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image ® Rolls-Royce

Hybrid Search: Effectively Combining Keywords and Semantic Search

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Outline of Talk

- Aim of paper
  - Search for what and in what conditions?
- Hybrid Search as a way to overcome limitation of classic semantic search
- Implementing Hybrid Search into K-Se
- Experimental Evaluation in vitro and ir
- Conclusion and future work

3 mins+3 slides

7min+9slides

4 mins+5slides

8 mins+15 slides

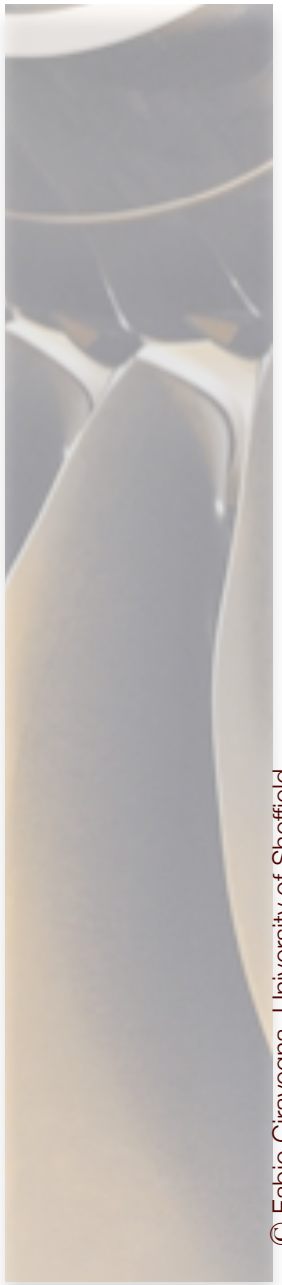
3 mins+2 slides

Aim of the paper

- We propose a search method
  - Designed for the Semantic Web
    - Seen as a collection of both documents and metadata,
  - Designed to achieve two tasks:
    - Document retrieval: searching for documents using concepts or keywords of interest
    - Knowledge retrieval: retrieving facts from a knowledge base (i.e. triples)

Metadata and User Needs

- Differently from [1, 2, 3, 4, 9],
  - We expect metadata to cover only partially the user information needs
    - Reasons:
      - limitations in the ontology wrt user needs
      - limitations in the annotation capabilities
        - i.e. limitations in IE capabilities
      - metadata unavailable for a specific document

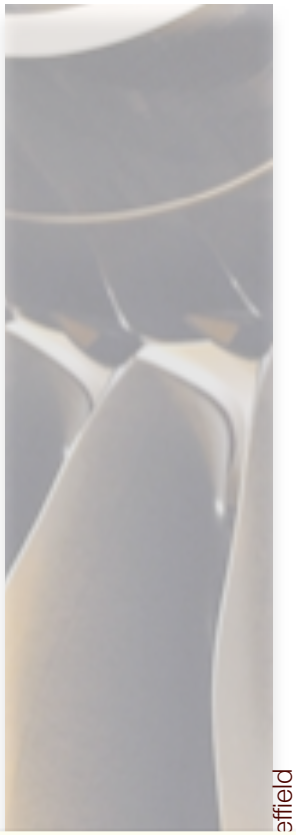


Pure Semantic Search (OS)

- Semantic search as metadata-based search defined according to an ontology,
  - Annotations are unambiguous
    - OS Does not suffer from ambiguity and synonym issues of keyword-based systems (KS)
- Issue:
  - OS can fail to encompass user information needs
    - When metadata does not completely cover user needs

Hybrid Search

- We propose a model of searching combining
  - the flexibility of keyword-based retrieval
  - querying and reasoning capabilities of semantic search
- HS is formally defined as:
  - the application of semantic (metadata-based) search for the parts of the user queries
    - where metadata is available
  - the application of keyword-based search for the parts not covered by metadata.



- But also it must leave freedom to users to chose among the two paradigms!
  - As we will see users make a creative use of it

Queries in Hybrid Search

differently from other approaches (e.g. [9]), in HS conditions on metadata and keywords coexist.

- Any boolean combination of three t
  conditions
  - pure semantic:
    - via unique identification of objects/relations
      - e.g. via URIs or unique identifiers
  - keyword-based
    - matching on the whole document
  - keyword-in-context
    - matching keywords only within portion of documents semantically annotated with a specific type or instance

Queries in Hybrid Search

differently from other approaches (e.g. [9]), in HS conditions on metadata and keywords coexist.

- Any boolean combination of three t
  conditions
  - pure semantic:
    - via unique identification of objects/relations
      - e.g. via URIs or unique identifiers
  - keyword-based
    - matching on the whole document
  - keyword-in-context
    - e.g. it enables searching for the string "fuel" but only in the context of all the text portions annotated with the concept affected-engine-part [14]

Example of Hybrid Query

∀x,y,z /

(discoloration y) & (located-on y x) & (component x)

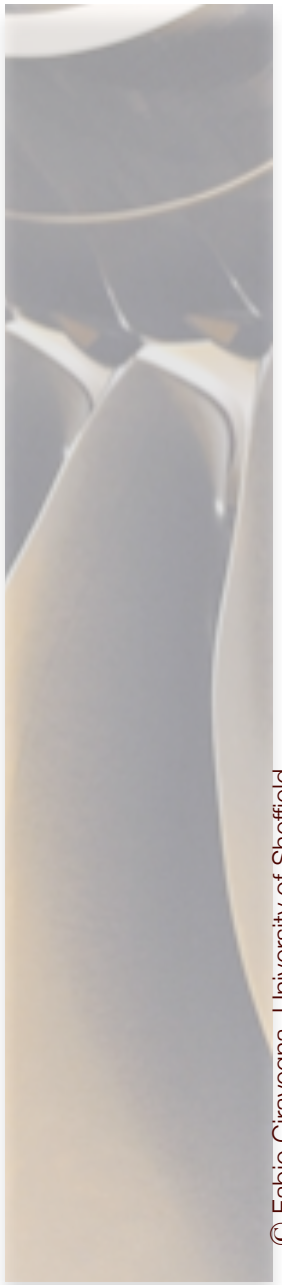
Querying Metadata

& (provenance-text-contains x “blade”)

Keyword in Context Query

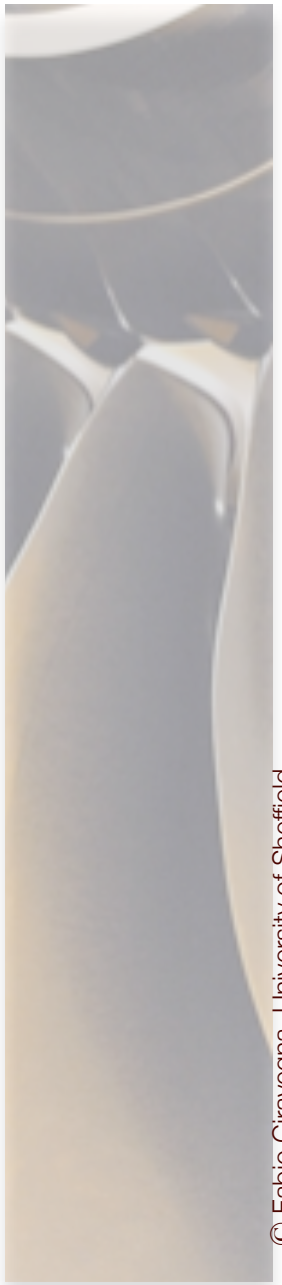
& (contains z “trailing edge”) & (document z) & (provenance x z)

Keyword-based Query



Implementing HS: Indexing

- Documents are indexed using a standard keyword–based engine such as SolR
- Facts (e.g. extracted by an IE system) are stored in a Knowledge Base
  - e.g. a triple store like Sesame2 in the form of RDF triples.
- Provenance of facts recorded
  - E.g. As triples connecting
    - the facts' URIs and those of the document of origin
    - the facts' URIs and the original strings used in the documents



Implementing HS: Retrieval

- Query is parsed and the different components (keywords, keywords-in-context and metadata) identified
  - keyword matches ➜ traditional information retrieval system
  - metadata searches
    - Translated into a query language like SPARQL
    - Sent to a triple store
  - keywords-in-context queries
    - matched with provenance of annotations in documents
      - E.g. Using SPARQL and a triple store
- Finally, results are merged, ranked and displayed

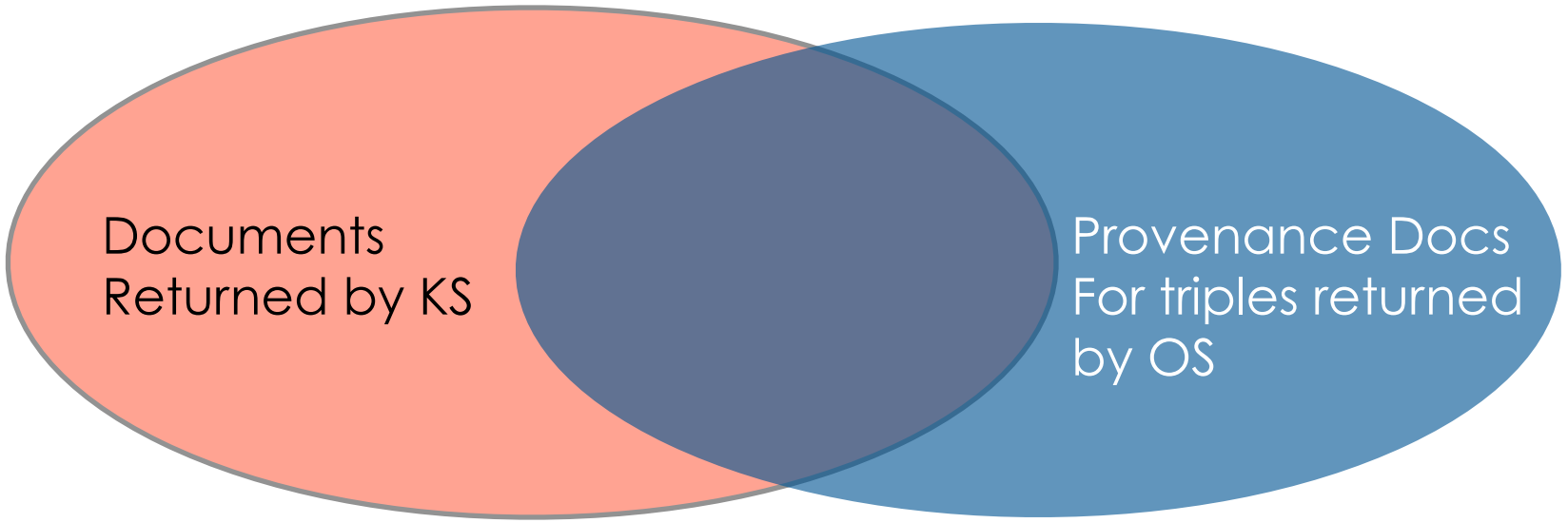
Result Merging

- Merging keyword and semantic results is not straightforward
  - Keyword matching returns an ordered set of URIs of documents
  - a semantic search returns an unordered set of assertions < subj, rel, obj>
- Merging is a different task if:
  - Document Searching
    - Returns documents
  - Knowledge Searching
    - Returns triples

Merging results

- Provenance of triples returns document ids for triples (URIs)
  - Document Searching:
    - Provenance URI set is intersected with URIs of documents returned by keywords
    - `HybridSearchUriSet= KSDocUriSet ∩ OSDocUriSet`

I won't mention ranking here

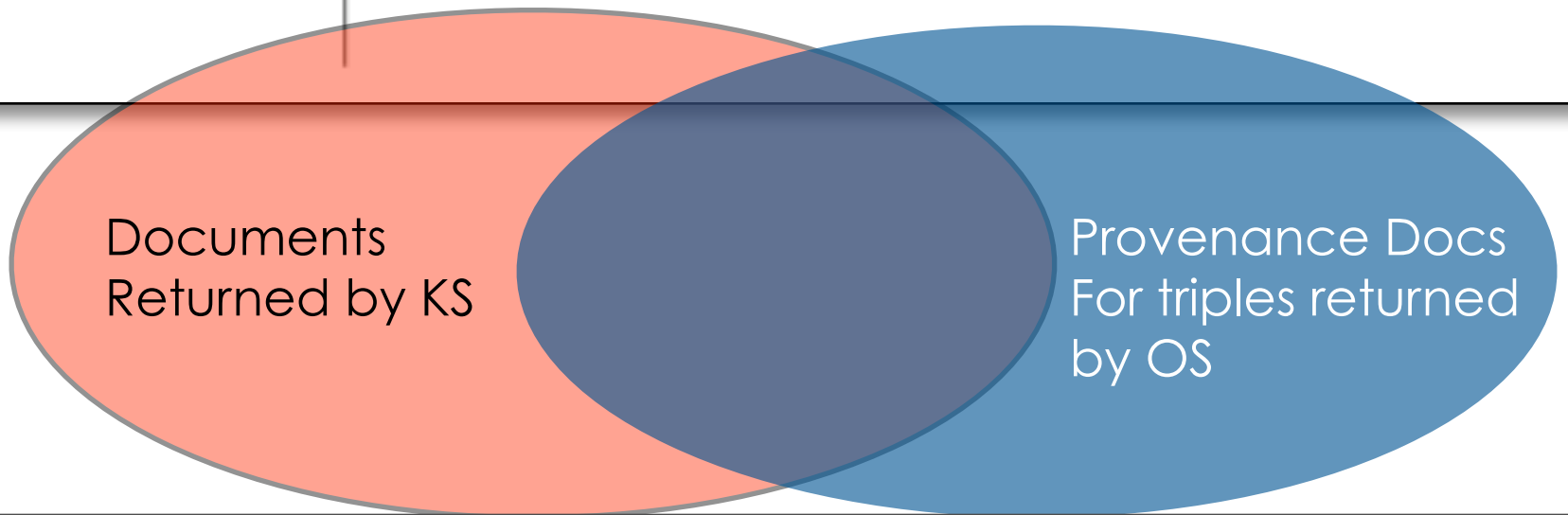


Merging results

- Provenance of triples returns document ids for triples (URIs)
  - Knowledge Searching
    - Triples returned by semantic search are filtered t
      remove those whose provenance does not point to
      any of the documents returned by the keywords

I won't mention ranking here

$$HSTripleSet = \{ \text{All } triples \in OSTripleSet \text{ Where } Provenance(triple^i) \in KSDocUriSet \}$$



Expected effect of HS: Document Searching

- With respect to OS
  - Recall expected to increase
    - Use of keywords where metadata is missing enables to answer otherwise impossible queries
  - Precision may suffer because of polysemy
- With respect to KS
  - Precision and recall expected to increase
    - Ambiguity and synonymity are dealt with by semantic search when available
      - Higher recall and precision
    - As keywords are combined with metadata in the same query, the context given by the available metadata helps in disambiguating keywords as well
      - higher precision

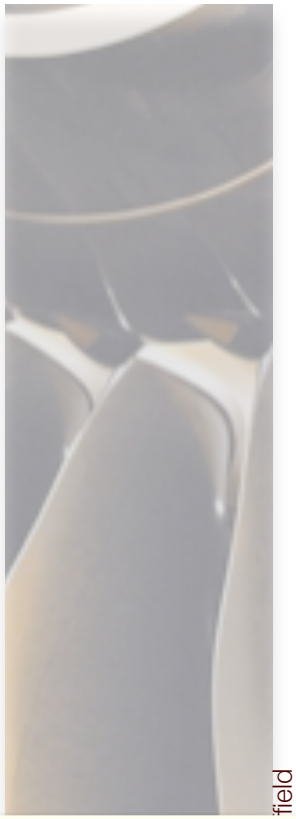
Expected effect of HS : Knowledge Searching

- With respect to OS
  - Precision increased
    - Use of keywords where metadata is missing enables more precise queries
      - although less precise than the ideal ones

OR

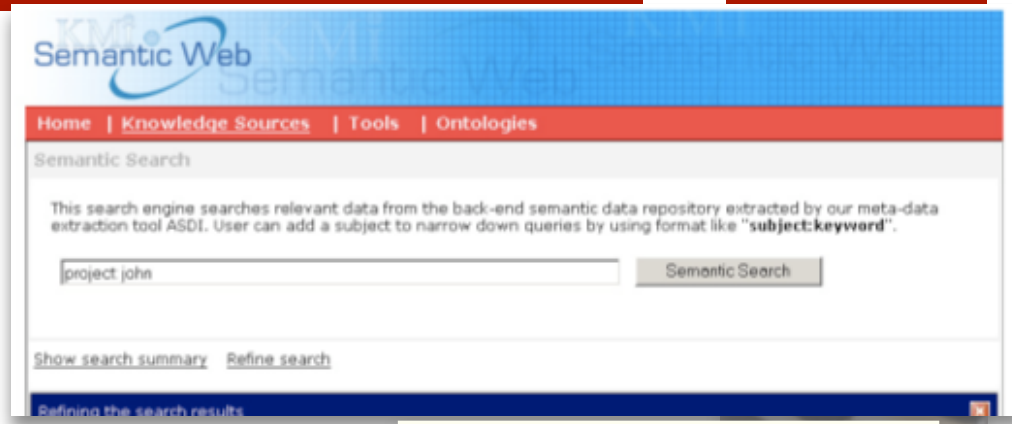
  - Recall increased
    - Use of keywords where metadata is missing enables to answer otherwise impossible queries
  - Precision may suffer because of polysemy

- With respect to KS
  - KS does not cover Knowledge Searching



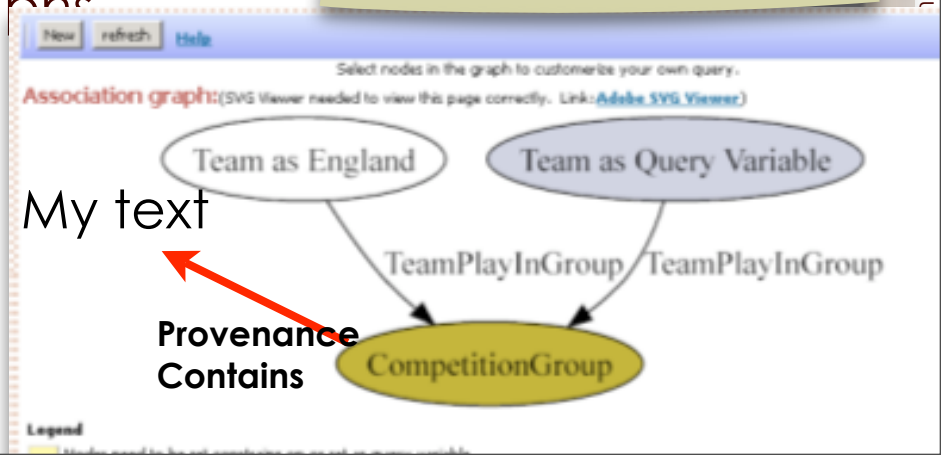
Next slide:
We have implemented a version to confirm our expectation

Implementing HS: What Search Strategy?



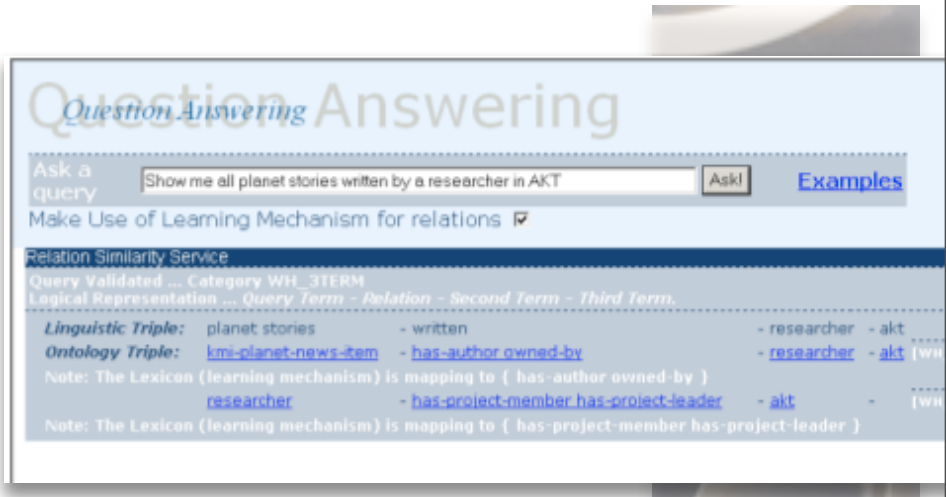
- Keyword-based approaches
  - Require translating all the keywords in order to perform the query
    - E.g. SemSearch
    - HS implemented by replacing keywords in the query with c the ontology when possible while leaving the rest for pure k based searching
    - Keywords in context rather difficult
- View-based approaches
  - Based on querying by building visual graphs
    - E.g. Falcon
    - HS support by adding two arc types
      - document-contains
      - Object description contains

Go through this and next slide very quickly !!

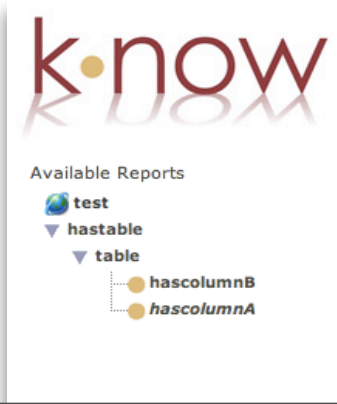


Search Strategy (ctd)

- A natural language approach
  - E.g. Aqua
  - HS suported by recognising expressions like
    - "and the document contains…"
    - And its description contains

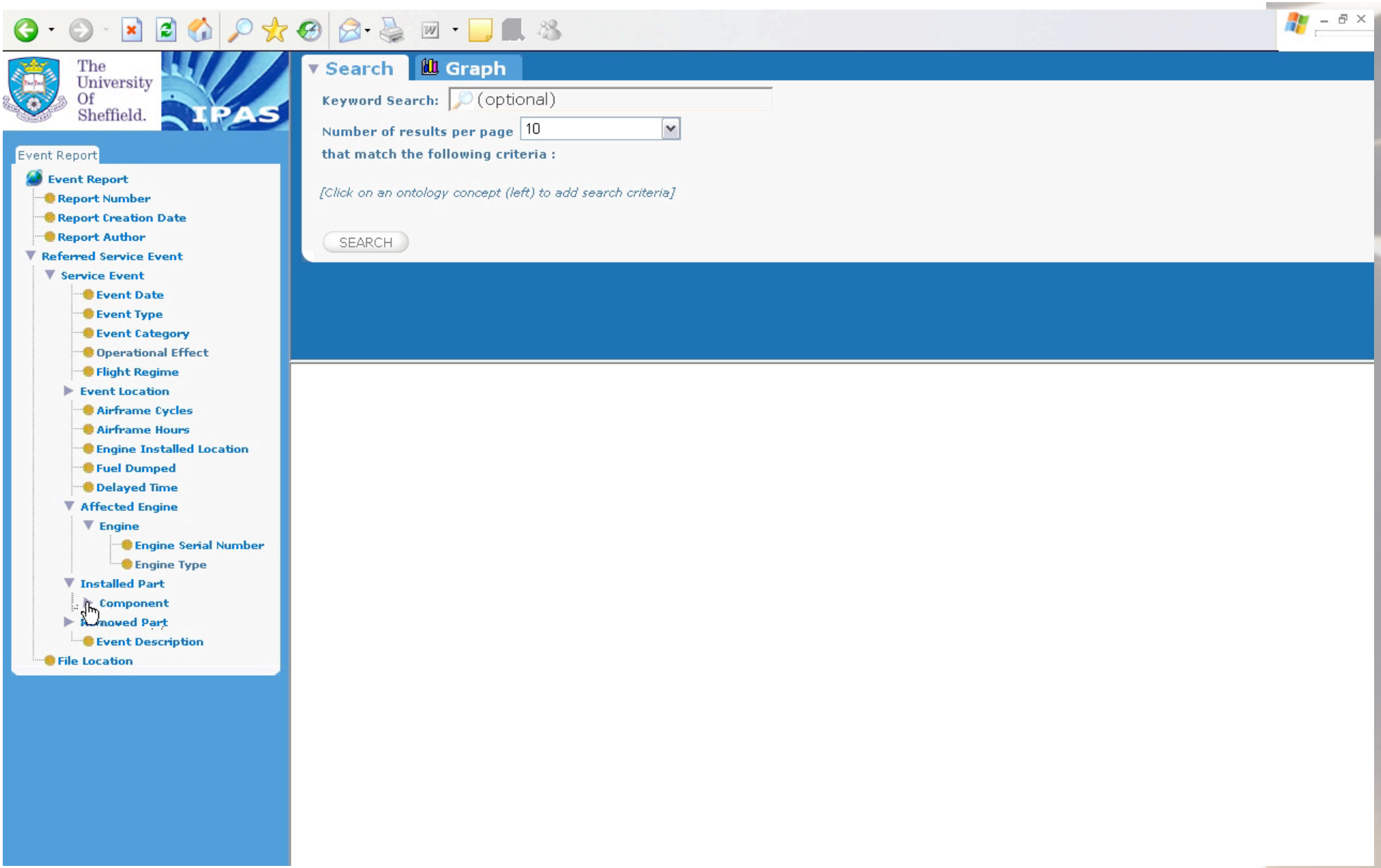


- Form-based approaches
  - HS supported by introducing
    - Keyword Search field
    - Enable keyword Matching on fields

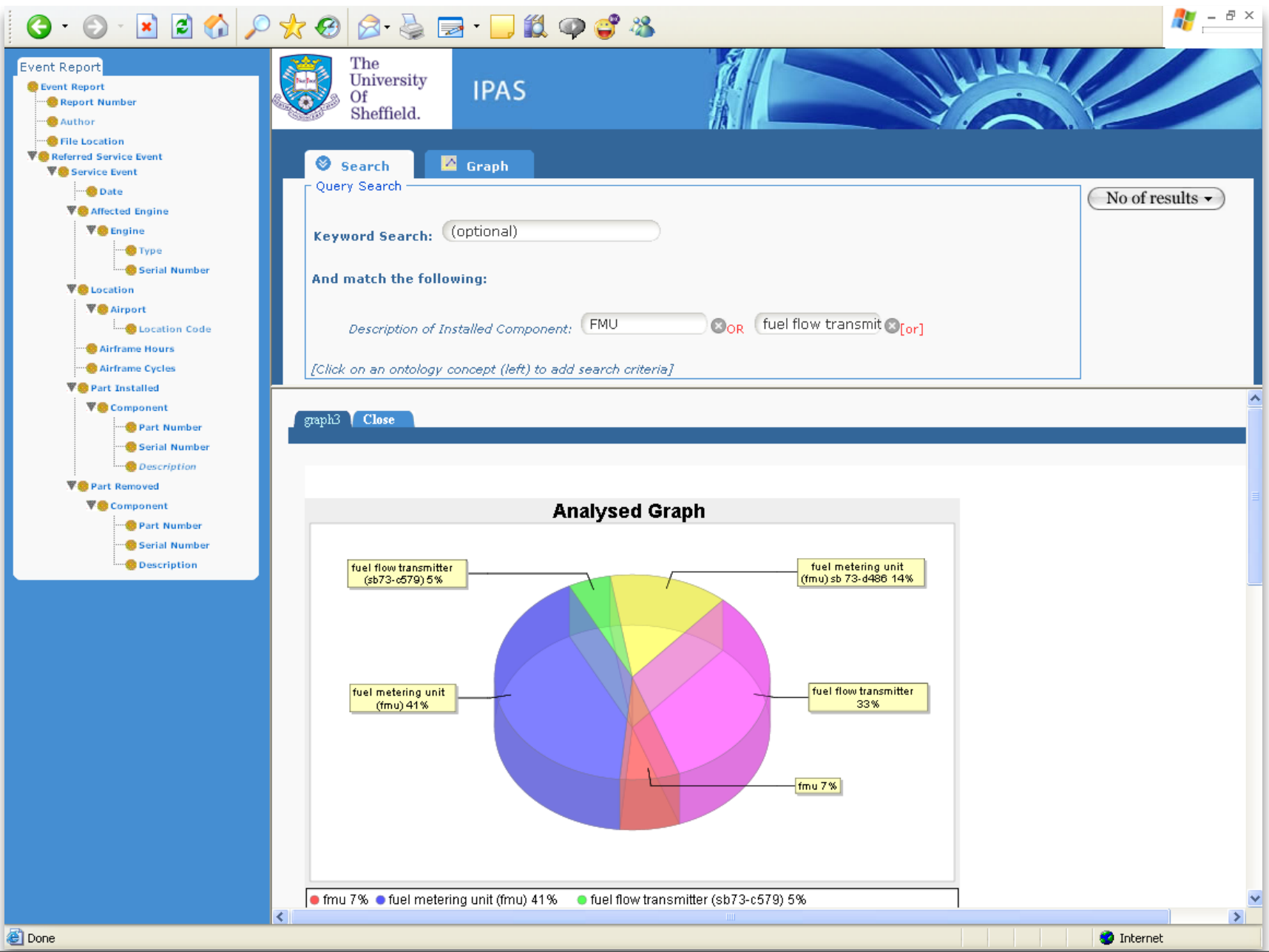


- Form-based implementation of hybrid search initially created for Jet Engine Designers

K-Search

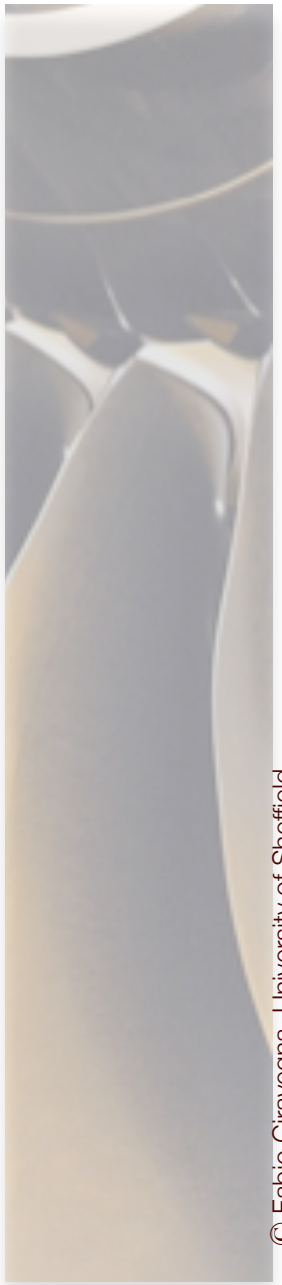


K-Search



K-Search evaluation

- We have performed 2 types of evaluations using K-Search:
  - in vitro:
    - Effectiveness of query strategy with respect to standard KS and OS
  - in vivo: testing the system with real users
    - 32 users Rolls-Royce engineers
      - Evaluation enables verifying suitability for use in a real environment



Annotating Documents

- Automatic extraction of information from event report
  - 18,000 documents analysed
    - Mainly Forms implemented in Word
- Metadata generated according to an ontology developed by Aberdeen U
- Automatic extraction of metadata and indexing of documents

IE unable to cover all the ontology with sufficient accuracy

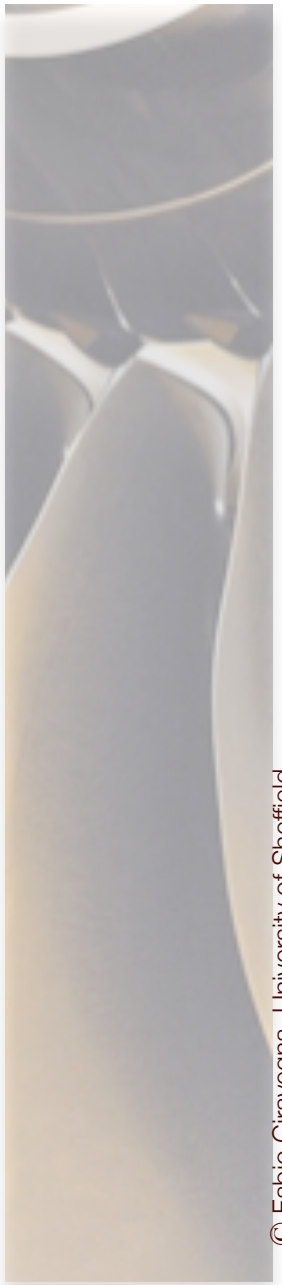
Applying information extraction

- AktiveMedia to annotate texts
- TRex system (Jiria et al. 2006) to train and extract
  - http://tyne.shef.ac.uk/t-rex/
- IE captures all the information in tables
  - 99% of the information captured (recall=99)
  - 98% of proposed information is correct (precision=98)

	POS	ACT	CORR	WRONG	MISSED	PREC	REC	F1
airport	120	120	120	0	0	100	100	100
has_airframe_cycles	104	104	104	0	0	100	100	100
has_airframe_hours	104	104	104	0	0	100	100	100
has_author	120	120	120	0	0	100	100	100
has_engine_serial_number	120	120	120	0	0	100	100	100
has_engine_type	120	120	120	0	0	100	100	100
has_event_date	120	120	120	0	0	100	100	100
has_event_report_no	356	358	356	2	0	99	100	100
has_part_description_installed	120	113	111	2	9	98	93	95
has_part_description_removed	120	133	120	13	0	90	100	95
has_part_number_installed	120	113	111	2	9	98	93	95
has_part_number_removed	120	133	119	14	1	89	99	94
TOTAL	**1644**	**1658**	**1625**	**33**	**19**	**98**	**99**	**98**

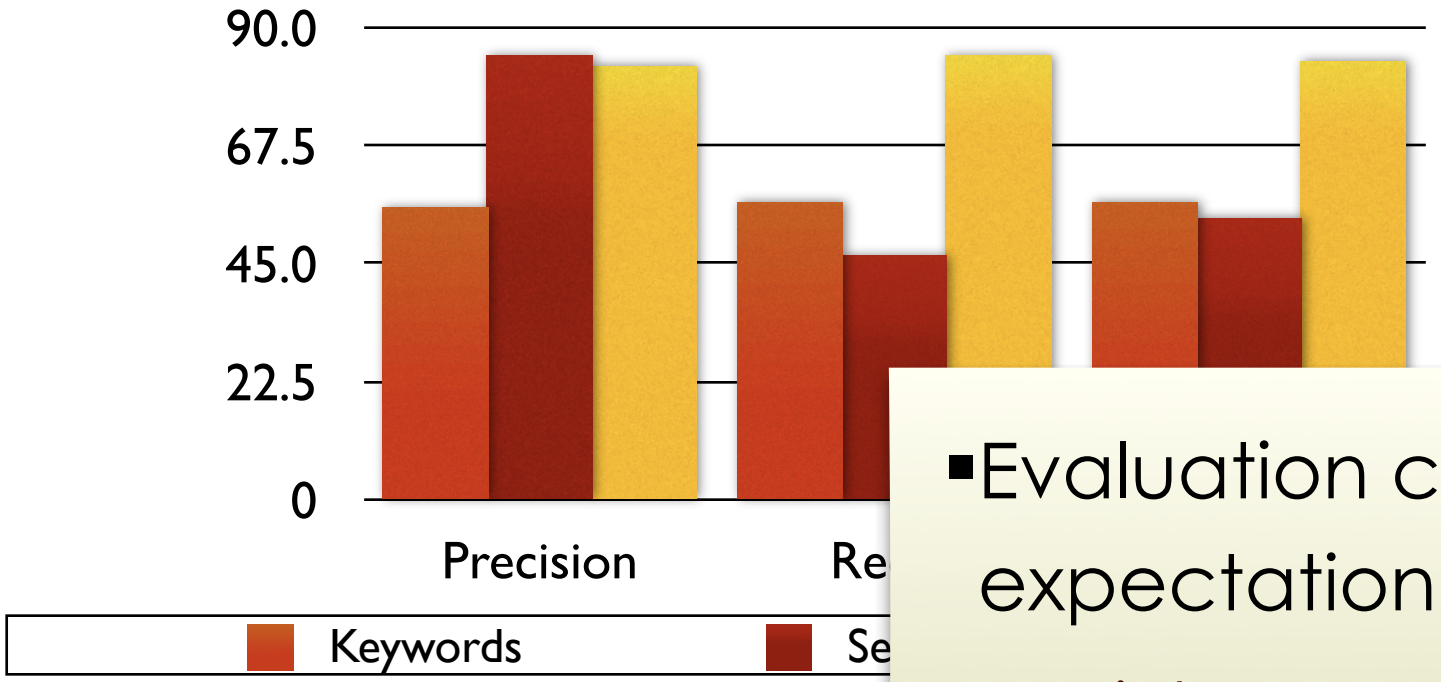
In vitro evaluation

- 21 topics of search, discussed with users, e.g.
  - "How many events were caused during maintenance in 2003?"
  - "What events were caused during maintenance in 2003 due to control units?"
  - 'Find al l the events associated with damage to acous- tic liners fol lowing bird strike"
- Queries:
  - "what events caused during maintenance in 2003 were due to control units?"
- Translated into a set of queries in KS, OS and HS



K-Search on Event Reports

- Accuracy in the first 20 hits on a sample of 400 docs



- Similar results for 50 hits

- Evaluation confirms our expectation:
  - Higher recall wrt OS and KS
  - Higher precision wrt KS
  - Slightly lower precision wrt OS

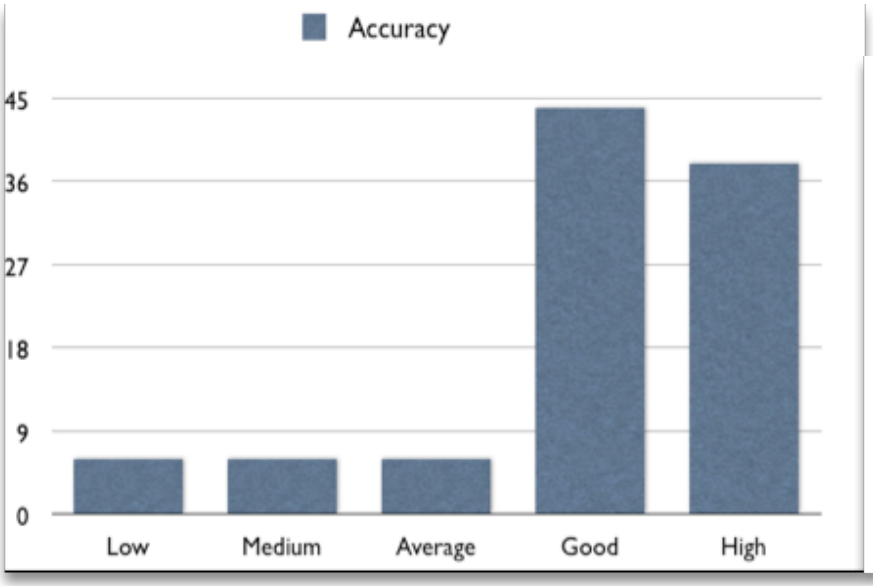
Final User Evaluation

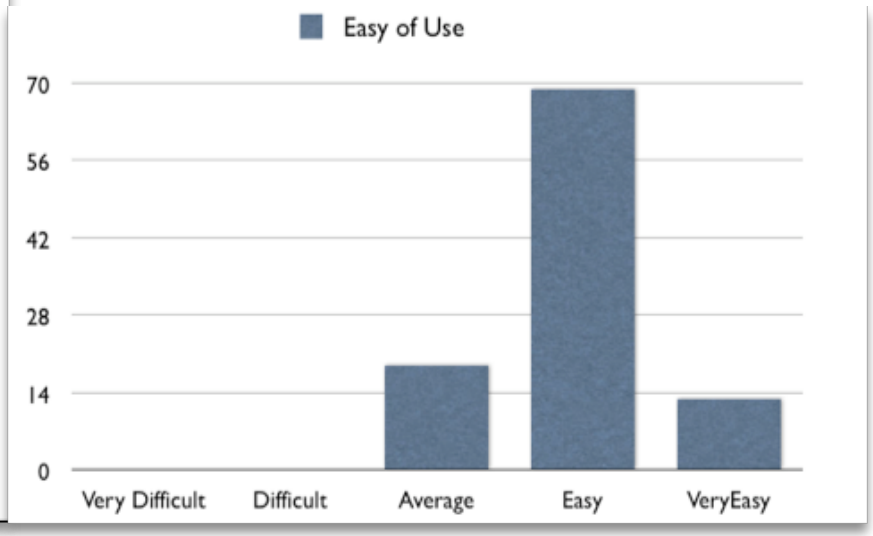
- Goal: verifying suitability for use in a real environment
  - 32 users Rolls-Royce engineers from different parts of the company
  - 90 minutes of test
    - Short introduction
    - 3 monitored tasks
      - One given (including solution)
      - One given (no solution)
      - One free task
  - Availability of system on intranet for the following period
- Evaluation: video recording, interview + log analysis

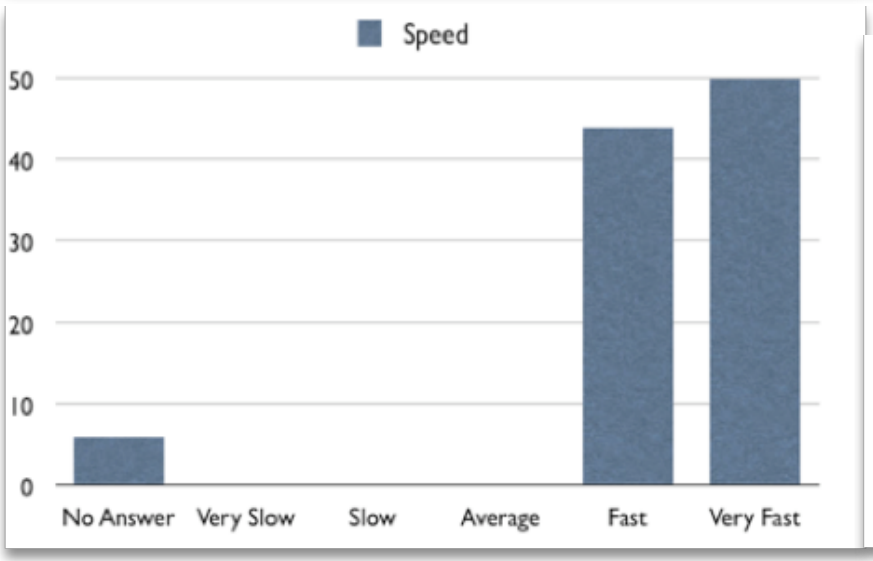
Evaluation Questions

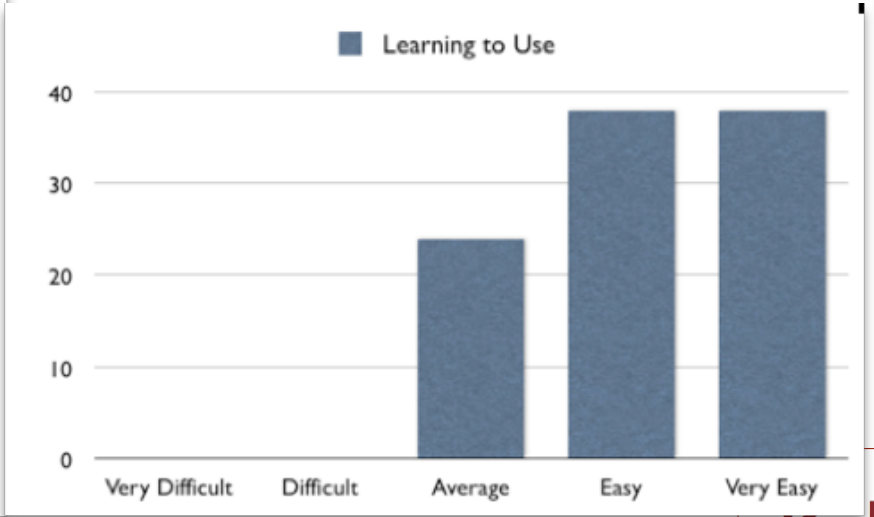
- Do user understand the hybrid paradigm?
- Are they able to search using HS?
- Do they actually use HS when confronted with a real searching task?
- Would the users be willing to use the system for their everyday work?

Liked by the users?









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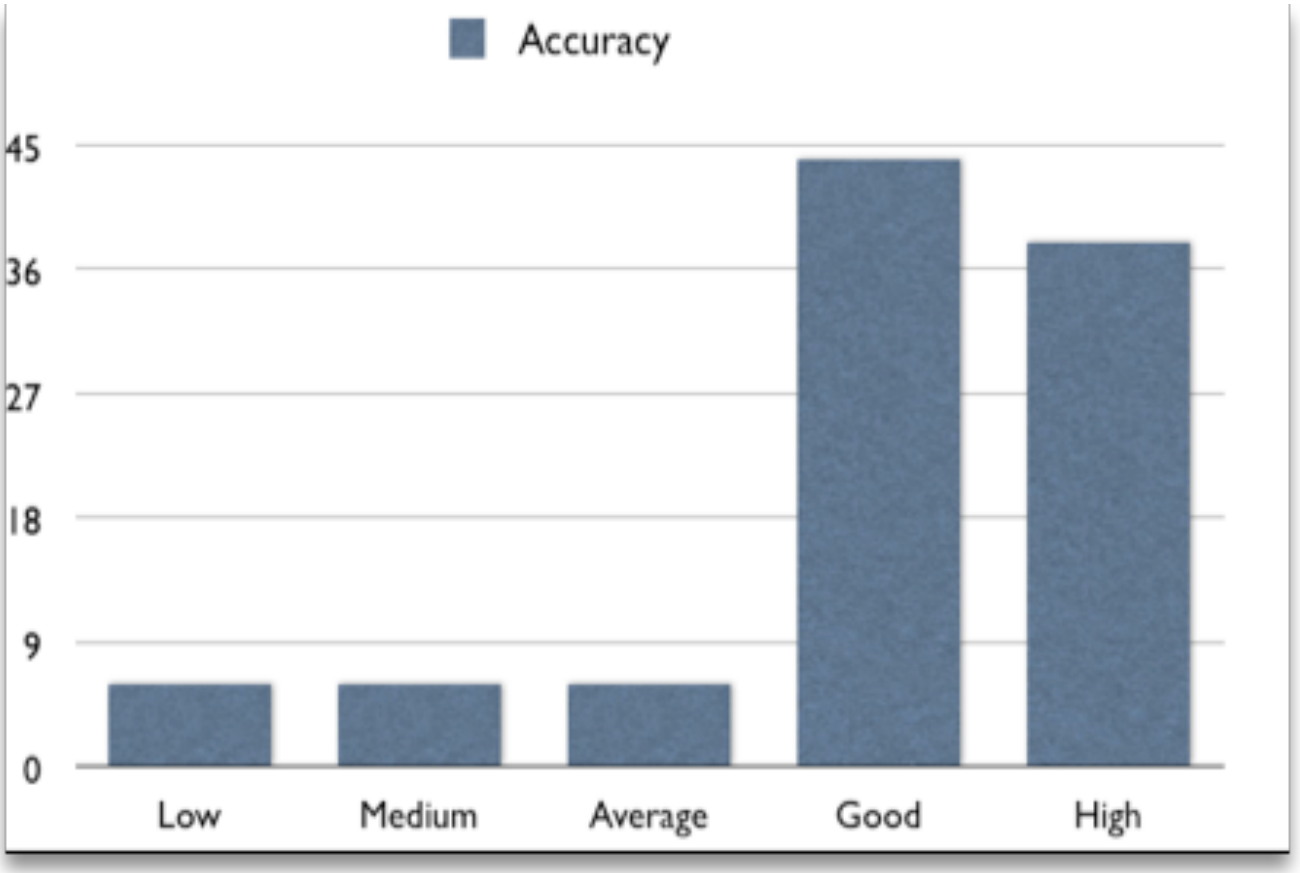

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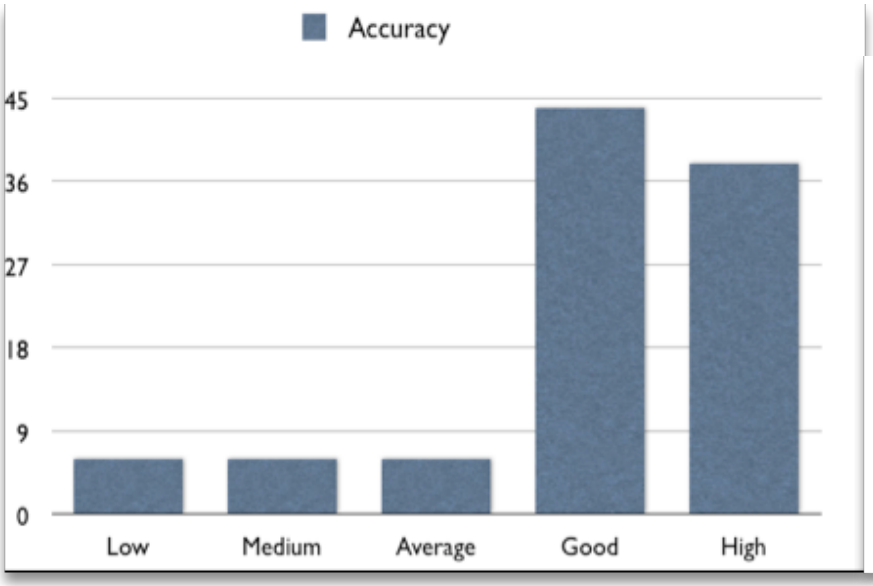

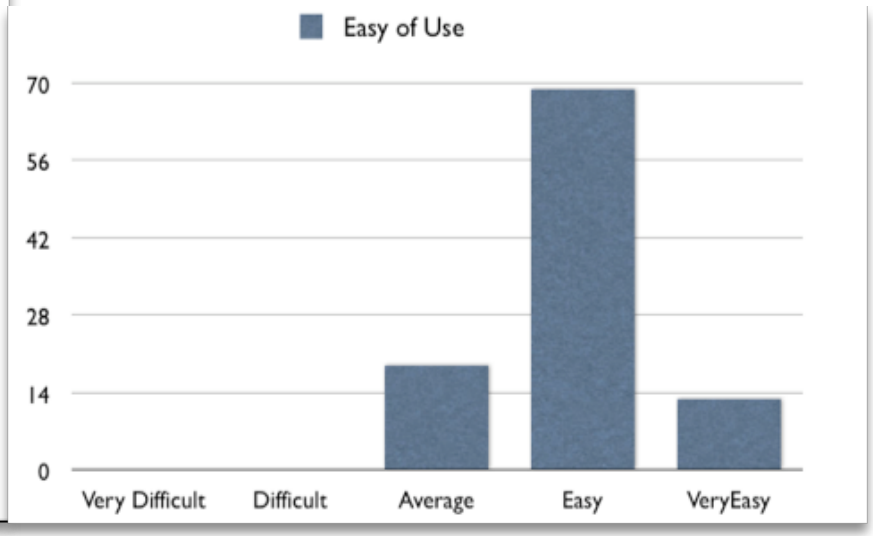

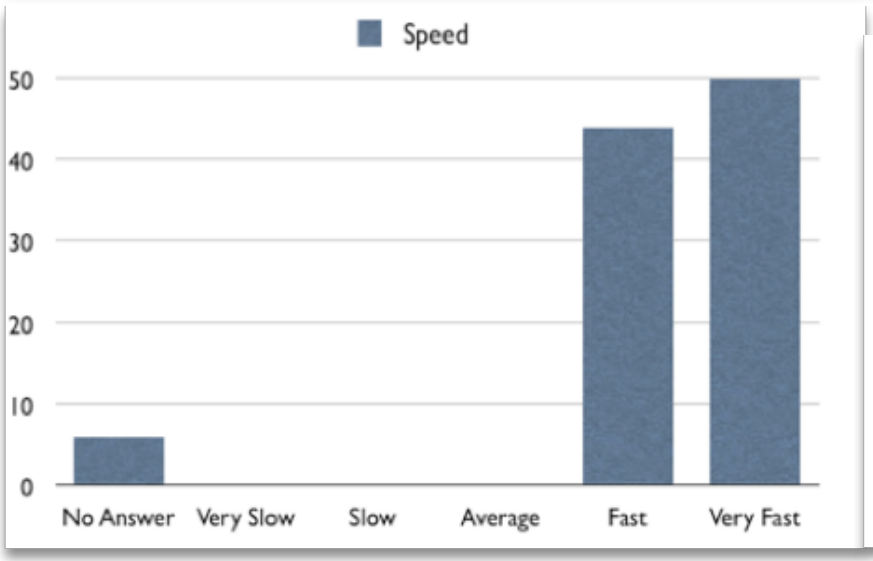

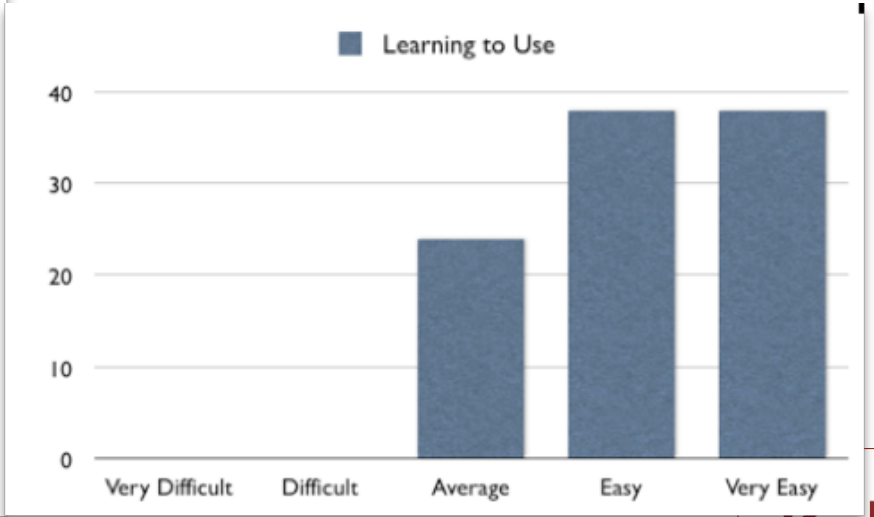

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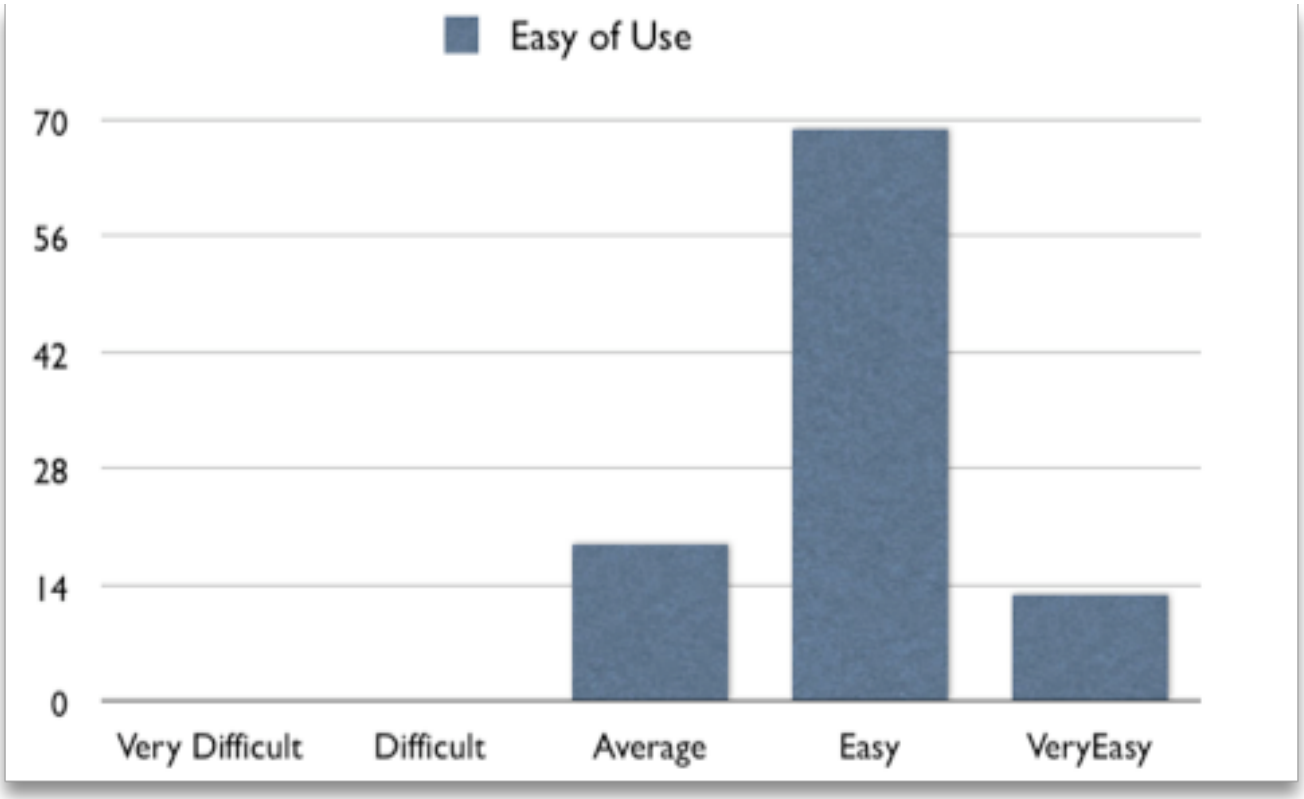

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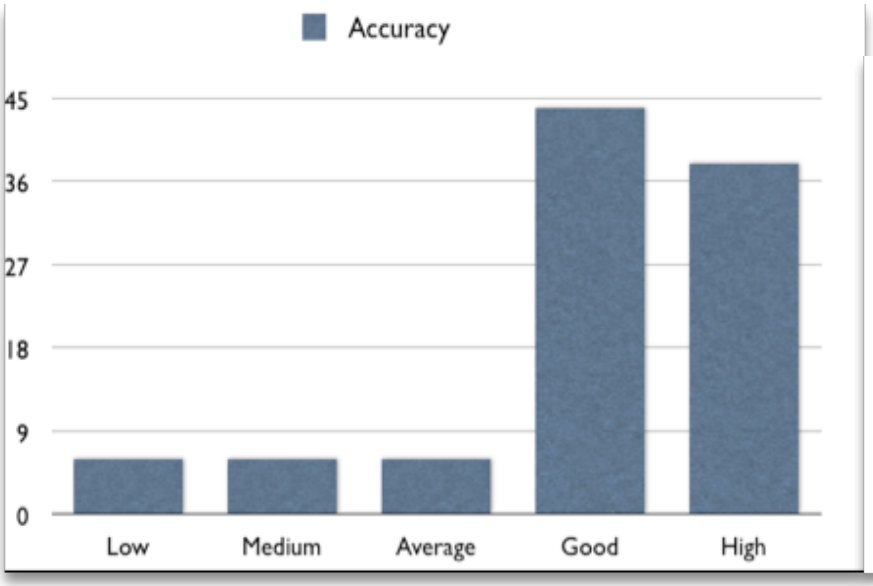

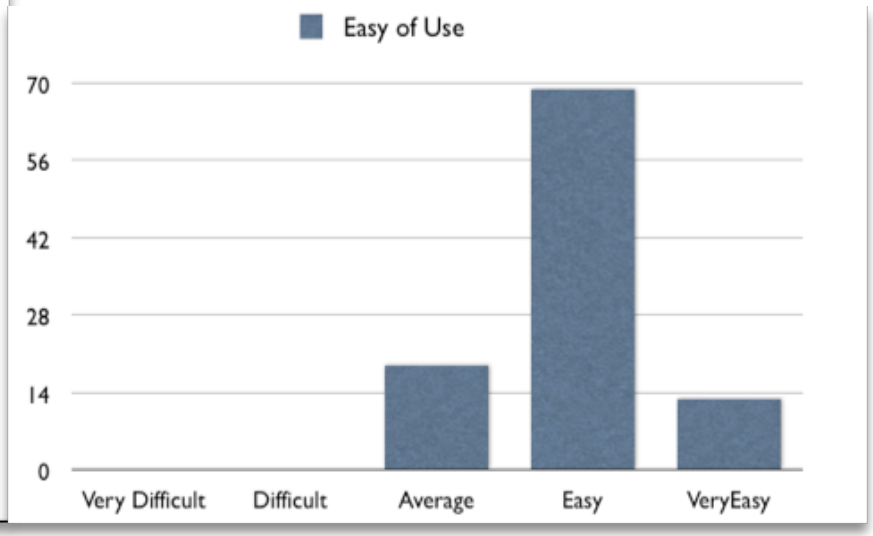

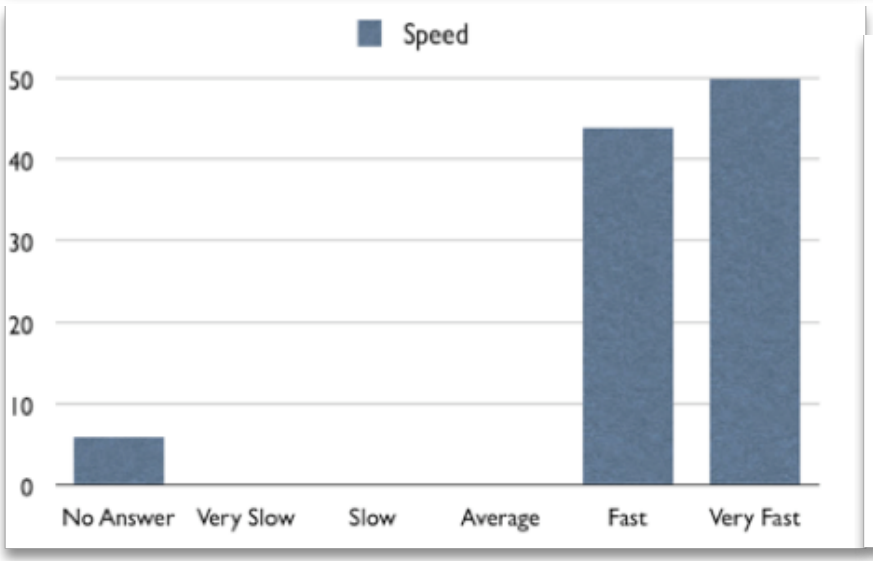

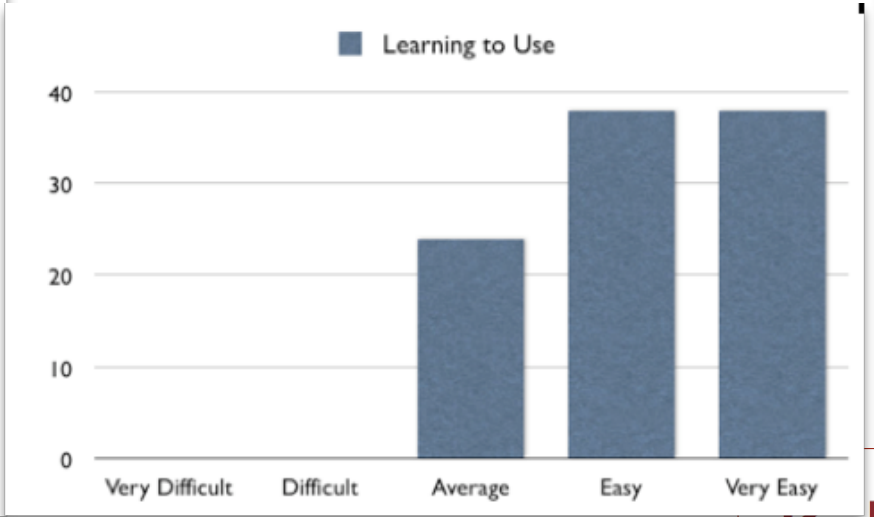

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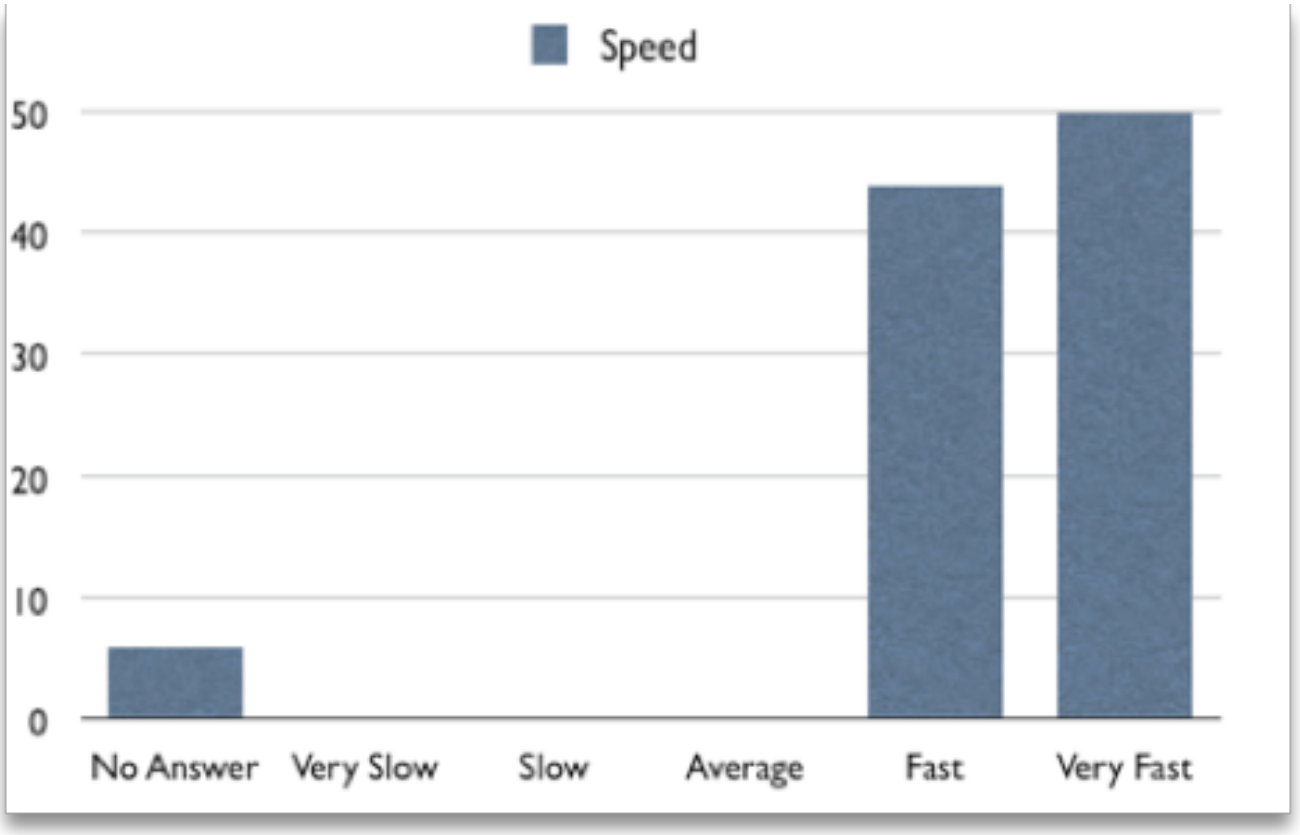

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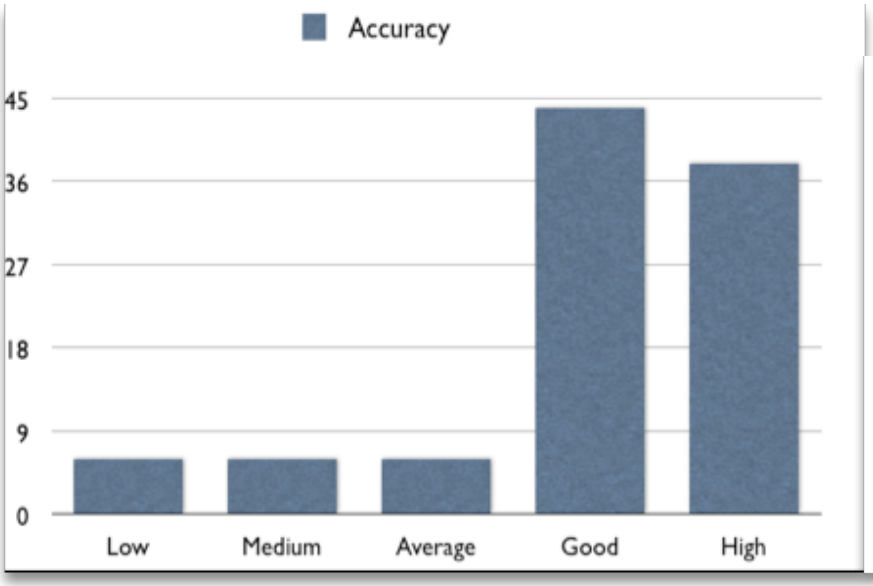

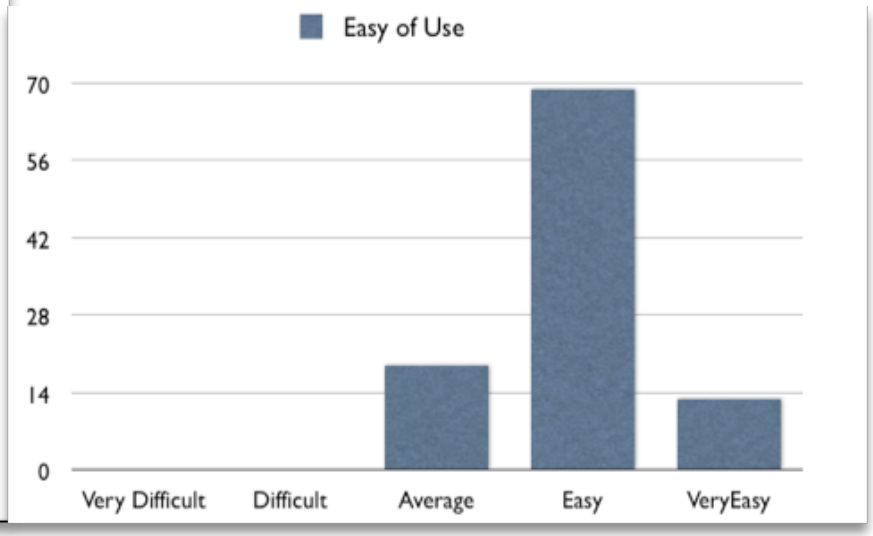

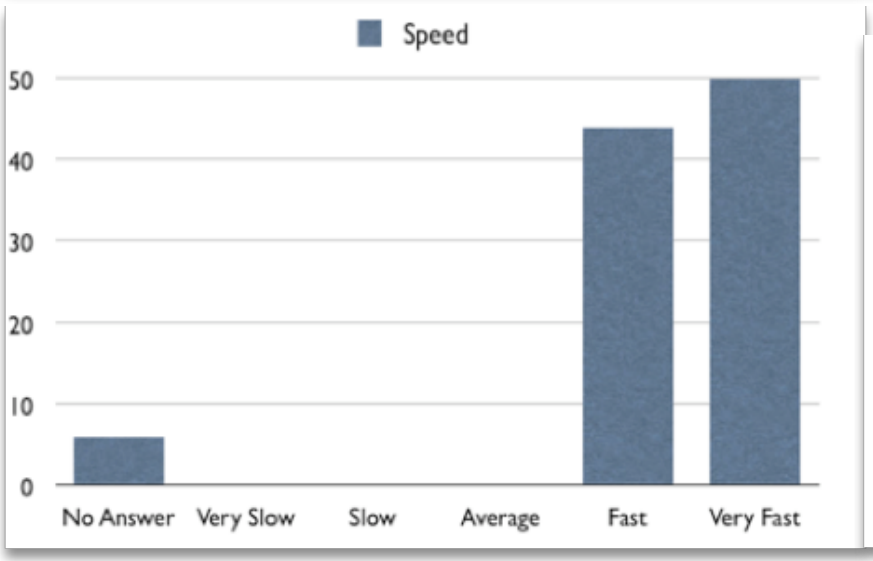

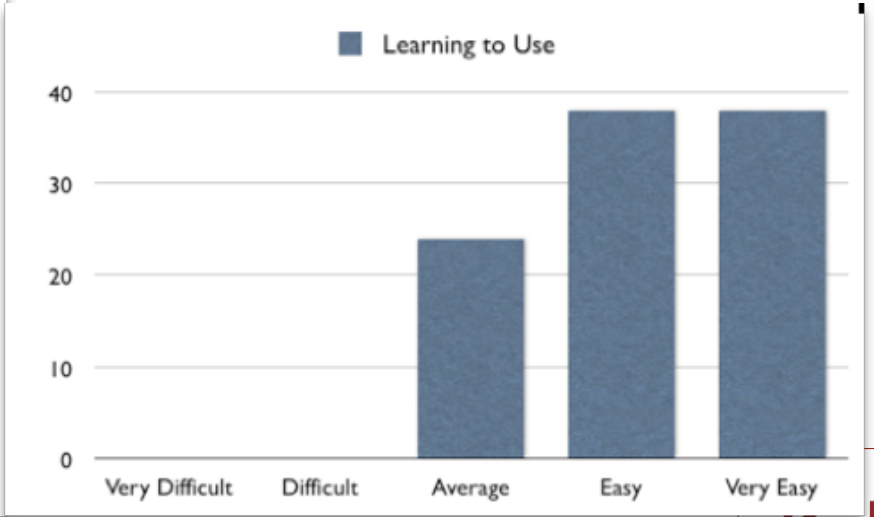

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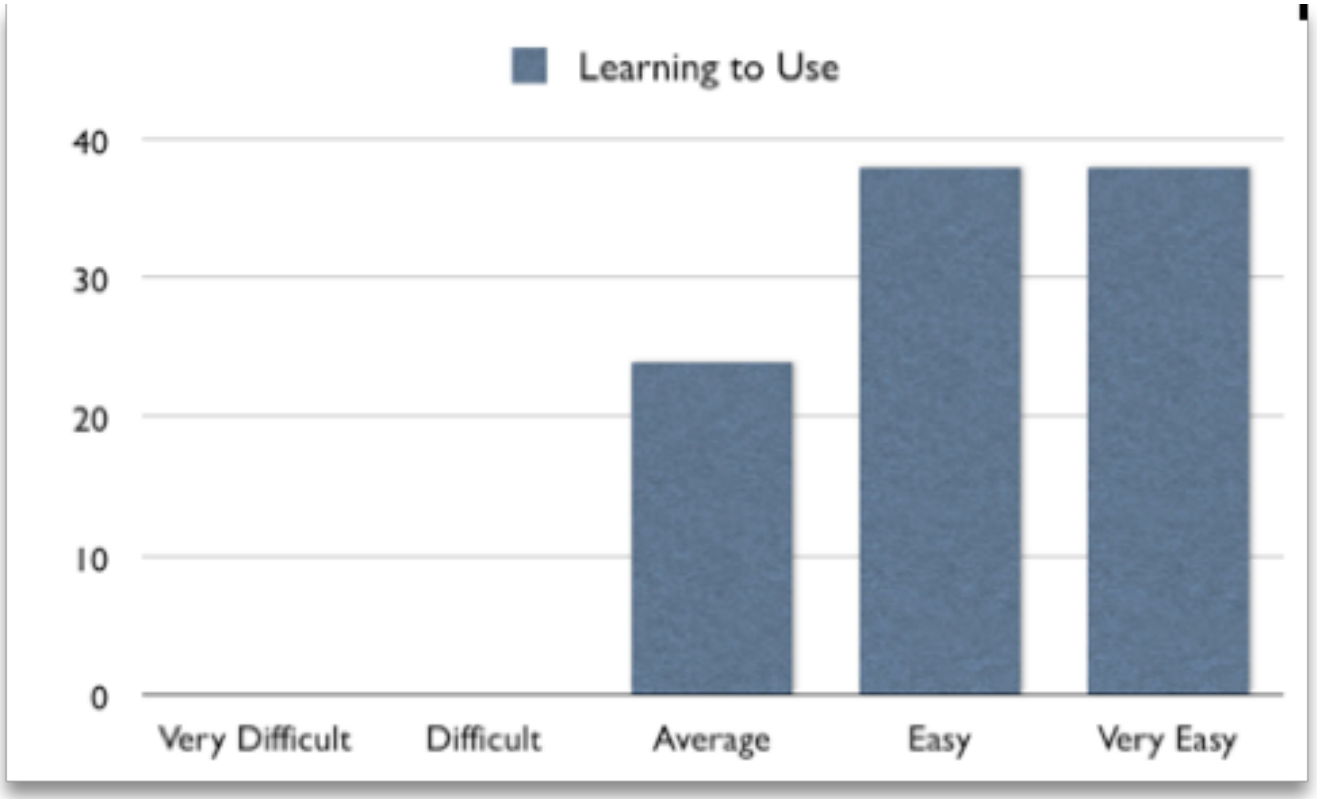

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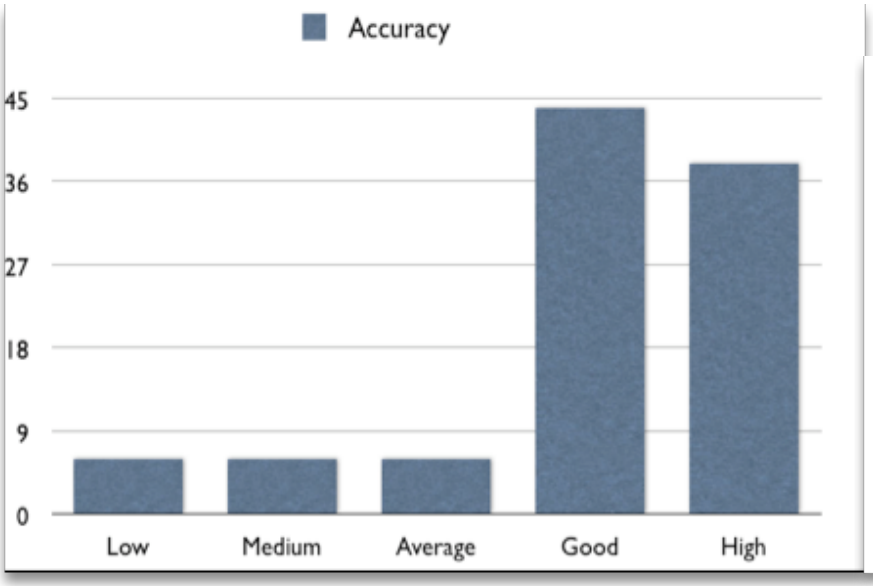
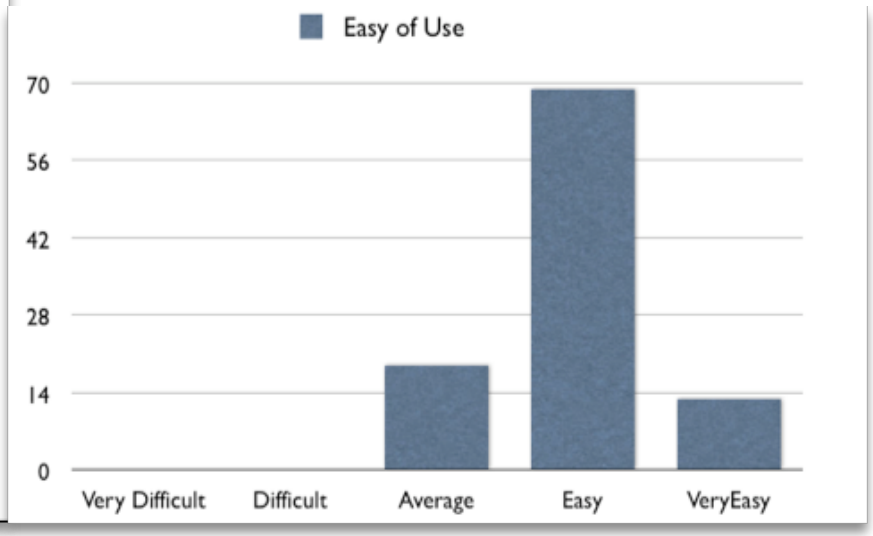
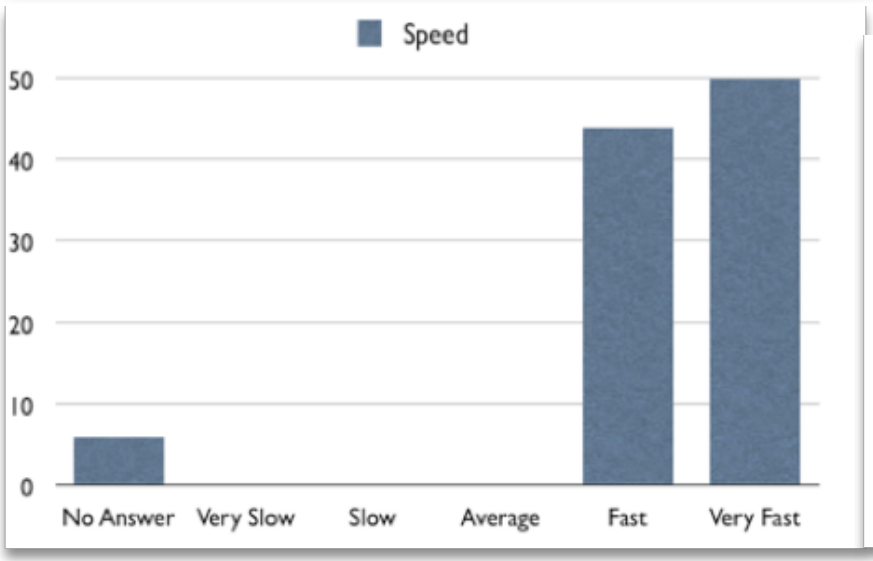
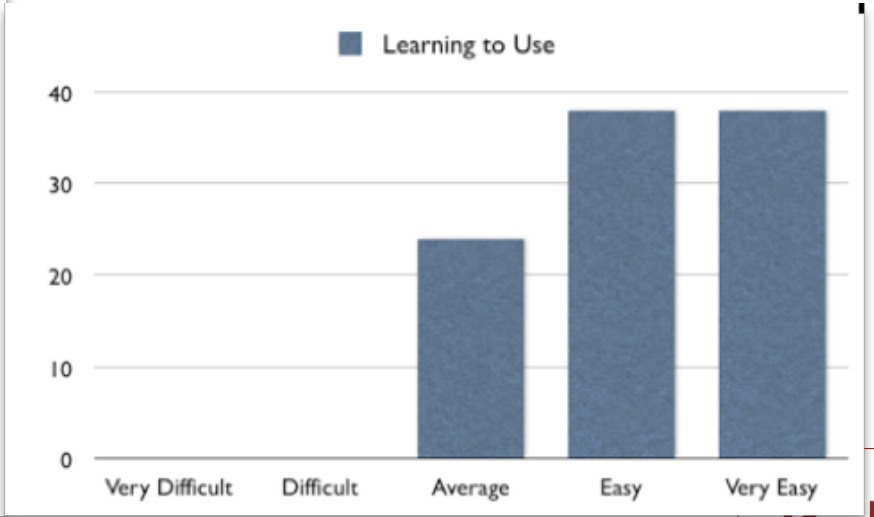








Search preferences: Service Engineers

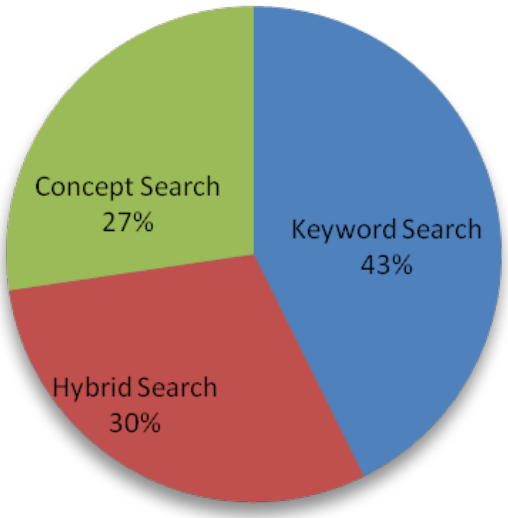
- Service engineers showed a clear predilection for hybrid search:
  - 61% of the search were executed using the hybrid modality
  - 24% using semantic search
  - 15% using keyword search.

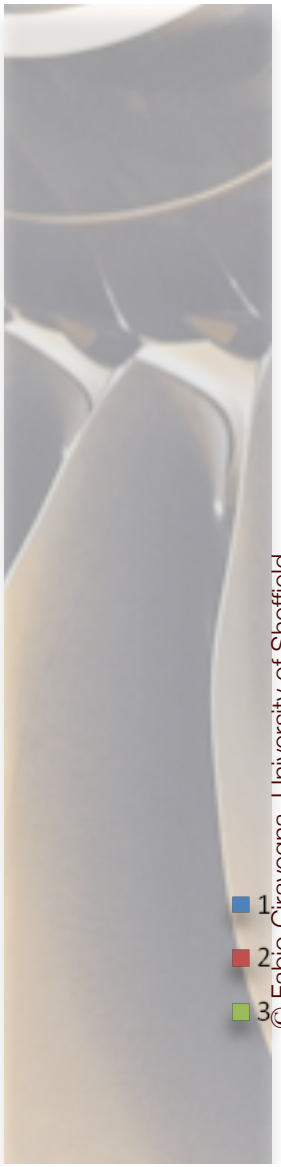
Go quickly on slides: just say different people used different strategies

Reason: data they were looking for was not all covered by the metadata

Search preferences: designers

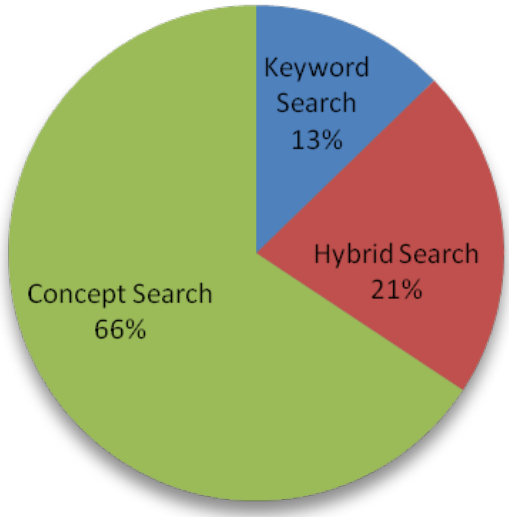
- Designers tended instead to favour keyword search:
  - 43% of the searches were executed using keyword search
  - 30% using hybrid
  - 27% using semantic search.





Search Strategies: Others

- The users belonging to other groups showed a predilection for concept search:
  - 66% of the searches were executed using semantic search
  - 24% using hybrid
  - 15% using keyword search.



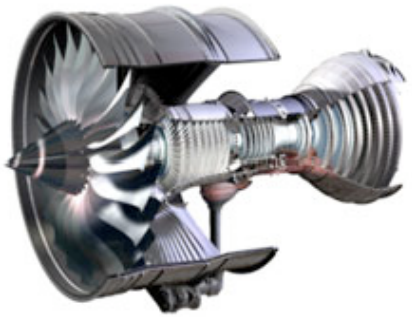
Liked by Users?

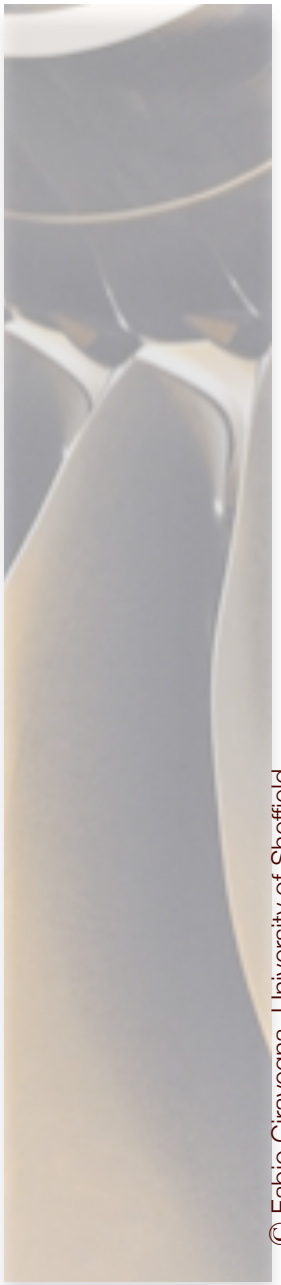
- Finalist of Rolls-Royce Director's Creativity Award 2007
  - Voted by employes for its innovation potential

Liked by Users?

- Support to the design of new Trent XWB
  - Porting to 9 Information Sources
    - 2008-2009
  - Carried out by:
    - 50% University
    - 50% k-now ltd (university spinout-company)

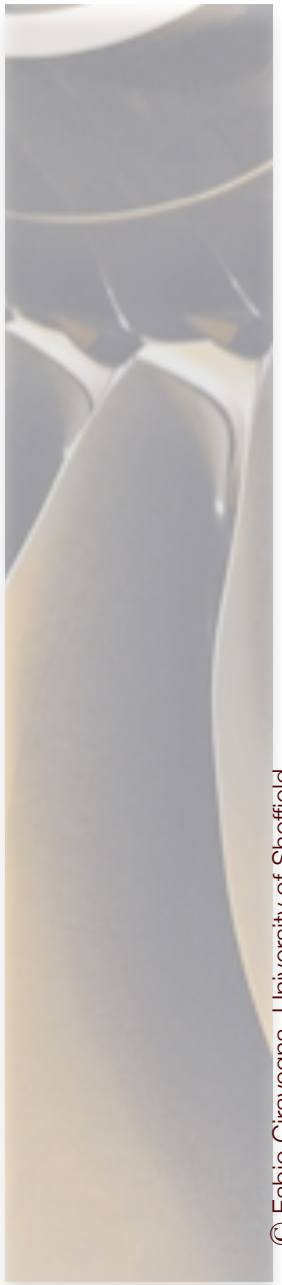
- Funds requested to UK Government for use of K-Tools for use in manufacturing





Conclusions

- Hybrid Search
  - It is compatible with the most used semantic search paradigms
    - Overcomes limitation of most current approaches based on metadata only
  - Accommodates different search strategies
    - Users can choose how to perform the query
  - Experimentally definitely outperforming both KS and OS



Future work

- Search across linked ontologies over intranet
- New ways of capturing information
  - User centred for new data
    - Cross-media
      - K-Forms
  - IE for legacy data
    - Cross-media

Thank You!

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