Search and Relationship-mining of Heterogeneous Flight Control Documents

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Flight controllers for space shuttle and International Space Station (ISS) missions routinely locate specific operations documents and records from among tens of thousands stored on computers in the Mission Control Center (MCC). Relevant information – team notes, console logs, action requests, Flight Rules, anomaly reports, and flight procedures – is accumulated in a bewildering array of flight operations support systems, each of which must be accessed via a separate interface. Users must consult these different systems and manually integrate results to get a comprehensive view of the information relevant to tasks they are performing. This is a time-consuming and error-prone process.

To improve access to flight control information, we designed and built an application called XSearch that integrates data from disparate flight operations databases.

Through a common search interface, MCC personnel using XSearch can issue a single search query and simultaneously interrogate multiple mission operations data sources, including the ChitS system (used to store mission action requests), the Flight Notes system (used to store internal flight control team communications), the Anomaly Reporting System, the Polytron Version Control System change management system, and the Flight Rules repository. These systems store historical data back to 1995, and contain over 300,000 records. XSearch users can perform full-text searches across key text fields (e.g., title, problem description, action request, etc.) and view integrated results across these data sources.

The XSearch interface is displayed in figure 1. To use the interface, the flight controller types a search query (e.g., "EPS [Electrical Power System] load shed") in the

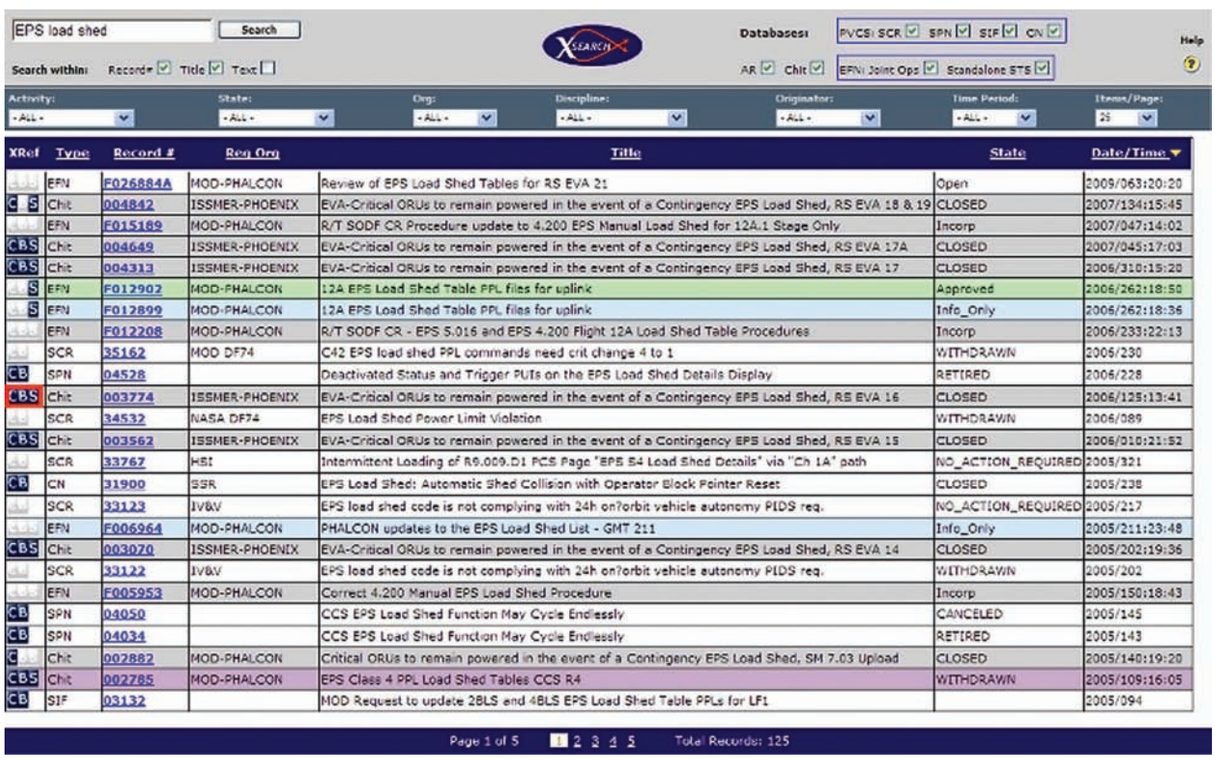

Fig. 1. *The XSearch interface display.*

box at the top of the screen and selects the databases to be searched. The controller can also select the fields to be searched, choosing one or more of the record number, title, and text fields. Search results are then retrieved from the specified databases and shown in a tabular display, with key information summarized in columns. Pull-down filters allow the user to narrow the results further.

In addition to conducting searches, the system provides two other important capabilities intended to contextualize search results: detection of cross-references and detection of textually similar records. Identifying records that are either cross-referenced by, or similar to, a given search result enables flight controllers to recover key information that may be necessary to properly interpret that result. This supplementary information provides the controller with important context intended to facilitate safer and more effective mission operations decision-making through enhanced situation awareness.

To detect embedded cross-references within results, XSearch parses text fields found in the results using a set of syntactic patterns that locates record citations (e.g., patterns that detect standardized document or record identifiers routinely used by authors). Using this technique, XSearch can identify both "outbound" and "inbound" references. Outbound ("Cites") references point "out" from a specific record to other records cited; "inbound" ("Cited-by") references point "in" to the specific record from other records that cite it.

To detect records that appear similar to a given search result, XSearch calculates and ranks the textual similarity between the result and all other records in the corpus. Those ranked highest are displayed to the flight controller. Similarity detection is computed using a standard vector space algorithm (term frequency inverse document frequency (TFIDF)) developed by researchers in the field of information retrieval. TFIDF identifies records that may be relevant to a given record based purely on textual similarity. It thus finds relationships that are different than those detected by the explicit citation-based, cross-reference detection approach.

Figure 2 illustrates the concept of cross-referenced and similar records. In the figure, we assume the flight controller has searched for the term "ALS [advanced life support] heater," which is found in the text of Chit 004361. Also within the text are citations to an anomaly report (AR 00447) and a flight note (EFN F0121902). These are Cites-type cross-references. Cited-by cross-references referring back to Chit 004361 can be found in subsequently written records (e.g., Chit 004374). EFN F013094 is found to be relatively "similar to" Chit 004361 based on the usage of similar words and phrases in their respective texts. For example, both records refer to "temperature instability" and "ALS heater failure."

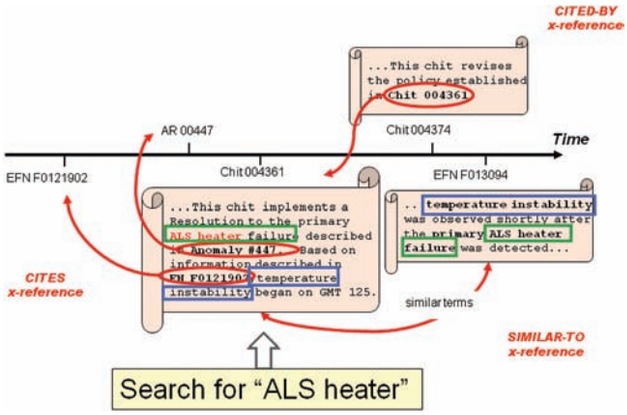

Fig. 2. *The concept of cross-referenced and similar records illustrated.*

Cross-references and similarities detected by XSearch are reflected in the user interface in figure 1. The leftmost column ('XRef') contains an indication of which types of cross-references are located for the search result: C for "Cites," B for "Cited-by," and S for "Similar-to." If a flight controller wishes to view these cross-references, he or she clicks the C, B, or S indicator and a cross-references display is presented (figure 3). This display contains a tab for each of the cross-reference types found. Clicking on the record number hyperlink brings up the record for viewing.

Our intention is to expand the scope of XSearch by adding more data sources into the integrated search, specifically the Inventory Management System, the flight controller Console Log Database, and the ISS problem reports database. The initial version of XSearch also provides a solid framework on which to develop more sophisticated and powerful relationship-mining capabilities. Our long-term strategy is to expand the information extraction methods we employ to recover many other types of cross-record linkages.

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Cross References for Chit # 003774

Help

Type	Record #	Req Org	Title	State	Date/Time
Chit	003774	ISSMER-PHOENIX	EVA-Critical ORUs to remain powered in the event of a Contingency EPS Load Shed, RS EVA 16	CLOSED	2006/125:13:41

Cites | Cited By | Similar

Type	Record #	Org / Serial #	Title	State	Date/Time	# Citations
Chit	003563	ISSMER-VI	Failure Scenarios and Time-to-limit for Transitioning to Contingency Maneuver for MT Thermal Protection	CLOSED	2006/011:15:49	1
Chit	003562	ISSMER-PHOENIX	EVA-Critical ORUs to remain powered in the event of a Contingency EPS Load Shed, RS EVA 15	CLOSED	2006/010:21:52	1
Chit	003533	ISSMER-PHOENIX	RPCM S03A-E RPC 18 Trip Troubleshooting Tasks	CLOSED	2005/350:21:04	2
Chit	003070	ISSMER-PHOENIX	EVA-Critical ORUs to remain powered in the event of a Contingency EPS Load Shed, RS EVA 14	CLOSED	2005/202:19:36	1
Chit	002685	ISSMER-PHOENIX	EVA-Critical ORUs to remain powered in the event of a Contingency EPS Load Shed, RS EVA 13	CLOSED	2005/069:15:39	1
Chit	002549	ISSMER-Manager	EVA-Critical ORUs to remain powered in the event of a Contingency EPS Load Shed, RS EVA 12	CLOSED	2005/018:23:45	1
Chit	002164	ISSMER-Manager	EVA-Critical ORUs to remain powered in the event of a Contingency EPS Load Shed, RS EVA 11	CLOSED	2004/232:16:13	1
Chit	002105	MOD-PHALCON	EVA 10 - Critical ORUs to be Inhibited for EPS Manual Load Shed	CLOSED	2004/210:01:47	1
Chit	001572	MOD-PHALCON	EVA-Critical ORUs to be Inhibited for EPS Load Shed	CLOSED	2004/035:20:45	1

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Fig. 3. *A cross-reference display.*

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