A tool for constructing data albums for significant weather events
Research Team

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  – Manil Maskey (Fixer)

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  – Xiang Li
  – Shannon Flynn (Undergrad)
Curated Data Albums

- **Data Albums** are *compiled* collections of information related to a specific science topic or event with links to relevant data files (granules) from different instruments. Additional information include:
  - Tools and services for visualization and analysis
  - News reports, images or videos to supplement research analysis

- **Curation** provides the author of a Data Album the means to select the aggregated information
Motivation

- Case study analysis and climatology studies commonly used in Atmospheric Science research are instances where researchers studying a significant event:
  - Require data should be organized around the event rather than observing instruments
  - May need to discover new datasets that they would not have considered before
- Gathering relevant data and information for case studies and climatology analysis is **tedious** and **time consuming**.
- Design of current Earth Science data systems assumes researchers access data primarily by instrument or geophysical parameter.
- *Need exists for tools to filter* through large volumes of online content and gather relevant information based on user’s science needs.
• Tool can be driven by an event feed. The feed parser will extract keywords, geolocation and time information. Keywords is fed to the OIS (Ontology Inference Service). The OIS provides additional contextual keywords including a list of relevant datasets to help refine the final query. These additional keywords, datasets, geolocation and temporal parameters are then fed to the Noesis Engine.
Noesis Engine, responsible for framing the query for appropriate brokers, delegates the data search to the Data Search broker by providing dataset, keywords, location and time information. The Data Search broker then tasks an OpenSearch broker to obtain collection level metadata from the EOS Clearinghouse (ECHO) and NASA data centers, and return dataset descriptions.
Noesis Engine is also responsible for extracting information/knowledge from unstructured resources such as storm reports described in web pages and pdf documents. Noesis encodes “extraction rules” that are used to parse these documents to extract structured information and assemble these individual fragments into usable information.
Noesis Engine also feeds the expanded keywords to the Query Submission Broker to search for supplementary information potentially useful for research. The Query Submission Broker tasks individual brokers for different online content repositories, including Google API for news, YouTube for videos, Google scholar for any relevant published articles, Twitter and Flickr and Google Images for interesting photos.
Noesis Engine combines the aggregated data and content results and map this information into a Data Album. The Data Album is implemented as a custom Drupal node stored in the Drupal Geodatabase. The node is also annotated by all the keywords used to perform the query including expanded keywords, dataset names, geolocation and time.
Author with the appropriate permissions will be able to indicate a new event feed to trigger the creation of Data Albums. The author will be able to specify the different digital and data repositories to be searched, an important personalization feature to empower curation capabilities for their Data Album. The Data Album can also be shared with the rest of the research community on the portal, and published as an information cast.
Once users start creating and sharing Data Albums, an online research community on hurricane research will evolve. The community can use the portal to discover useful Data Albums and to rate or annotate published Data Albums with new tags. The users will be able to search for specific published Data Albums and aggregate a series of Albums to create Research Portfolios for climatology studies.
Data Album Implementations

- **Catalog of Hurricane Case Studies at GHRC.** Noesis 2.0 will be integrated into the GHRC to create a portal to support hurricane case study research. (*Prototype Ready*)

- **Case study generator at NASA’s SPoRT Center.** One goal of Noesis 2.0 will be installed at SPoRT to help automate the selection of weather events and other information needed for evaluating the SPoRT’s mesoscale configuration of the Weather Research and Forecasting (WRF) model for convective cases (*To be implemented*)
Ontology-based Relevancy Ranking Service

• General service that can be customized for specific applications

• Service needs to provide the following capability:
  – Feed application ontology to the system
  – Feed collections of documents that are need to be ranked
  – Provide search keywords
  – System provides the ranked documents.
Service Architecture

ontography

Inference Engine
Ontology Processor

Linked weighted ontology

Activation valued ontology

Information Extraction Module

Document

Text Parser

Parsed Documents

Ranker

Ranked Results

User

Query Expansion

Expanded query

Annotation

Weighted terms

Annotation, Statistical and Ranking Modules

Statistical Analyser
Initial Hurricane Ontology
Ontology-based Ranking Algorithm

• Algorithm combines ontology based and traditional statistical score to estimate relevancy of a resource

• Algorithm based on:
**Ranking Algorithm: Concept Weights**

The weight of links between two concepts calculated with following equations

\[
W(c_j, c_k) = \frac{\sum_{i=1}^{m} n_{i,j,k}}{\sum_{i=1}^{o} n_{i,j} + \sum_{i=1}^{p} n_{i,k}}
\]

\( W(C_j, C_k) \) is weight between \( C_j \) and \( C_k \)

\( n(i,j,k) \) is total number of related concepts to both \( C_j \) and \( C_k \)

\( n(i,j) \) is total number of related concepts to \( C_j \)

\( n(i,k) \) is total number of related concepts to \( C_k \)

Weights are stored in database

<table>
<thead>
<tr>
<th>Subject</th>
<th>Predicate</th>
<th>Object</th>
<th>wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane</td>
<td>sibling</td>
<td>Typhoon</td>
<td>0.71</td>
</tr>
<tr>
<td>Hurricane</td>
<td>sibling</td>
<td>TropicalDepression</td>
<td>0.71</td>
</tr>
<tr>
<td>Hurricane</td>
<td>sibling</td>
<td>TropicalStorm</td>
<td>0.71</td>
</tr>
<tr>
<td>Cyclone</td>
<td>superClass</td>
<td>Phenomenon</td>
<td>0.44</td>
</tr>
<tr>
<td>Cyclone</td>
<td>subClass</td>
<td>Typhoon</td>
<td>0.33</td>
</tr>
<tr>
<td>Cyclone</td>
<td>subClass</td>
<td>Hurricane</td>
<td>0.33</td>
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<tr>
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<td>TropicalDepression</td>
<td>0.33</td>
</tr>
</tbody>
</table>
**Ranking Algorithm: Activation Value**

- Spread Activation algorithm is used to calculate activation value for each concept in ontology.
- The concepts that are specified by user form the initial concept set. These initial concept sets are set to value 1.

\[ I(c_j) = I(c_i) \times W(I(c_i), I(c_j)) \]

- \( I(c_j) \) is activation value of current concept
- \( I(c_i) \) is activation value of previous concept
- \( W(I(c_i), I(c_j)) \) is link weight between two concepts
- Activation values are stored in database

<table>
<thead>
<tr>
<th>Concept word (c)</th>
<th>Val (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane</td>
<td>1.0</td>
</tr>
<tr>
<td>TropicalDepression</td>
<td>0.71</td>
</tr>
<tr>
<td>TropicalStorm</td>
<td>0.71</td>
</tr>
<tr>
<td>Typhoon</td>
<td>0.71</td>
</tr>
<tr>
<td>Typhoon</td>
<td>0.71</td>
</tr>
<tr>
<td>Cyclone</td>
<td>0.33</td>
</tr>
<tr>
<td>Flood</td>
<td>0.19</td>
</tr>
</tbody>
</table>
• Term weight: TF-IDF model is used to provide weight to each concept words present in the documents.

• TF (Term Frequency): It measures the frequency of each concept word (c) in each document (d)

\[
tf(c, d) = \frac{f(c, d)}{|d|}
\]

Where:

- \( f(c, d) \) is frequency of concept word (c) in document (d)
- \(|d|\) is count of words in document (d)
Ranking Algorithm: Statistical Analysis

- IDF (Inverse Document Frequency): measures the importance of concept word (c) in entire document collection (D).
  
  \[ idf(c, D) = \log\left(\frac{|D|}{df_c}\right) \]

  - \(|D|\) is count of the corpus (D)
  - \(df_c\) is document frequency of (c): the number of document that contain (c)

- The tf-idf for the concept word calculated as below:
  
  \[ tf.idf(c, d, D) = tf(c, d) \times idf(c, D) \]

  - \(tf.idf(c,d,D)\) is the tf.idf for (c) in (d) that is in corpus (D)

- The obtained tf.idf saved in memory to use for the ranking calculation.
Ranking Algorithm: Relevancy Score

- Score ($S_d$) for document (d) in collection of documents (D) is as below:

$$S_d = \sum_{i=1}^{m} I(c_i) \times \text{tf.idf}(c_i, d, D)$$

- $S_d$ is final score of document (d)
- $\sum_{i=1}^{m} I(c_i) \times \text{tf.idf}(c_i, d, D)$ is sum of score of each matched concept word and is obtained by multiplying ontology-based score and the statistical score

- The obtained score is used to rank the document (D)
Algorithm Evaluation

- Compared algorithm results versus “truth data”
- Truth data:
  - A total of 35 GHRC collections were manually selected
    - Considered as useful and relevant to hurricane studies
- Top 35 ranked results from the algorithm are used for performance evaluation.

<table>
<thead>
<tr>
<th></th>
<th>Yes (Algorithm)</th>
<th>No (Algorithm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (Manual)</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>No (Manual)</td>
<td>14</td>
<td>111</td>
</tr>
</tbody>
</table>

- **Accuracy** = \( \frac{21 + 111}{160} = 82.5\% \)
- **Precision** = \( \frac{21}{35} = 0.60 \)
- **Recall** = \( \frac{21}{35} = 0.60 \)
Algorithm Application

- Precision vs Recall Graph

![Precision vs Recall Graph](image)

- Ideally you want high precision, high recall
- For data search, we want higher recall:
  - Gets everything that is important
  - Gets non-relevant data (users can filter out)
Algorithm Improvements

• Improving the ontology richness
• Utilizing semantic relationships to improve weight calculations
• Utilizing concept word “location” to improve weight calculations.
  – Example: Keywords vs Description
Key Features

• Autogenerates infographic view of Hurricanes

• Visual faceted search interface for Hurricanes
  – Results ordered alphabetically
  – Storms color coded by category

• Visual faceted search interface data for a given Hurricane
  – Data collection color coded by relevancy
  – Relevancy thresholds can be adjusted by the user

• Analytics
  – Summary statistics for events such as box plots, density map
  – Interactive plots that allow user to configure and display six parameters within a scatter plot

• Download scripts to facilitate access to the data files
Version 2 Snapshots

Data Albums
Compiled collections of information related to a specific science topic or event

About the Data Album

What is in a Data Album?
It contains data in relevant data files (failing) two different approaches, tools, and services for visualization and analytics. Information about the event contained in many reports. Images in the data album also provide reference data.

Value to Researchers?
To gather relevant data and information for case studies and to interpret results, the latest information is needed. The information is not available in accessible form and is not available on demand, whereas data albums provide specific events. Data albums address this need by automatically aggregating all the information and data needed.

Underlying Technology?
Data Albums are auto-generated by reliable and scalable knowledge discovery engines. They automatically discover and summarize relevant data across multiple data sources and are selected according to their relevance to the current query. The data albums are based on knowledge and data relationships between the various fragments of information and data.

Visual faceted search for Hurricanes

Faceted Search:
- 0 of 17 years selected
- 8 of 8 categories selected
- 58 of 48 storms selected

Legends:
- Solid: Storms that occurred at least twice
- Dashed: Storms that occurred once
- Thick: Storms that occurred at least twice in a row
- Thin: Storms that occurred once in a row

- Angle of a storm represents the duration of the storm in days.

Box Plot Interactivity

Standard Boxplot with Mean

Month/Year Pressure for 2009

- 0
- 3
- 6
- 9
- 12

Get Links to all Users
Get Links to Selected Users

Storm Track

Storm Statistics & Multimedia

Collections based on Researchers or Interactions

Threshold
- Min: 0
- Max: 0.75
- Current threshold: 0.44

Legends:
- Collection reading for
- Bar represents the lowest value that value is the highest

Data Album for Bess (2011)

- Tropical Storm
- Hurricane
- Super Typhoon

- Maximum Wind Pressure
- Minimum Central Pressure
- Average Track Length
- Intensity Change
- Genesis

- 2008-2009
- 2011-2012
- 2009
- 2010
- 2012
- 2011
- 2013
- 2014
- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
Visual Faceted Discovery Interface
Storm View – Data Collections
# Other Aggregated Information

## Storm Statistics & Multimedia

<table>
<thead>
<tr>
<th>Storm Name</th>
<th>Year</th>
<th>Cyclogenesis Date</th>
<th>Cyclolysis Date</th>
<th>Highest Saffir-Simpson Category</th>
<th>Maximum Wind Speed</th>
<th>Minimum Central Pressure</th>
<th>ACE Index Value</th>
<th>Damage</th>
<th>Track Errors</th>
<th>Intensity Errors</th>
<th>Genesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Igor</td>
<td>2010</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

![Storm Images]

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**Storm Track**

- Map of storm track over North America.

- Video: "Clarenville's Experience with Hurricane Igor Sept 2010."
Summary Analytics

Interactivity

Standard Boxplot with Mean

Monthwise Pressure for 2009

Pressures

Interactivity

Event-based Density map

Download Density Plot as PNG
Interactive Analytics
Innovations Enabled

• Generalized tool designed to support “search, aggregation and access” of data and other online resources around events and can be easily configured for other uses (disasters)

• Automates the gathering of online resources with information filtering

• New ways of displaying search results
  – Infographics – graphic visual representation of information, data or knowledge intended to present complex information quickly and clearly
  – Results enriched with additional information (rel. score, storm cat)

• Analytics dashboard on the gathered information for events

• Use of semantic technology for relevancy ranking
Remaining Tasks

- Feature freeze and Hurricane Portal Release
  - Migrating to Dev Server, internal testing
  - Science Team Evaluation
  - Pushing to production server

- Additional Features to be added in the near feature
  - Calendar View to see which data collection are available for which days
  - Displaying browse images
  - Additional data parameters for analytics (# of death, ACE index, forecast evaluations)

- SPoRT Severe storm scenario application for Year 2
Data Albums for Severe Storms

• Focus on extreme events
  – Tornadoes, Flooding, Wind Gusts, Hail Events
Birds Eye View of Other Projects
Automated Event Services

Utilize Big-Data technologies to...

- Enable interactive and collaborative scientific data analysis on big data
- Share data and analysis methods seamlessly, ...in order to...
- Relieve scientists from data management,
- Empower scientists to focus on science, and
- Boost science productivity.

1. Identify occurrences (events) of phenomena
   - Entities in the 4D spatiotemporal space
2. Associate additional relevant data with events.
3. Characterize phenomena with defining features extracted from data.
4. Correlate defining features of various phenomena in both space and time.
5. Improve predictions of future events using correlations among phenomena for better decision making.

Big-Data Vision

Technology Infrastructure

Science Enablement
Polaris: Discovery Engine

- All Special Sensor Microwave / Imager ( / Sounder; SSM/I and SSMIS) gridded data files of 1440x720 pixels staged on the cluster
- Data sets – Rain Rate, Surface Wind Speed, Atmospheric Water Vapor, Cloud Liquid Water
- Total volume is less than 1 Tb
- Cluster with 70 compute nodes consisting of two single core processors each used
- Data was preprocessed by striping it across the available compute nodes

Initial evaluations by researchers has clearly demonstrated the value of such a tool

Polaris has been adopted by a joint project with NASA GSFC National Center for Climate Simulations

Exploring opportunities to make the tool operational at NASA DAACs and NASA’s Earth Exchange (NEX).
NASA Science on Drupal

Content Based Image Retrieval Module

- Allows users to interactively query a large database of browse images based on image contents.
- Search service provides confidence scores for the matching images and filters the images based on the scores.
- Provides basic analytics on the results is available via histogram on the count of number of matching results for years, months, and days.
Collaborative Workbench (CWB) to Accelerate Science Algorithm Development

Sharing Knowledge is at the heart of science, yet it is challenging for researchers to effectively share information and tools.

**Goals**
- An architecture for scalable, controlled collaboration
- Selective sharing of science resources
  - among individuals
  - within science teams
  - with the entire science community.
- Software that fits how researchers currently do scientific analysis to promote adoption

**Benefits**
- Accelerate science algorithm development by distributed science teams
- Reduce redundancy
- Improve productivity
- Securely share all science artifacts (data, information, workflow, virtual machines)
- Generalizable to support collaborative science algorithm development for other mission and model enterprises
Questions?

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