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The Neural ElectroMagnetic Ontology (NEMO) System:

Design & Implementation of a Sharable EEG/MEG Database with ERP ontologies

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OBJECTIVE

We present the "*Neural ElectroMagnetic Ontology*" (NEMO) system, designed for representation, storage, mining, and dissemination of brain electromagnetic (EEG and MEG) data. Scalp EEG and MEG recordings are well-established, noninvasive techniques for research on human brain function. To exploit their full potential, however, it will be necessary to address some long-standing challenges in conducting large-scale comparison and integration of results across experiments and laboratories (cf. Ref. [1]) . One challenge is to develop standardized methods for ***measure generation*** — that is, methods for identication and labelling of "components" (patterns of interest). Despite general agreement on criteria for component identication, in practice, such patterns can be hard to identify, and there is considerable variability in techniques for measure generation across laboratories. NEMO will address this issue by providing integrated ***spatial and temporal ontology-based databases*** that can be used for large-scale data representation, mining and meta-analyses. The present paper outlines our system design and presents some initial results from our efforts to define a unified ontology for representation of spatiotemporal patterns ("components") in averaged EEG/MEG data (event-related potentials, or ERPs).

DATA REPRESENTATION

- Multiple ***representational spaces***
  - Scalp topographic space (Fig 1A)
  - Latent factor space (Fig. 1B-C)

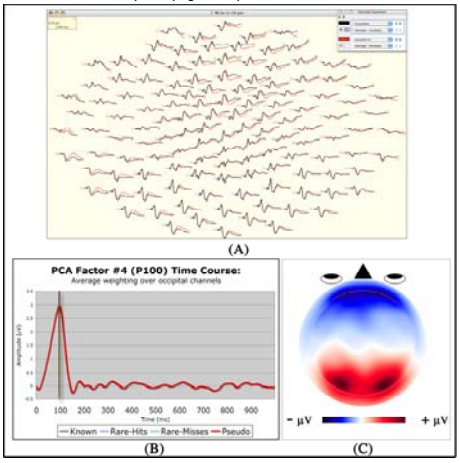


Figure 1. A. 128-channel ERP data showing brain electrical response to word and nonword stimuli. B. Latent temporal (PCA) representation of classical "P100" potential. C. Scalp topography for P100 potential shown in B.

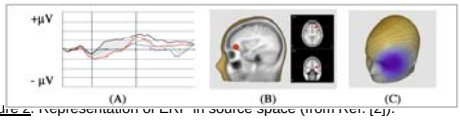


Figure 2. Representation of ERP in source space (from Ref. [2]).

EEG/MEG & ERP MEASURE GENERATION

Net Station software architecture is being augmented to include tools for ***automatic measure generation*** (Fig. 3).

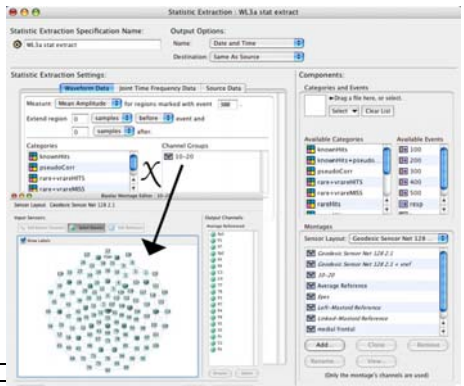
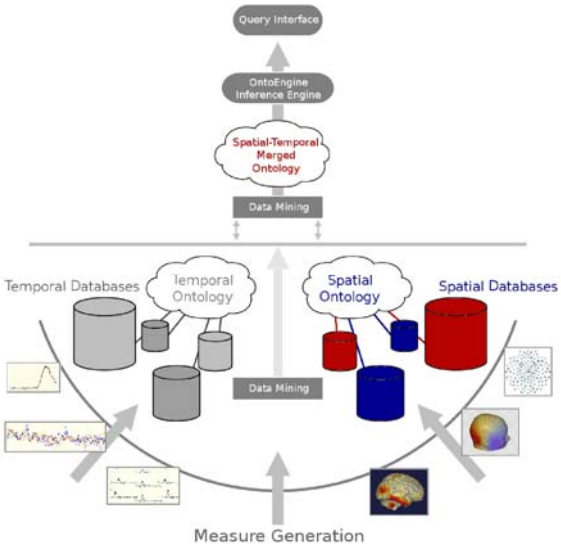


Figure 3. Interface for Statistical Extraction tool in Net Station

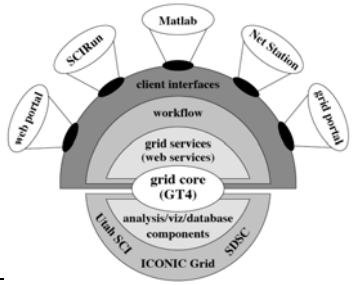
NEMO ARCHITECTURE

- Core NEMO architecture composed of three modules (Fig. 4):
  - ✓***database mining*** module
  - ✓***inference engine***
  - ✓***query (user) interface***
- Definitions of ***ontologies and databases*** to rely on comprehensive and standardized methods for ***measure generation***
  - ✓spatial ontologies
  - ✓temporal ontologies
  - ✓cognitive functional mappings
  - ✓***Semantic mappings*** between ontologies
- Architecture will support complex, flexible ***user interactions***
  - ✓query formulation
  - ✓mapping-rule definitions
  - ✓data exchange
- ***Scalable integration*** system for
  - ✓query answering
  - ✓data exchange
- Online repository for storing ***metadata***
  - ✓spatio-temporal ontologies
  - ✓database schemas
  - ✓mappings



GRID-BASED ELECTROMAGNETIC INTEGRATED NEUROIMAGING (GEMINI)

- NEMO will be integrated with our Grid-based Electgromagnetic Integrated Neuroimaging (GEMINI) system, which is designed to support high-performance imeplementation & interoperability of tools for analysis of neuroimaging data.
- GEMINI architecture design (Fig. 5):
  - ✓ Integration of multimodal neuroimaging data
  - ✓ Management of data processing workflow
  - ✓ Interoperability of tools for analysis of neuroimaging data



DEVELOPMENT WORK

Table 1. Spatial & temporal attributes of several well-known brain electrical (ERP) components, defined for an average

N3	anterior temporal	negative	260ms	280ms	1.5 µV	Left Hem Right Hem	276 ms 261 ms
P2a	frontal	positive	160ms	220ms	2 µV	-	204 ms
MFN	frontal	negative	330ms	400ms	3 µV	-	357 ms
N400	parietal	negative	350ms	420ms	1.5 µV	Left Hem Right Hem	384 ms 406 ms
LPC	parietal	positive	450ms	650ms	3.5 µV	Left Hem Right Hem	554 ms 550 ms

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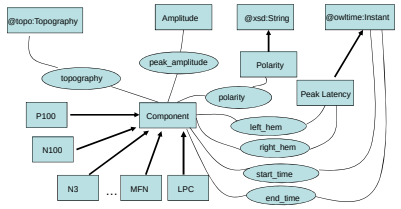
ERP Temporal and Spatial Ontologies

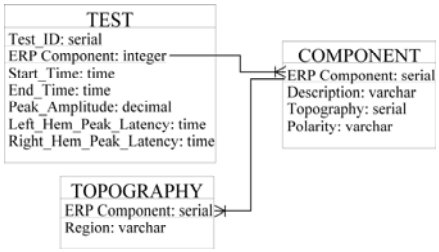


Axiom 1: ∀c - Component (= c P100) → (polarity c "Positive")
∧∃ o - @topo:Occipital (topography c o)

Axiom 2: ∀c - Component (= c N100) → (polarity c "Negative")
∧ (∃ o - @topo:Occipital (topography c o)
∨ ∃ t - @topo:Temporal (topography c t))

...;;more axioms

ERP Ontology-based Database schema



SUMMARY & CONCLUSIONS

- We present initial results from our work on temporal and spatial ERP ontologies in our ontology language (Web-PDDL).
- We also model ERP databases based on the ERP ontologies. This data modeling process can be automatic for classes and properties but may need the interaction with human experts for other semantic definitions (e.g., logic axioms.)
- The ontology-based integration and inference engine works well for large relational databases with manually generated mappings (Dou & LePendu, 2005).
- Once the NEMO system has been built and piloted within our group, we intend to make the system available for public use.

REFERENCES

[1] Gardner, D., Toga, A., Ascoli, G., Beatty, J., Brinkley, J., Dale, A., et al. (2003). Towards effective and rewarding data sharing. *Neuroinformatics Journal, 1*, 289-295.

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[3] Dejing Dou and Paea LePendu. ``Ontology-based Integration for Relational Databases." In *Proceedings of ACM Symposium on Applied Computing (SAC) 2006 DBTTA Track*, 2006

[4] Frank, R., & Frishkoff, G. (2006, submitted). Automated Protocol for Evaluation of Electromagnetic Component Separation (APECS): Application of a framework for evaluating methods of blink extraction from multichannel eeg.