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SEI+II Information Integration Through Events

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**Final Report for Period:** 10/2009 - 09/2010

**Principal Investigator:** Beard-Tisdale, Mary-Kate

**Organization:** University of Maine

**Submitted By:**
Beard-Tisdale, Mary-Kate - Principal Investigator

**Submitted on:** 12/30/2010

**Award ID:** 0429644

**Title:**
SEI+II Information Integration through Events

<table>
<thead>
<tr>
<th><strong>Project Participants</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Senior Personnel</strong></td>
</tr>
<tr>
<td>Name: Beard-Tisdale, Mary-Kate</td>
</tr>
<tr>
<td>Worked for more than 160 Hours:</td>
</tr>
<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Name: Stefanidis, Anthony</td>
</tr>
<tr>
<td>Worked for more than 160 Hours:</td>
</tr>
<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Name: Pettigrew, Neal</td>
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<tr>
<td>Worked for more than 160 Hours:</td>
</tr>
<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Name: Worboys, Michael</td>
</tr>
<tr>
<td>Worked for more than 160 Hours:</td>
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<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td><strong>Post-doc</strong></td>
</tr>
<tr>
<td>Name: Elston, Susan</td>
</tr>
<tr>
<td>Worked for more than 160 Hours:</td>
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<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Dr Susan Elston started on the project in January as a post doctoral associate. Her responsibilities to the project include data analysis and preparation of research papers. She is supported full time on the project.</td>
</tr>
<tr>
<td><strong>Graduate Student</strong></td>
</tr>
<tr>
<td>Name: Deese, Heather</td>
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<tr>
<td>Worked for more than 160 Hours:</td>
</tr>
<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Heather is a PhD student in oceanography hired as a research assistant for this project. She is a physical oceanographer and is working on developing both an ontology of primitive time series events as well as the broader ontology for oceanographic events</td>
</tr>
<tr>
<td>Name: Vijayasankaran, Nagafakshmy</td>
</tr>
<tr>
<td>Worked for more than 160 Hours:</td>
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<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Naga has been hired as a research assistant on the project. She is responsible for the event extraction from time series imagery</td>
</tr>
<tr>
<td>Name: Jiang, Jixiang</td>
</tr>
<tr>
<td>Worked for more than 160 Hours:</td>
</tr>
<tr>
<td>Contribution to Project:</td>
</tr>
<tr>
<td>Jixiang started the project in September 2005 and is supported full time on the project as a research assistant.</td>
</tr>
</tbody>
</table>
Name: Emerson, Raymond
Worked for more than 160 Hours: Yes
Contribution to Project: Developed time series database, revised events database,

Name: Rude, Avinash
Worked for more than 160 Hours: Yes
Contribution to Project: Developed algorithms for event detection

Name: Devine, Jon
Worked for more than 160 Hours: Yes
Contribution to Project: This student has been working as a graduate research assistant on methods for event extraction from scalar data fields using Support vector machines.

Name: Green, Blaine
Worked for more than 160 Hours: Yes
Contribution to Project: Blaine has been hired as an undergraduate assistant. He is responsible for software development on the event explorer

Name: Saraf, Parang
Worked for more than 160 Hours: Yes
Contribution to Project: Parang Saraf is a summer intern undergraduate student supported on this project and responsible for the web accessible events database

Name: Gross, Alexander
Worked for more than 160 Hours: Yes
Contribution to Project: Alex Gross has been hired part time as a programmer for the Event Viewer

Name: Semich, Karl
Worked for more than 160 Hours: Yes
Contribution to Project: Developed eventviewer

Name: Belanger, Joshua
Worked for more than 160 Hours: Yes
Contribution to Project: Josh has been a member of the undergraduate team working on software development for the Eventviewer

Name: Frank, Chris
Worked for more than 160 Hours: Yes
Contribution to Project: Chris Frank was hired as a full time programmer - database developer for the project

Research Experience for Undergraduates
Organizational Partners

Other Collaborators or Contacts

Antony Galton
School of Engineering, Computer Science and Mathematics
University of Exeter

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

- Evaluation and formal specification of changes in topological properties of events.
- Identification of important features necessary for classifying topological change.
- Design of distributed algorithms for capturing and classifying topological change using real-time detection.
- Development of support vector methods for high-level event extraction from point data and scalar fields.
- Development of code for identifying multiple types of events (threshold events, max/min, first difference events) over multiple temporal granularities (hourly, daily, seasonal events), from sensor based time series.
- Analysis of associations between events observed at different sensor locations and across different input data streams (e.g. salinity, temperature, and wind events)
- Automated event categorization according to likely underlying physical processes (based on hydrographic event signatures)
- Development of an approach for composite event specification from primitive events demonstrated using meteorological data from the Gulf of Maine to identify storms based on primitive events obtained from time series.
- Development of a metadata specification for primitive events
- Development of a GoMOOS events database
- Development of the Eventviewer prototype for viewing and exploring events from the database.
- Collaboration with undergraduate students in New Media to design the Eventviewer. A paper coauthored with undergrad students was submitted to GEOWS 2009: The International Conference on Advanced Geographic Information Systems & Web Services. The undergraduates on the project presented their work at the on-campus undergraduate research exposition in May 2010

Presentations, Workshops, and Conferences

- J. Jiang, Exploring locally basic topological changes during evolution of areal objects. Presentation at Atlantic Institute Graduate Research Forum. June, 2007
- Deese, H.E. 'Seasons and weather in the ocean', COMPASS Ecosystem-Based Management communication training workshop for early-career scientists, Portsmouth, NH, December 12-14, 2007.
Findings: (See PDF version submitted by PI at the end of the report)

Findings:
Informatics findings:
Identified a complete set of primitive topological changes in which evolving area objects can participate and proved an important property of topological change, namely that any topological change can be formed as an ordered composition of primitive topological changes. The primitive topological changes include: appear, disappear, merge, split, and no change. The results can be applied to the implementation of a sensor network monitoring system, which is able to track dynamic geospatial phenomena and form qualitative reports describing the evolution of a phenomena in terms of topological changes. With the formal model, primitive types of topological changes can be incorporated into query languages which makes possible the formation of queries on dynamic topological properties of phenomena. For example such queries might include: retrieve information on appearance of warm water gyres in the Gulf of Maine, and if they merged with other gyres.

Support vector clustering and support vector machines can be adapted to provide objective methods for obtaining the spatial boundaries of high-level events from space-time fields (e.g. the clouds of points that might constitute a disease cluster or regions exceeding thresholds in scalar field data.

Primitive events represent states of observed variables and indirectly partial states of complex multivariate processes. Primitive events form useful building blocks to specify complex high level events and they provide effective temporal abstractions for classification of high level events as demonstrated in a classification of storms from their constituent primitive events.

The conceptual framework of the Eventviewer provides a new modular information display paradigm that allows visualization of spatial, thematic, and temporal patterns within the same framework. The Eventviewer has application as a graphic front end for On-Line Analysis and Processing (OLAP) and SOLAP systems as well as a graphic display tool for events extracted from sensor networks. The EventViewer has application for a wide range of domain areas including crime analysis (paper submitted for Association of American Geographers Conference 2011), and health care diagnostics and analysis (paper in preparation).

Oceanographic findings:
Through objective identification of event periods, we are able to compare event characteristics (duration, magnitude), across variables, locations, seasons, and years. The event-oriented analysis complimented standard time series analysis and supported detailed investigation of the temporal evolution of hydrographic variations. The event based approach led to a number of new scientific results regarding: the arrival and advection of freshwater pulses through the Gulf of Maine from both river and oceanic sources; the timing and character of seasonal density stratification events in spring and fall (which are critically important for biological events including the spring and fall phytoplankton blooms and Harmful Algal Bloom 'red tide' events); and the spatio-temporal nature of a major interannual negative salinity anomaly that occurred during 2004–2006 and the likely causes of this anomaly. Results provided insights into the strength and number of change events that contribute to variability at different locations and time-scales. Similar events identified at neighboring locations provided evidence of both large-scale processes that affect broad areas of the gulf of Maine and advection of hydrographic features between observation sites.

Training and Development:
Graduate research assistants and undergraduate students were involved in all research team meetings and functioned as active participants in the
research process. The participating students gave formal reports on their research progress to the faculty PIs at regularly scheduled meetings. The graduate students made several oral presentations of their work at professional conferences and workshops.

Student presentations:

?H.E. Deese, 'Seasons and weather in the ocean', COMPASS Ecosystem-Based Management communication training workshop for early-career scientists, Portsmouth, NH, December 12-14, 2007
?H.E. Deese, 'Salinity and temperature contributions to stratification in the Gulf of Maine: seasonal and interannual patterns and causes', School of Marine Sciences Annual Symposium, University of Maine, Walpole, ME, May 12-13, 2008

H. Deese, 'The role salinity plays in stratification in the Gulf of Maine and the influence of inflowing Scotian Shelf Water on salinity', University of Maine School of Marine Science Graduate Symposium. May 2009.


Jixiang Jiang: Completed doctoral degree: May 2009 Thesis title: Specifying and detecting topological changes to areal objects


Avinash Rude: expected Masters Degree May 2011. Title: Temporal Data Abstraction and Classification from Space Time series

Outreach Activities:
The project post doc, graduate students and faculty attended several meetings and workshops and presented to various groups over the course of the project research (summarized in activity report). The event approach we are taking is novel to many of these groups and has been well received.

Journal Publications


Books or Other One-time Publications
Editor(s): J. Drummond, R. Billen, E. Joao, D. Forrest
Collection: Dynamic and Mobile GIS

Editor(s): M. Raubal, H. Miller, A. Frank, and M. Goodchild, Eds.
Collection: Proceedings Geographic Information Science-Fourth International Conference GIScience 2006,
Bibliography: Geographic Information Science - Fourth International Conference, GIScience 2006, M?nster, Germany. Lecture Notes in

and Interannual Change in the Gulf of Maine", (2006). Book, Published
Collection: EOS Transactions AGU, 87(52)

Observing Network.", (2007). Book, Published
Bibliography: Estuarine Research Federation 2007 International Conference

Elston, S. A., Pettigrew, N. R., and Beard-Tisdale, M. K., "Weather Events and Harmful Algal Blooms in the Gulf of Maine
Observing Network.", (2007). Book, Published

Elston, S. A., Pettigrew, N. R., and Beard-Tisdale, M. K., "An Updated Tidal Climatology for the Gulf of Maine using assimilated data from
the GoMOOS Network", (2007). Book, Published
Bibliography: The 88th Annual Meeting of the American Meteorological Society. submitted abstract, New Orleans, LA.

Editor(s): A. Ruas & C. Gold
Collection: Proceedings, Spatial Data Handling ?08
Bibliography: Montpellier, pp. 197-216.

Conference Proceedings, Published
Editor(s): A. Riedl, W. Kainz & G. Elmes
Collection: Spatial Data Handling 2006
Bibliography: Springer Verlag, pp. 229-245

Bibliography: 16th ACM SIGSPATIAL

Editor(s): T.J. Cova, H. J. Miller, K. Beard, (Editor), A. U. Frank, M. Goodchild

Editor(s): T.J. Cova, H. J. Miller, K. Beard, (Editor), A. U. Frank, M. Goodchild
Collection: Proceedings, International Conference on Geographic Information Science (GIScience)
Editor(s): S. Nittel, A. Labrinidis and A. Stefanidis
Collection: Advances in GeoSensor Networks

Editor(s): S. Nittel, A. Labrinidis, & A. Stefanidis
Collection: Advances in GeoSensor Networks

Editor(s): A. Riedl, W. Kainz & G. Elmes
Collection: Spatial Data Handling 2006
Bibliography: Spatial Data Handling, Springer Verlag, pp. 229-245.

Editor(s): S. Nittel, A. Labrinidis, A. Stefanidis
Collection: Proceedings Geosensor Networks
Bibliography: Springer-Verlag. Boston, USA, October 1-3, 2006

Collection: In Security Informatics, Int. Archives of Photogrammetry & Remote Sensing


### Web/Internet Site

**URL(s):**
http://www.spatial.maine.edu/~beard/Event_integration_project.htm
http://eventviewer.asap.um.maine.edu/evviewer3/

**Description:**
The first URL presents a project overview.

The second site provides a link to the prototype eventviewer, an interface for viewing and exploring event patterns. The NSF acknowledgement has not yet been added to this page as it is still in a testing phase.

### Other Specific Products

**Product Type:**
Software (or netware)

Product Description:
An event viewer is being developed as a user friendly front end to view events from the events database

Sharing Information:
The Eventviewer will be accessible from the web

Product Type:
Data or databases

Product Description:
The UMaine SEI+II research group has developed the Event PostgreSQL database integrated with a PostGIS spatial database to temporally and spatially catalog near real-time data from the Gulf of Maine Ocean Observing System (GoMOOS) buoy network. The schema for the Event database was designed and developed for data from the GoMOOS buoy network and has been extended to accommodate open-source data from additional US and Canadian governmental agencies. To date, the database accommodates data from the following sources: the GoMOOS buoy network, the National Data Buoy Center (NDBC) buoy and C-MAN station network, Environment Canada Marine Environmental Data Service (MEDS) data network, Environment Canada climate and surface water data network, Fisheries and Oceans Canada, Ocean and Ecosystem Science Division data network, the NOAA National Ocean Service (NOS) water level/tide data network, the Environment Canada Air Quality Division, the Maine DEP Bureau of Air Quality, the Maine Geological Survey data network on earthquakes and cryoseisms, and data from the National Climatic Data Center (NCDC) storm events database. As of June 26, 2007, the Event database contains events from four realms (Atmospheric, Oceanic, Terrestrial, and Atmospheric/Oceanic), eleven different Event Categories (e.g., air quality events, GoMOOS events, NCDC events, storm events, and harmful algal bloom (HAB) events), over 75 different Event Groups (e.g., ozone events, particulate matter events, wind events, tide events, and earthquakes), and 694,717 individually determined events, which include but are not limited to coastal flood events, winter weather events, non-storm (high pressure) events, extreme water level events, growing, heating, and cooling degree day events.

Sharing Information:
The event database is still under development but can be accessed currently at: http://eventviewer.asap.um.maine.edu/phpPgAdmin

A user-friendly web interface for searching the Event database is under development with expected deployment fall 2007

Product Type:
Software (or netware)

Product Description:
The Eventviewer is a graphical user interface for exploring spatial, temporal, and thematic patterns in events. The Eventviewer allows users to simultaneously visualize and explore the three dimensions of space, theme, and time through the assignment of spatial, temporal, and thematic categories to a set of graphic elements called event bands, stacks, and panels. The spatial, temporal, and thematic categories are functionally similar to the concept hierarchies of multidimensional databases as they identify aggregation pathways for events. The interface was designed to explore events extracted from the GoMOOS ocean observing sensor system but can be generalized to other domains and contexts.

Sharing Information:
The eventviewer is web accessible at: http://tok.asap.um.maine.edu/eviewer4/#

Contributions within Discipline:
The conceptual framework of the Eventviewer provides a new information display paradigm that allows visualization of spatial, thematic, and temporal patterns within the same framework. The Eventviewer has particular application as a graphic front end for OLAP and SOLAP systems as well as for displaying data from sensor networks that has been transformed to events.

A primitive event ontology provides a new shareable description and characterization for events extracted from sensor networks.

Contributions to Other Disciplines:
The Eventviewer has value as an information visualization tool for a range of disciplines. Oceanographers in the School of Marine Science are using it to explore a range of physical oceanographic processes and events. We are in the process of extending functionality to work with
epidemiological events under the Maine Cancer GIS project with Maine Institute for Human Genetics and Health, as a tool for the analysis of crime events, and as a tool for visualization of events associated with emergency response.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:
Our event database is the start of a comprehensive database of oceanographic and atmospheric events that will be a resource for other oceanographic scientists, and teachers and students generally.

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Organizational Partners
Contributions: To Any Human Resource Development
Contributions: To Any Beyond Science and Engineering
Any Conference
Summary of key findings

A. Findings on: Systematic evaluation and formal specification of changes in topological properties of events

Applying the concepts of the event-oriented model, changes are treated as objects, and form classes of changes with common properties. The topological properties of dynamic areal objects we call topological changes. Key findings are:

1. **Topological changes in continuous evolution can be represented and classified using a tree model.**

   The topological properties between the regions and holes in an areal object can be represented by a tree. The topological changes of the areal objects can be represented by tree morphisms between the representation trees before and after the change. Four basic classes of topological changes, namely insert, delete, split and merge, can be identified according to the types of the tree morphisms. The composition of the four basic changes in a particular sequence can form all the topological changes.

2. **The 2-tree model can represent richer topological properties and help specify and distinguish more classes of topological changes.**

   A combination of two trees can be employed to represent richer topological properties. In addition to the topological properties represented in (1), the two-tree representation allows us to distinguish weakly and strongly connectedness. More types of topological changes can be specified according to the types of the morphisms between the corresponding trees before and after the change.

B. Findings on: specification and extraction of oceanographic and atmospheric events from time series

Events are evidence of physical processes acting at various time scales. Events are extracted from observational time series as change sequences with common properties. Key findings:

1. **Event extraction is most dependent on variable and temporal granularity.**

   There is no one size fits all event extraction method. Characteristics of an observed variable over different time intervals dictate different event extraction methods. For example for variables with an annual cycle we use harmonic analysis to extract the annual scale (max, min) events. Interannual anomalies (residuals after removing annual cycle) may be considered another set of events or further processed to extract synoptic scale (2-10 day) events (see Figure below).
2. **Processes of interest (events to be captured) are not self similar at different temporal scales.**

Wavelets analysis has been applied in a number of domains to segment time series at different scales but assumes self similarity across scales. For our purposes wavelets may be part of a suite of event detection methods but are not a complete solution.

C. Findings on: the connection(s) between changes in and among atmospheric, oceanic, and combined atmospheric/oceanic properties in the Gulf of Maine (GoM) domain are still preliminary. Hypotheses about relationships between different types of physical events and between physical and biological events are emerging as we build the database of events.
The major research activities of the UMaine SEI+II research group have been several fold. The central activities this year have been: 1) Systematic evaluation and formal specification of changes in topological properties of events, 2) exploration, classification, and investigation of the connection(s) between changes in and among atmospheric, oceanic, and combined atmospheric/oceanic properties in the Gulf of Maine (GoM) domain, 3. specification and extraction of oceanographic and atmospheric events from GoMOOS and several additional open source databases, 4) design, development and implementation of an open-source spatially-enabled database for event viewing and exploration, 5) development of a user friendly web application for event viewing

SEI+II Workshops, Conference Attendance, & Presentations (reverse chronology):

*PASI course on Contemporary Issues in Estuarine Physics, Transport, and Water Quality, August 2007 (PASI: Pan-American Advanced Studies Institutes Program)*

Attendance and participation by S. A. Elston. [Course website: http://pasi.coastal.ufl.edu]


*American Geophysical Union Fall Meeting, San Francisco, CA, December 2006*

Poster presentation (and attendance) by H. E. Deese, M. K. Beard-Tisdale, and N. R. Pettigrew entitled “Event Oriented Analysis of Ocean Observing System Data – Insights into Annual and Interannual Change in the Gulf of Maine.” [PDF]


*Gulf of Maine CAFÉ Workshop III, Portland, ME, November 2006 (CAFÉ: Climate-based Assessment and Forecasting for Ecosystems)*

Attendance and participation by H. E. Deese and S. A. Elston

*Biological & Technological Research for Offshore Aquaculture, Portsmouth, NH, November 2006*

Attendance by H. E. Deese