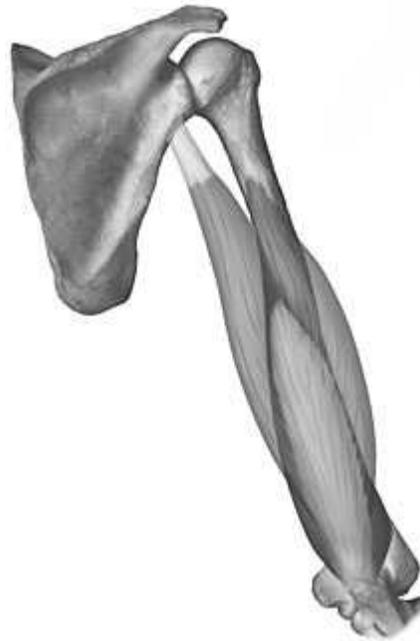
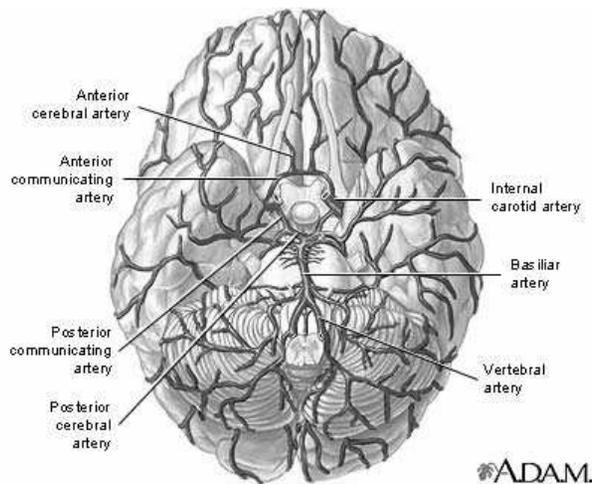


Mapping FMA relations to RCC (2)

adjacent to
continuous with
continuous with proximally
continuous with distally
branch of
branch
tributary of
tributary

muscle origin
muscle insertion
muscle attachment
location+adjacent(true)
attributed continuous with+adjacent(true)

EC



Mapping FMA relations to RCC (3)

drains
drains to
venous drainage of
venous drainage
lymphatic drainage of
lymphatic drainage

DC \vee EC

EC Lung | venous drainage | Bronchial vein

DC Right paratracheal lymph node | drains to |
Right bronchomediastinal lymphatic trunk

bounded by
bounds

EQ

EQ Surface of thorax | bounds | Thorax

surrounded by
surrounds

EC \vee EQ

EQ Pleural sac | surrounds | Lung

EC Wall of right side of heart | surrounds |
Cavity of right atrium



Mapping FMA relations to RCC (4)

arterial supply of
venous supply of
nerve supply of } DC ∨ PO ∨
TPP ∨ NTPP

arterial supply
venous supply
nerve supply } DC ∨ PO ∨
TPPi ∨ NTPPi

TPP Right coronary artery | arterial supply of | Heart

DC Gastric branch of right vagus nerve | nerve supply of | Stomach

DC Spinal cord | arterial supply | Vertebral artery

DC / PO
vs. EC ??

contains PO ∨ TPPi ∨ NTPPi ∨ EQ

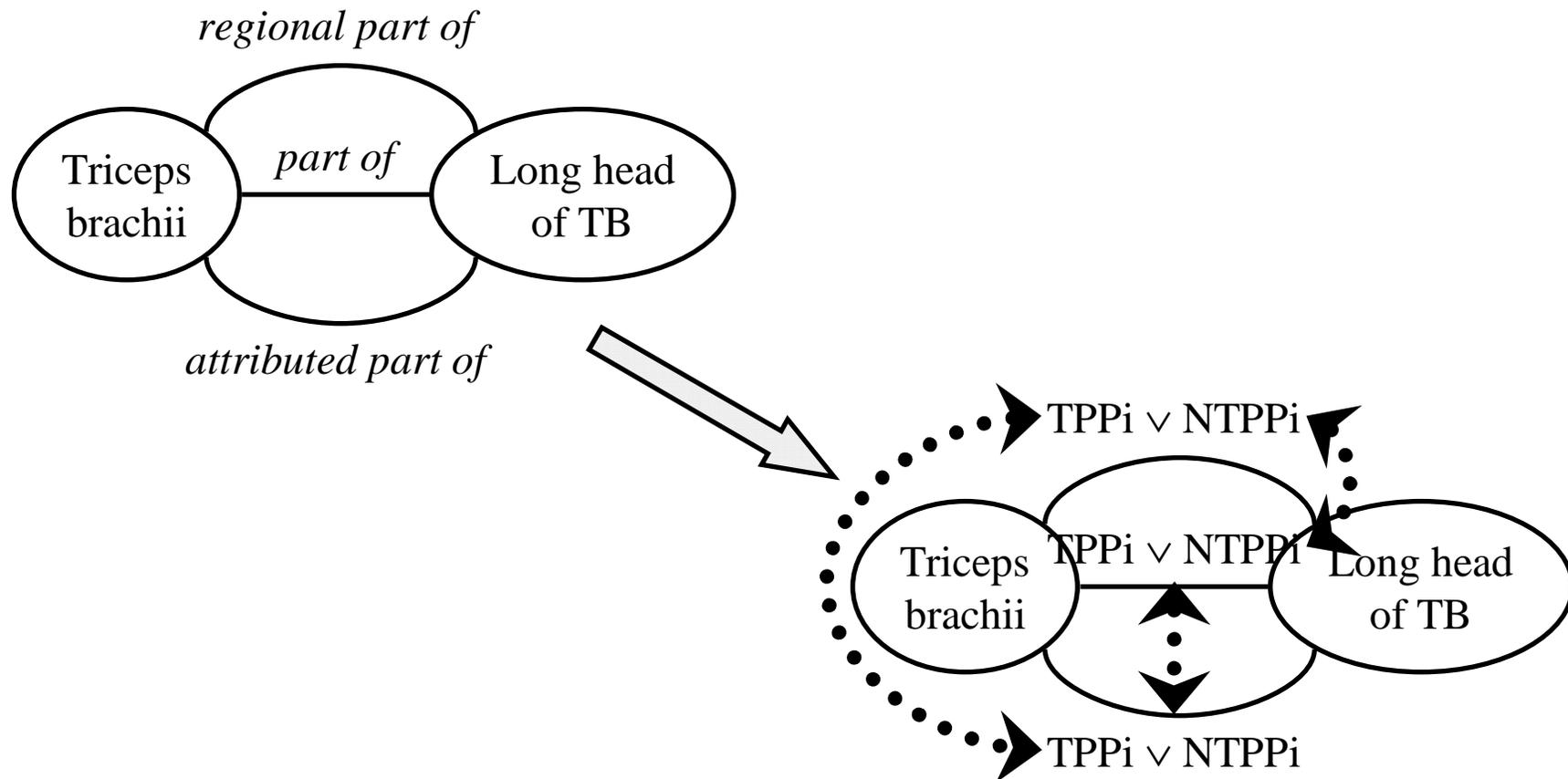
contained in PO ∨ TPP ∨ NTPP ∨ EQ

TPP Posterior compartment of arm|contains|Triceps brachii

location+adjacent(false)
attributed continuous with+adjacent(false) } DC

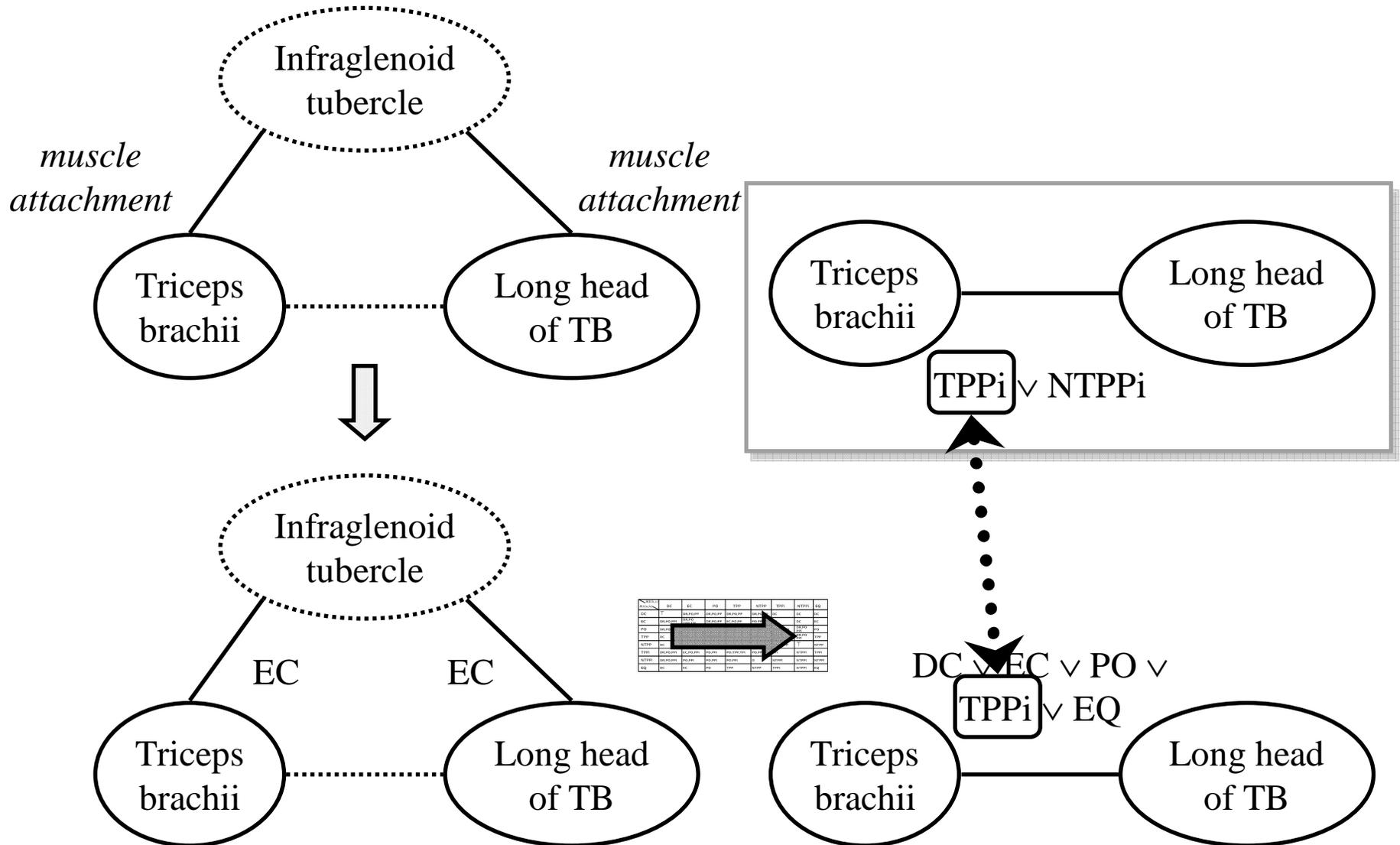


Example (direct)



Example (indirect)

$R2(b,c)$ \ $R1(a,b)$	DC	EC
DC	\top	DR,PO,PP
EC	DR,PO,PPi	DR,PO TPP,TPi



Quantitative results

◆ Conversion

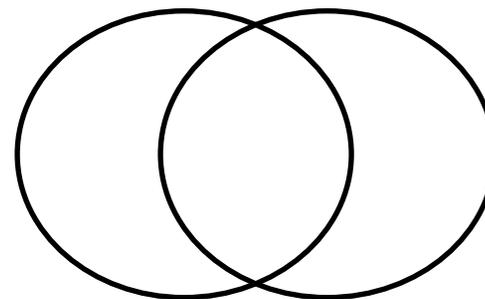
- 84,284 pairs with RCC relations
 - 18,112 with only one relation
 - 66,172 with multiple relations
 - 64,354 consistent
 - 1,818 inconsistent

◆ Composition

- 707,284 pairs

composition

698,588



conversion

75,588

8,696



Quantitative results

◆ Composition

- 698,588 pairs specific to composition
 - 28,042 with only one relation
 - 670,546 with multiple relations
 - 669,026 consistent
 - 1,520 inconsistent

◆ Inconsistent

- Conflicting relations
- Inaccurate conversion rules



Example of inconsistency

Surface of brain bounds Brain
Surface of brain bounds Forebrain
Forebrain regional part of Brain

EQ
EQ
TPP \vee NTPP

EQ
TPP \vee NTPP

EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ

TPP \vee NTPP

$$(TPP \vee NTPP) \wedge EQ = \perp$$

*bounded by
bounds*

} EQ ?



Advantages

- ◆ Supports consistency analysis of spatial relations
- ◆ Almost fully automatic
 - Except for establishing the mapping between FMA and RCC relations
 - Analysis requires domain knowledge



Limitations

- ◆ Loss in expressiveness
 - Different FMA relations are converted into the same RCC relation
(e.g., *continuous with* and *adjacent to* into EC)
- ◆ Interpretation
 - Inconsistent is not necessarily wrong
 - Consistent is not necessarily valid
- ◆ Granularity issues
- ◆ Issue with shared parts



Conclusions

- ◆ RCC relations
 - Less expressive than FMA relations
 - Enable reasoning
 - Useful for detecting inconsistency
- ◆ Disjunctions can be reduced by comparing direct relations to composed relations
- ◆ Usage in FMA
 - Detect potentially inconsistent representation
 - Focus the effort of experts
- ◆ Refine conversion rules



References

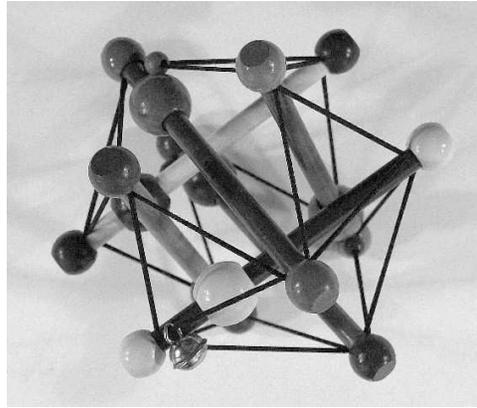
- ◆ D A Randell, Z Cui, and A G Cohn. *A spatial logic based on regions and connection*. In Proc. 3rd Int. Conf. on Knowledge Representation and Reasoning, pages 165--176, San Mateo, 1992. Morgan Kaufmann
- ◆ B. Bennett. *Spatial reasoning with propositional logics*. In J Doyle, E Sandewall, and P Torasso, editors, *Principles of Knowledge Representation and Reasoning: Proceedings of the 4th International Conference (KR94)*, San Francisco, CA., 1994. Morgan Kaufmann



References

- ◆ Bennett, B. (1998). *Determining consistency of topological relations*. *Constraints*, 3, 213--225.
- ◆ Schulz S, Hahn U, Romacker M. *Modeling anatomical spatial relations with description logics*. *Proc AMIA Symp.* 2000;:779-83.





Medical Ontology Research

Contact: olivier@nlm.nih.gov

Web: mor.nlm.nih.gov



Olivier Bodenreider

Lister Hill National Center
for Biomedical Communications
Bethesda, Maryland - USA