Knowledge Representation for Digital Brain Atlases

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1. Biomedical information systems
2. What’s a digital brain atlas (for)?
3. What can ontologies do for digital brain atlases?
4. Example and Application
Biomedical Information Systems

- Structured representation of biological systems
- Adequate visual presentation
  → imagine “Google Drosophila”

Long-term Goal:
Presentation of ALL spatio-temporal referenced information, relations, and functions in their spatio-temporal context
3D atlases serve as spatial reference systems. Data from different experiments and imaging techniques can be related to each other.

Analysis support of morphology, function, and genetic factors.

Standard atlas of the fruitfly brain, courtesy of Rein et al. 2002.
Anatomical Digital Atlases in Biomedicine

• **Generation** (Example: Honeybee brain)
  – Image acquisition and preprocessing of individual brains
  – Segmentation of structures
  – Averaging
  – Surface reconstruction
  – Integration of new structures

Confocal laser scanning microscopy of a bee brain

Segmentation of structures

Registration and averaging of individual data sets

Surface extraction
Anatomical Digital Atlases in Biomedicine

• **Generation** (Example: Honeybee brain)
  – Image acquisition and preprocessing of individual brains
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*Standard atlas of a honeybee’s brain: 22 neuropils and 3 neuron types*
Anatomical Digital Atlases in Biomedicine

• Problems
  – Atlas exploration usually requires knowledge about atlas generation or the data contained in the atlas
  – Knowledge about the structures’ functions is not represented
  – Visualization generation is expensive and not intuitive

→ Integration and usage of ontologies for
  - Data structuring
  - Intuitive exploration
  - Effective visualization generation
Ontologies and Digital Brain Atlases

• Digital atlas generation concentrates on modeling neural structures of mammals and invertebrates

• Ideal brain ontology [Bota2008]
  – Complete set of structural parts
  – Complete set of nerve types
  – Projections between regions and nerve types
  – Type specific
Example – Honeybee Standard Brain

• Data:
  – Confocal microscopy image data with structure staining
  – Surface-based standard atlas (geometries)
  – 200 neuropils, 50 neurons of different types
Example – Honeybee Standard Brain

• Ontology:
  – Usage of the Foundational Model of Anatomy (FMA)
  – About 100 classes, 600 instances, 1500 edges of 15 types
  – Geometries separated according to the ontology and linked via IDs
• Visualization Requirements:
  – Support the understanding of hierarchical organization of structures and their spatial and functional relations
  – Intuitive user interface
  – Knowledge integration

• Our approach:
  – Automatic creation of intuitive focus+context visualizations with a specific level-of-detail strategy for hierarchical structures
  – Knowledge is formalized in the ontology and in predefined queries
Ontology-Based Visualization Scheme

1. Definition of queries and according relations
2. Automatic query-based visualization generation
   1. Query evaluation
   2. Creation of visualization parameters
Query Definition

• Description of visualization for certain scenarios
• Derivation of more abstract concepts such as „Overview“
• Selection of structures important for the query
• Mapping of the query to relations

<table>
<thead>
<tr>
<th>Query</th>
<th>Desired Visualization</th>
<th>Relevant Structures</th>
<th>Important Relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuropil Overview</td>
<td>Where can the neuropils and its substructures be found?</td>
<td>Spatial context</td>
<td>hasPart, adjacentTo</td>
</tr>
<tr>
<td>Neuron Path</td>
<td>Show the neuron together with its tract and input and output regions in a spatial context.</td>
<td>Input Region, Tract, Output region, Spatial Context</td>
<td>hasInput, hasTract, hasAxonTerminations, adjacentTo</td>
</tr>
</tbody>
</table>
1. User selects a structure and a query, example: Path of neuron X
Query-Dependent Generation of Visualization

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2. Determination of the focus set [Kuß08]
Query-Dependent Generation of Visualization

1. User selects a structure and a query, example: Path of neuron X
2. Determination of the focus set [Kuß08]
3. Definition of the context [Hartmann 2002]
4. Mapping to visualization parameters [Kuß08]
• Path of a neuron
Conclusion and Future Work

- 3D digital atlases are useful
- Ontologies can enhance 3d digital atlases

- Improve bee brain ontology
  - Extend neuron types and neuron relations
  - Make it somewhat more “OBO-ready”
- Find subsequent project
Thanks for your attention!

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