Department of PHILOSOPHY

University at Buffalo
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MAPPING THE HUMAN BODY

Buffalo, NY

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The Body Region Connection Calculus

Analyzing anatomical ontologies with the RCC-8 model

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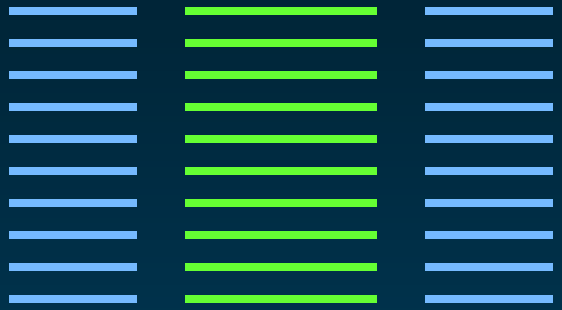
Outline

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

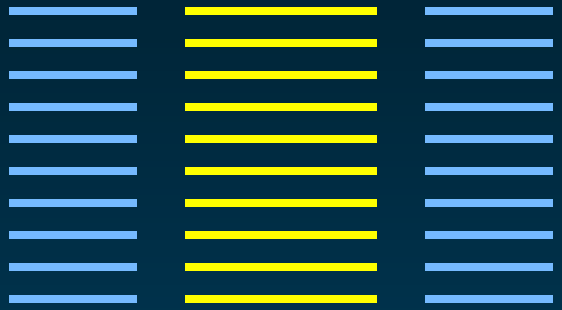
Objectives

- 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

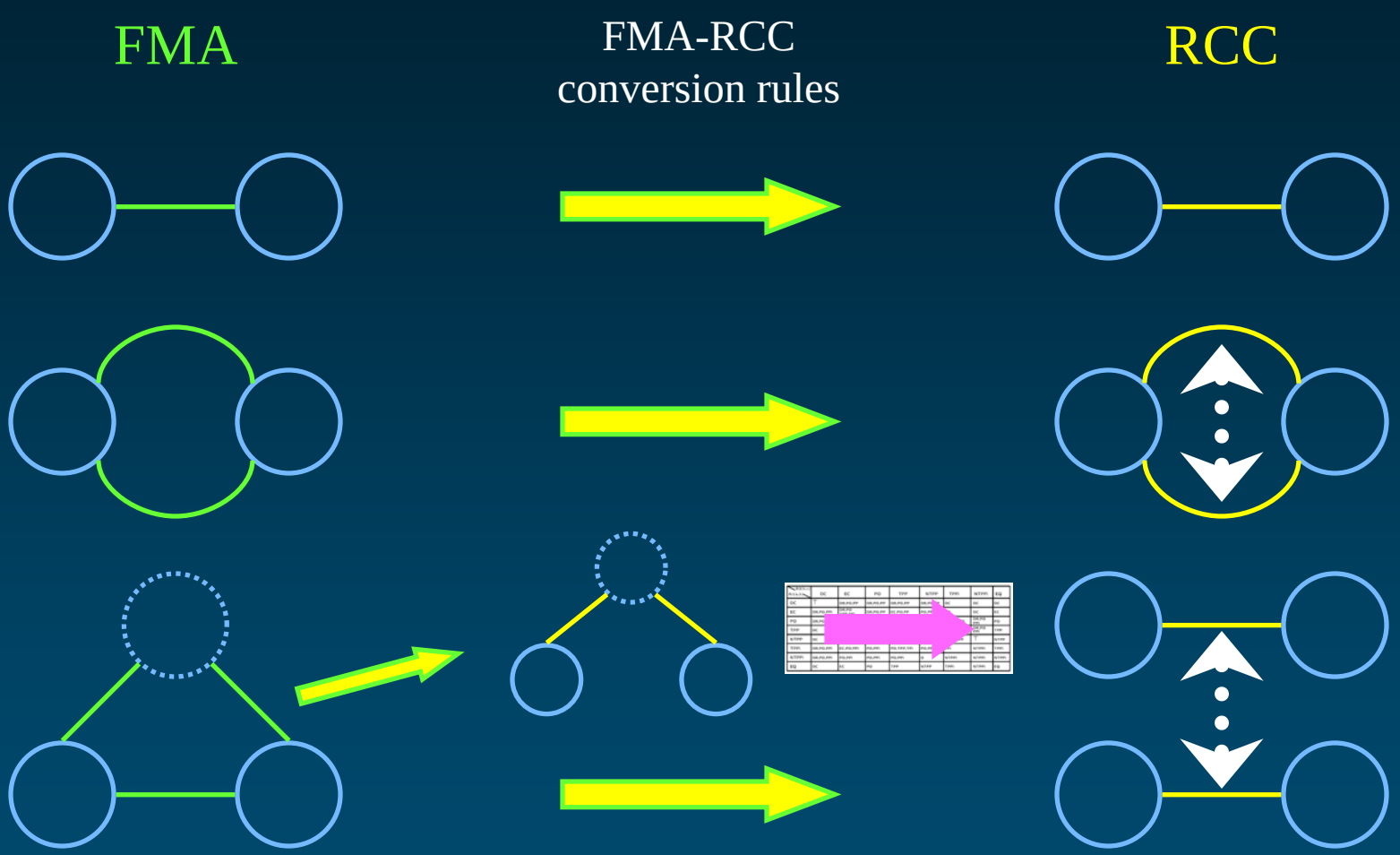


RCC-8 relations

RCC-8 consistency?

	DC	EC	PO	TPP	NTPP	TPPi	NTPPi	EQ
DC	*	*	*	*	*	*	*	*
EC	*	*	*	*	*	*	*	*
PO	*	*	*	*	*	*	*	*
TPP	*	*	*	*	*	*	*	*
NTPP	*	*	*	*	*	*	*	*
TPPi	*	*	*	*	*	*	*	*
NTPPi	*	*	*	*	*	*	*	*
EQ	*	*	*	*	*	*	*	*

General idea Details



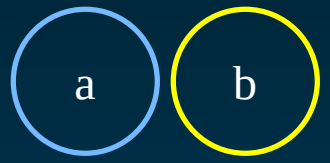
Foundational Model of Anatomy

- 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

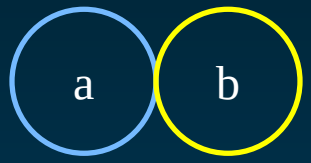
Region Connection Calculus (RCC)

- 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

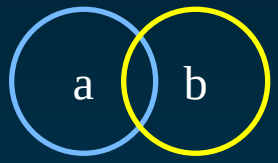
RCC 8 topological relations



Disconnection

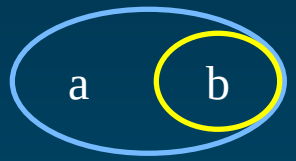


External Connection

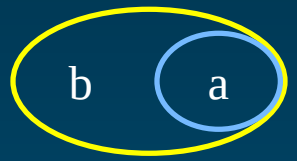


Partial Overlap

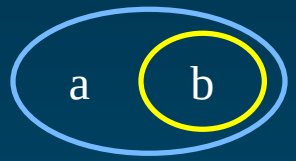
Equality



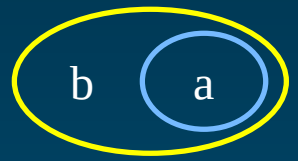
Tangential Proper Part



Tangential Proper Part (inv)



Non-Tangential Proper Part



Non-Tangential Proper Part (inv)

Composition table for the 8 RCC relations

R1(a,b) \ R2(b,c)	DC	EC	PO	TPP	NTPP	TPPi	NTPPi	EQ
DC	⊤	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	⊤	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	⊤	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]

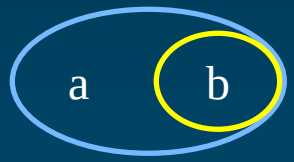
Mapping FMA relations to RCC (1)

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

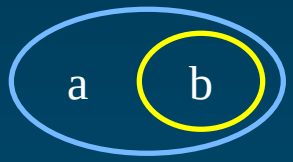
$\text{TPP} \vee \text{NTPP}$

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

$\text{TPPi} \vee \text{NTPPi}$



Tangential
Proper Part



Non-Tangential
Proper Part

attributed part
attributed constitutional part
attributed regional part

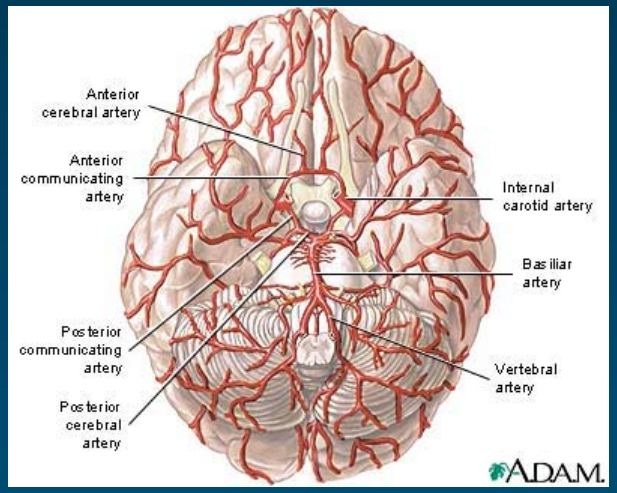
$\text{TPPi} \vee \text{NTPPi}$

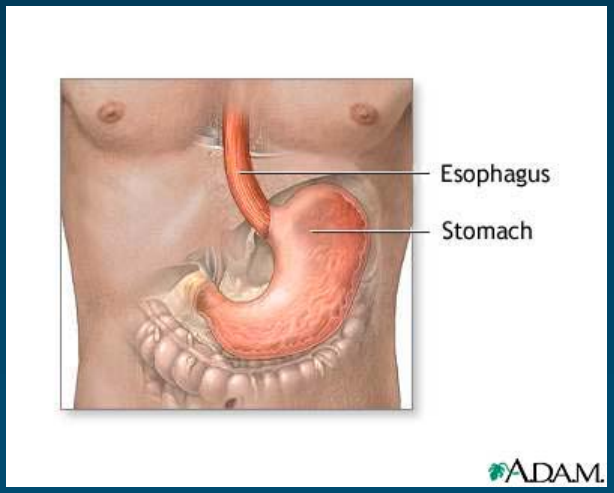
Mapping FMA relations to RCC (2)

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





http://www.rad.washington.edu/atlas/tricepsbrachii.html

Mapping FMA relations to RCC (3)

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

DC ∨ 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 ∨ 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

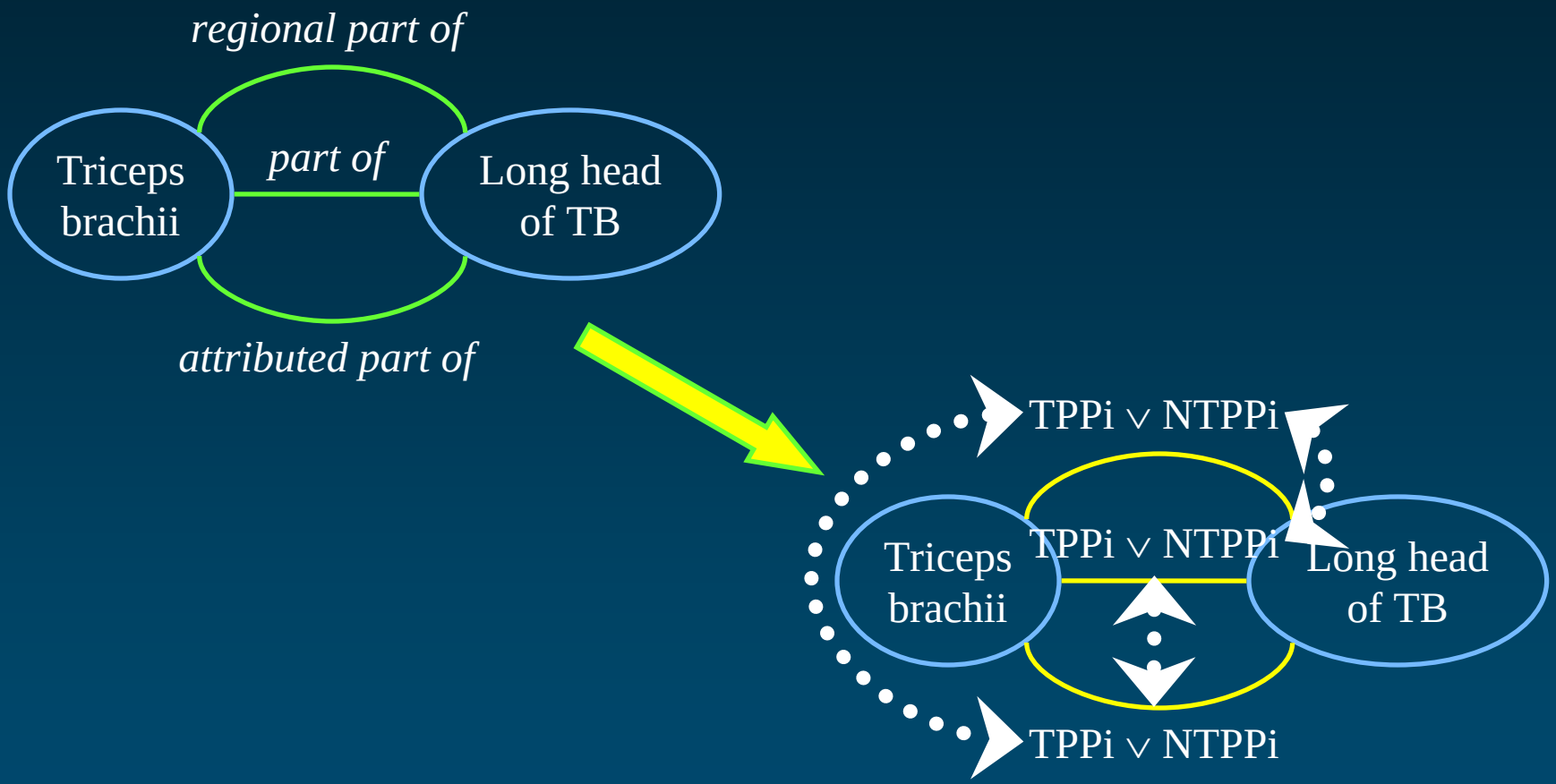
DC / PO vs. EC ??

contains PO ∨ TPPi ∨ NTPPi ∨ EQ *contained in* PO ∨ TPP ∨ NTPP ∨ EQ

TPP Posterior compartment of arm|contains|Triceps brachii

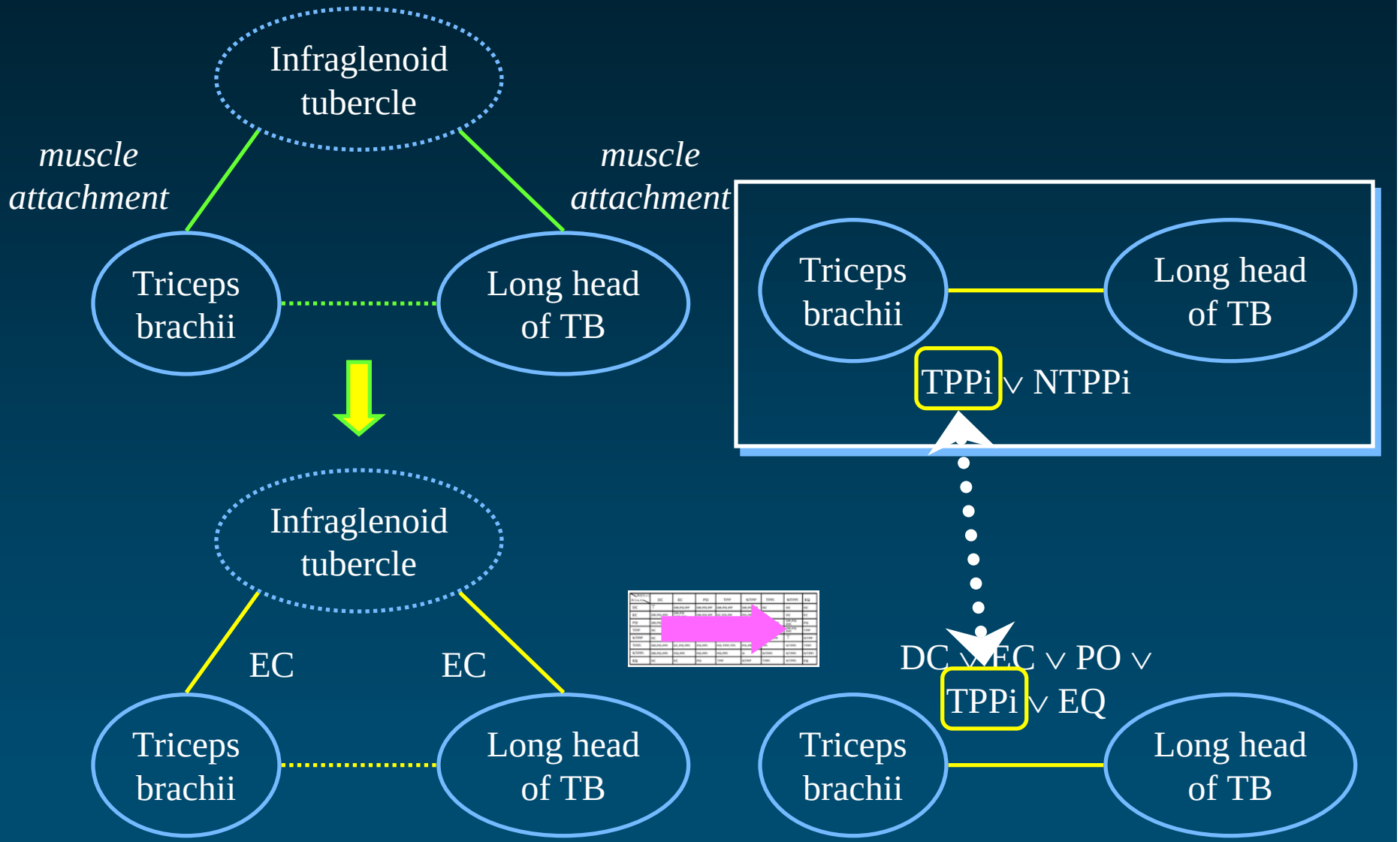
location+adjacent(false)
attributed continuous with+adjacent(false)
] DC

Example (direct)



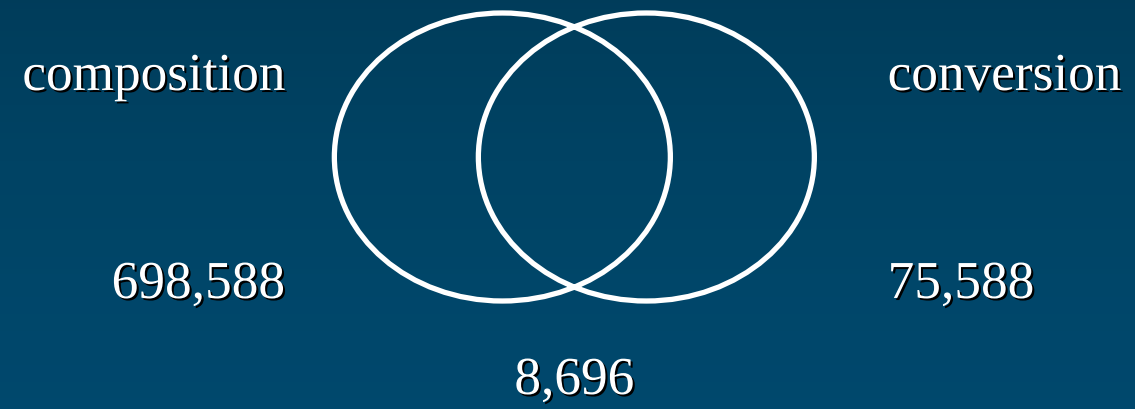
Example (indirect)

R1(a,b) \ R2(b,c)	DC	EC
DC	⊤	DR,PO,PP
EC	DR,PO,PPi	



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



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 NTPP

EQ

TPP NTPP

TPP NTPP

(TPP NTPP) ∧ EQ = ⊥

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

Shared part issue

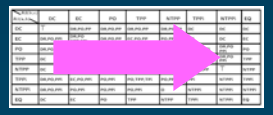
Esophagogastric junction | regional part of | Abdominal part of esophagus — TPP NTPP
Abdominal part of esophagus | regional part of | Esophagus — TPP NTPP

Esophagogastric junction | part of | Stomach — TPP NTPP
Stomach | continuous with | Esophagus — EC

TPP NTPP
TPP NTPP

TPP NTPP

TPP NTPP
EC



DC EC

(TPP NTPP) ∧ (DC EC) = ⊥

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

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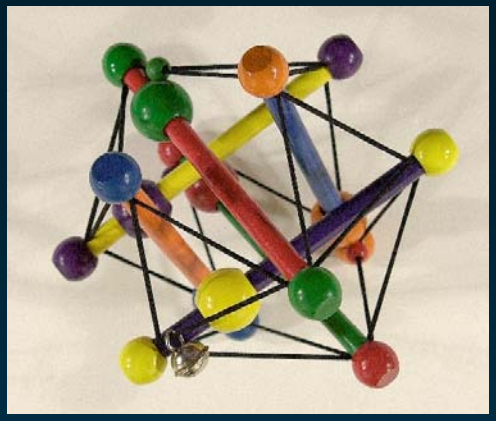

Medical Ontology Research

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