

Structuring and Visualizing Microgravity Material Science Data in a Topic Map Ontology

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ABSTRACT

Structuring and retrieving information is becoming a more and more challenging task. While classical search engines index data by performing a plain full text search, other approaches like semantic technologies aim at describing coherences among the data and thus refine them to valuable information. Those techniques find their way into the semantic web via new standards allowing interconnecting information on a worldwide scale. One ISO standard technology of expressing implicit knowledge structures constitutes topic maps. Topic maps combine the benefits of graph structures used in conceptual maps with the basic approach of indices. They are extensible, scalable and easily grasped by humans. Thus, they offer a powerful way of navigating large and interconnected knowledge structures.

This paper aims at adapting the topic map technology to experiments performed during parabolic flights on the DLR TEMPUS facility from 2003 onwards. TEMPUS is an electromagnetic levitation facility for containerless processing of metals and semiconductors under microgravity.

At DLR-MUSC, data concerning the TEMPUS experiments are structured and stored by using the Werum Hypertest platform. This commercial product was adapted to user requirements and needs and is subsequently further developed. It allows the edition of metadata like sample material, environmental parameters etc. which can also serve as atomic constituents for a domain ontology.

By pursuing that approach, the domain knowledge for several experiments is extracted from several information sources and modelled in a topic map ontology. The information resources contained in TEMPUS Hypertest are associated with the topic map. Possibilities of performing that task automatically and thus being able to populate the topic map by connecting the TEMPUS Hypertest database to the topic map ontology are discussed.

The information contained in the topic map is visualized via a web application which has been worked out at DLR-MUSC and which is based on the Ontopia Knowledge Suite (OKS). The quality of the ontology and added value is assessed by internal users.

Keywords: topic map, ontology, TEMPUS, Hypertest, ULISSE

INTRODUCTION

At DLR MUSC, a significant amount of data is being produced by various spaceflight projects. Most likely, the amount of data will increase due to ongoing and future experiments on the International Space Station ISS. To bypass possible bottlenecks and shortages, DLR MUSC set up long term data archives based on the Werum HYPERTEST® platform a few years ago. They support the tasks of data storage, archival, distribution and retrieval.

The more extensive and diverse data storage becomes, the more one strives to classify the contents in a larger context and find coherences and synergies among them. This in particular concerns the TEMPUS¹ project, because apart from the scientific interest, the TEMPUS experiments on short duration flight carriers like parabolic flights or sounding rockets serve as a preparation for future experiments on the ISS. This makes it interesting to efficiently have recourse to the stored knowledge, also for a future user who is new to the data pool and eventually does not know which kind of information is available. Hereby, semantic techniques may provide possibilities for linking distributed information in a more sophisticated manner.

As a state-of-the art technology, topic maps constitute a highly interesting data model because they provide a subject-centric access to the available knowledge.² In contrast to semantic web technologies like RDF/S and OWL, which are intended to provide a foundation for logical inferencing through the web, topic maps were created to support high-level indexing of sets of information resources to make information in them findable [5].

This paper aims at describing an application of the topic map technology to a productive local data archive, i.e. to the above described TEMPUS data archive which contains about 1.3 TB of data. The application *Hypergator* was developed at DLR MUSC and offers a web-based semantic navigation interface for the TEMPUS data archive and is based on the open-source Java framework OKS.

In a larger context, that questioning will be investigated in the general framework of space applications by the 7th European framework project ULISSE³ [6]. The participants will conceive a network of operative centres in space experimentation from different scientific disciplines pursuing the valorisation, dissemination and exploitation of scientific data from space experiments.

The paper is structured as follows: After a brief introduction into the TEMPUS Hypertest data management system, possible improvements related to a semantic enhancement are discussed. A short excursion into topic maps will build a basis for the Hypergator application which is described afterwards, illustrating its benefits.

¹ c.f. the German abbreviation „Tiegelfreies ElektroMagnetisches Prozessieren Unter Schwerelosigkeit“, translated to „containerless electromagnetic processing under microgravity conditions”

² Subject-centric computing is a branch of computing theory and practices which emphasizes the primacy of subjects and their interrelationships in all forms of information and knowledge management.

³ ULISSE stands for USOCs KnowLedge Integration and dissemination for Space Science and Exploration

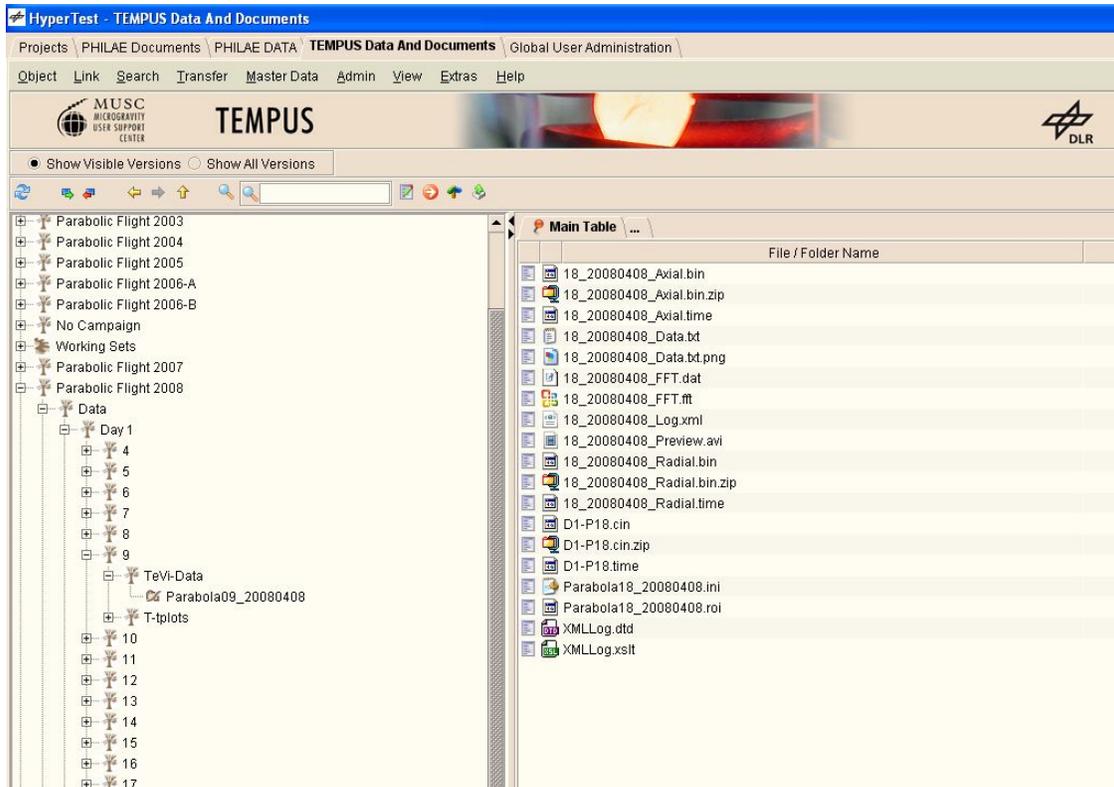


Figure 1: TEMPUS Hypertest navigation structure

THE TEMPUS HYPERTEST DATA MANAGEMENT SYSTEM

The TEMPUS Hypertest archive is capable of dealing with literally all kind of data coming from the various TEMPUS measurement devices. They comprise e.g. videos of an advancing solidification front recorded by a High Speed Camera as well as calibrated data files containing heating and positioning data for the samples. Therefore, the data yield of parabolic flight campaigns can be sets of heterogeneous data, accompanied by documentation and campaign reports.

HYPERTEST® does not reveal the physical storage location of data to the end user but provides access either via the Graphical User Interface (GUI) or the Application Programming Interface (API). The architecture has been developed as a distributed client/server application in J2EE technology and can be run over internet protocols. Among other features, it supports user authorization and access logging. Data can be retrieved either by search queries or by navigation in logical metadata structures. The GUI offers features for manual or semi-automatic data ingestion.⁴

For the TEMPUS Hypertest application, a typical data volume of about 250GB per flight campaign is uploaded to the system immediately after the campaign has finished. The data is then enriched with metadata which determines the navigation structure for the GUI (see figure 1).

⁴ For the Philae Lander project, also third-party ingestion tools exist at DLR MUSC communicating with HYPERTEST® through the API.

Show TEMPUS Folder Parabola15_20080408

Folder Name: Parabola15_20080408

Data Storage Name: pf2008 (file:/mnt/httempus/pf2008)

Path:

TeVi Relevance: Relevant Default path (relative to Data Storage) for files in this container

Data / Document Type: TeVi-Data Category: Data

Principal Investigator: MPI Sample Material: NIAI-Re1,25

Campaign: Parabolic Flight 2008 Day / Experiment: Day 1

Parabola #	Comment
15	

Date Current Version: 2008-04-23

Organization:

Author:

Title: Parabola15_20080408

Identifier: - - TeVi - -

Issue: Revision:

Process Atmosphere: Ar+He.quench	Camera Radial: Highspeed 200 Hz (608...	Camera Axial: Loglux 150 Hz (352 x 352 Pixel)
Sample Size: 6.5	Pyrometer Radial: <input type="text"/>	Pyrometer Axial: ZPY
TLimit: <input type="text"/>	Melting Point: 1668	Emissivity: 0.25

Keywords:

Figure 2: Excerpt of TEMPUS Parabola Metadata description

The description of TEMPUS data via metadata is organized around the entity of a flight campaign. It reflects the fact that flight campaigns take place once or twice per year and consist of several flight days each. Every flight day, exactly one flight on the A300 Zero-G takes place. The flight itself normally consists of 31 parabolas.

In the TEMPUS device, one single sample is processed during each parabola. This process can be considered as an experiment run for which a Principal Investigator (PI), either a person or a group, is in charge.

During the setup of TEMPUS Hypertest, necessary metadata were identified and implemented into the system. An according parabola object type was declared and associated with the identified metadata. It forms a central object type in the data organization and enables the indication of PI, sample material and probe properties as well as instrument settings.

Specific metadata associated with the parabola (like parabolic flight campaign and flight day as well as the ordinal number of the parabola) are evaluated by the application server to build up the tree-like navigation structure for the GUI, some other metadata like the above mentioned instruments settings contain experiment specific information like showed in figure 2.

The resulting data files belonging to single parabolas (or experiment runs) can be associated to a parabola object in HYPERTEST® as *TEMPUS subfiles*. They then appear in the navigation structure beneath the parabola nodes. Via metadata, it is possible to declare data files as e.g. *Documents* and thus make them visible in a dedicated documentation folder beneath the associated parabola node. Via GUI or API, data can be retrieved through the navigation structure or via queries over the metadata whereby metadata queries can use Boolean logic.

Taking an inventory

TEMPUS Hypertest has introduced the description of heterogeneous data through a defined set metadata. This enables a structured view to the data. However, some innovations are envisaged:

Improvement of navigation

In fact, TEMPUS Hypertest enables a structured view, but only *one specific* structured view which has been hard coded by the way the metadata structure is interpreted by the application server and presented in the GUI.

If one wanted to see the same data grouped according to the used samples, he would have the GUI to be programmed anew by the manufacturer. The tree structure has been optimally designed in view of parabolic campaigns. Some flexible view would be helpful.

System extension

Depending on the experimental setup, new metadata types may become desirable. A version of HYPERTEST® which enables the definition of variable metadata as attributes for objects has been introduced at MUSC. However, those variable metadata are still associated with pre-defined object types which may restrict general applications.

Furthermore, one could be interested in adding entire pieces of information like a taxonomy of alloys and their properties. Also information about the involved people and their activities in scientific programmes as well as related papers could be an issue.

There might be a whole bunch of applicable documentation, possibly structured or indexed in an independent system. One would like to seamlessly integrate it and at the same time link it to the right data.

Actually, the platform does not allow merging new information easily.

Implicit Data coherence and information retrieval

Data can be retrieved through the navigation structure, through a full-text search or via queries over the metadata whereby Boolean logic can be used to combine metadata properties.

However, lots of implicit information can not be directly accessed. If one wanted to know who has worked on which materials, he would have to set-up SQL-like, but proprietary queries, and channel them through the API. The result would come as a list rather than as a visualized structure.

Still then, and that's an intrinsic constraint, the coherence between information like metadata remains invisible. The system does not distinguish between the meanings of the Metadata "Principal Investigator" and "video settings". In view of the Hypertest system, they both are simple properties of the parabola (or more technically: properties of the associated TEMPUS folder object). The fact that the Principal Investigator stands for the entire experiment remains invisible, likewise that a video has been recorded by a specific camera or a parabola is part of a larger experimental programme. Again, a semantic approach solves the problem. Once having valorised the data with semantic information, a flexible visualisation structure should be able to reveal much more information.

A semantic approach for performing that task and its application to the use case of TEMPUS Hypertest shall be presented in the following.

TOWARDS A SEMANTIC DATA ARCHIVE

A semantic approach with topic maps

Adding semantics means giving data a meaning. Hereby, the leap from data to information is performed by adding relations among raw, and therefore meaningless, data. Knowledge can then be considered as an appropriate collection of useful information. Consequently, adding relations and recognising patterns between information can lead to knowledge. Several approaches for the description of knowledge structures exist, ranging from conceptual maps over taxonomies to semantic web technologies like RDF/S and the mathematically accurate OWL.

Another technique came up in the beginning of the 90's of the last century with the development of topic maps. The idea comprises the description of knowledge structures via maps and the association with pieces of information resources. Thus, they form a map of the described knowledge and allow direct access to pieces of information through indexed links. The benefit is obvious: one combines the advantages of graphs (e.g. conceptual maps) with those of plain indexes, as being used in libraries for centuries.

Three principle constituents build the framework of the topic map data structure. They are hereby briefly introduced and illustrated in the TEMPUS topic map example.⁵

- One starts from an arbitrary thing, not less general, which shall be denoted as a *subject* from now on. A **Topic** is then considered to be a representation of a subject. One strives for a one-to-one relation between topic and subject, means ideally there is only one topic per subject to have a single access point for the knowledge about that subject⁶.

Topics have a type (which is in turn a topic). Topics in figure 3 are *Nickel* and *Ni25Al75* of type *Material* (illustrated by a rhombus; in figure 3, different types are visualised by different shapes) or a *campaign report* of type *Document* (in figure 3, illustrated by a star).

- There can be **Associations** among topics. Again, associations can have different types whereby the participants of the association play different **Roles**. There can be an association of type *is component of* between two materials or a *Principal Investigation* association between an experiment run and a person. In the latter case, the person takes the role of *Principal Investigator*. In other associations, e.g. the *employment* association, the same person may take the role of an *employee*.

- Topics can be linked to information resources, which are relevant for the topic somehow. Those are called **Occurrences**. For instance, an occurrence for the material Nickel can be the occurrence *Ni* of the occurrence type *chemical sign*, or the string *0221-xyz* of occurrence type *phone number* as occurrence for the topic *L.G.*⁷ of topic type *person*. Also a piece of software can be an occurrence, e.g. a script for providing access to a document.

Note that topic maps exist outside and even independent of the information resource, they only describe abstract conceptual frameworks, also known as Ontologies. The ontology contains the information about topic types and their associations among as well as the allowed occurrence types. The concrete instantiation of topics of various types, the definition of their interconnection through the setup of concrete associations and finally the connection to concrete occurrences remains the task of topic map population.

⁵ A non-technical introduction to topic maps can be found e.g. [4], only the basic idea and its application to TEMPUS Hypertest shall be conveyed here.

⁶ The distinction between topic and subject and relation of topic and subject is a very old philosophical question, c.f. Plato's allegory of the cave

⁷ In this paper, references to PI's shall be anonymized.

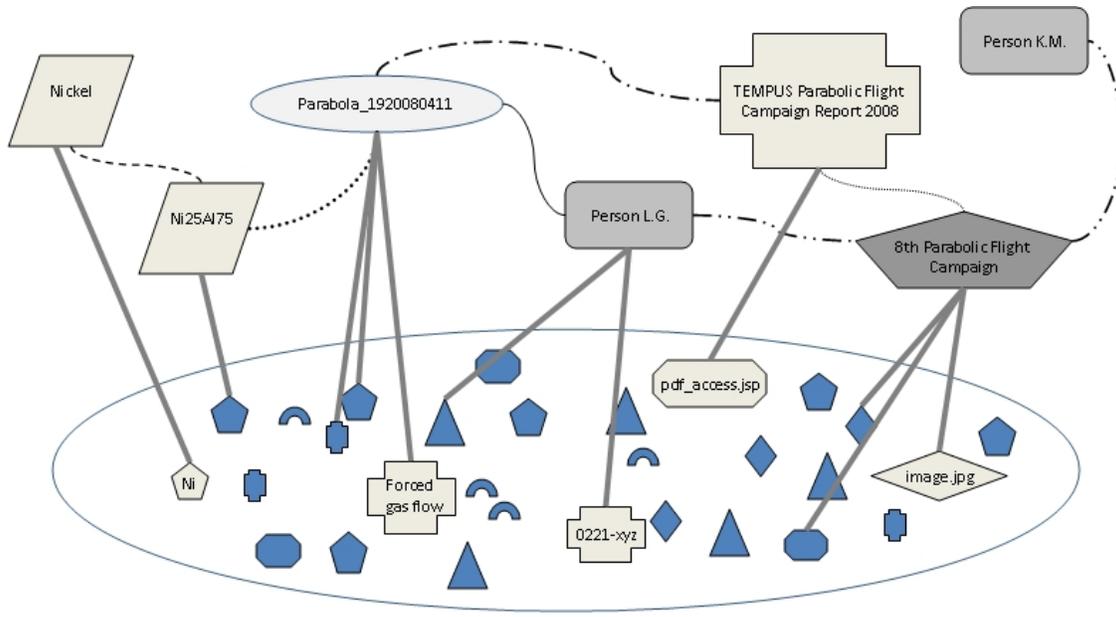


Figure 3: A schematic view of a TEMPUS Topic Map fragment

In most cases, the population of topic maps is a challenging task. Here, previous deliberations coming from the original design of the TEMPUS Hypertext data archive could partly be used to define and populate the topic map ontology.

Interconnecting Data

The representation of knowledge through topic maps offers various possibilities. One of the most attractive is merging topic maps. Independent information resources can be overlaid and a view at the merged topic map offers an insight into the comprehensive knowledge.

Clearly, it is very important for the merging of topic maps to precisely denote the treated subject when editing a topic⁸. This is achieved by the concept of *subject identity*. Here, *subject indicators* are considered to be resources which indicate the identity of a subject and prevent unambiguosness. The indicator itself is addressed by a *subject identifier* (usually an URI). Any two topics that share one or more subject indicators are considered to be equivalent to a single topic that has the union of the characteristics (the names, occurrences, and associations) [4].

In future topic map applications, it therefore will become a crucial challenge to provide access to published subject identifiers and promote their reuse for all kinds of topic maps.

⁸ Solving the synonym/homonym problem is a crucial topic in the semantic web. It becomes also necessary for concepts like web services, inferencing through the web etc.

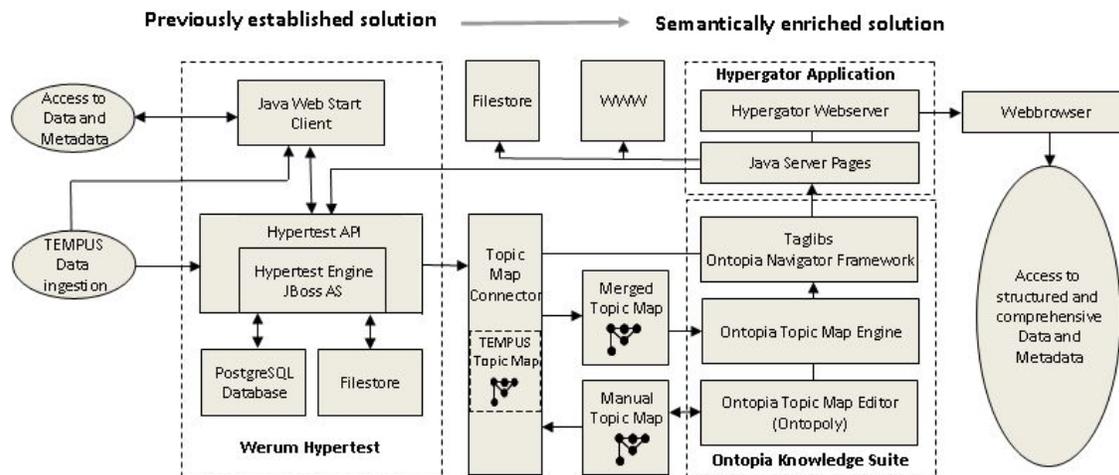


Figure 4: Application flow chart of TEMPUS data

APPLICATION TO THE TEMPUS DATA ARCHIVE

The Architecture

Figure 4 shows a flow chart of the semantically enriched data archive. The archive can fully be accessed through the newly developed web application *Hypergator* which shall be introduced in this section.

The topic map technology was applied to the TEMPUS Hypertest system by structuring available metadata into topic types and associating them among. The resulting TEMPUS topic map could then be populated by the TEMPUS Topic Map Connector, resulting in a semantically connected view of all available metadata. The Topic Map Connector also takes care of indexing the data in TEMPUS Hypertest as occurrences or, depending on the ontology, transforming them into topics. To perform that task, it uses libraries of the Ontopia Navigator Framework and of the Hypertest API.

During building up the TEMPUS topic map ontology, also additional metadata for already existing TEMPUS subjects were defined. Thus, the possibility for providing information at a higher level emerges, e.g. for describing experimental programs and connecting them with the parabolic flight experiments. Also information about persons, scientific groups and technical devices were considered important. Ways of extracting scientific publications from some DLR internal information resource and transforming them into a populated topic map are currently evaluated.

In figure 4, a *Manual Topic Map* serves as information store for that kind of information. The Manual Topic Map was created with the Ontopoly Topic Map Editor which can be used for further topic map population. Occurrences can either refer to DLR file stores (also through the Hypertest API) or refer to information on the internet.

The resulting merged and populated topic map serves as input for the *Hypergator* web application which was build upon the OKS framework. The application is accessible via an ordinary browser.

Select a TEMPUS Topic

- Campaign
- Dataset
- Experiment
 - Electrical resistivity experiment
 - Oscillation Drop Method Experiment
 - Solidification Experiment
- Experimental Quantity
- File
 - Control file
 - Data File
 - Processed data file
 - Document
 - Campaign Report
 - Technical Note
 - Image
 - Phase-diagram image
 - Phase-diagram image
 - Temperature-time plot
 - Log file
 - Video
 - High speed video
 - TeVi Video
- Material
 - Alloy
 - Metal
- Organisation
 - Company
 - Public Institution
 - Institute
 - Space Agency
 - University
 - Research Group
- Parabola
- Person
 - PI Descriptor
- Scientific Programme

W_PdsSi_2008
W_PdsSi_2008: Investigation of the parameters affecting the results of viscosity measurements by the oscillating drop method in an electromagnetic levitation device

Abstract

Because of the high chemical reactivity of many liquid metallic alloys of technological interest, classical measurement methods for their thermo-physical properties (where the liquid is in contact with a container for an extended period of time) often can not provide results with sufficient accuracy. Alternatively, containerless processing techniques in an electromagnetic levitation device can be applied where a metallic specimen is positioned and heated by strong radio-frequency electromagnetic fields. The DLR TEMPUS device implements this principle of function on board parabolic flights. This experiment covers a systematic experimental investigation of the parameters affecting the results of viscosity measurements by the oscillating drop method in the DLR TEMPUS device on board parabolic flights in the DLR flight campaign from April, 8th to 11th, 2008. The investigation is performed with the alloy Pd-10at%Si with a liquidus temperature of $T_l=956^\circ\text{C}$ because the viscosity of this alloy can also be accurately determined by conventional methods in ground based laboratory. In the oscillating drop method, surface oscillations on a freely suspended droplet are excited. The surface tension and the viscosity are evaluated from the frequency and the damping time constant, respectively. However, in ground based laboratory this method can not be applied for the measurement of the viscosity because of the strong turbulent fluid flow induced by the electromagnetic forces required to levitate a specimen. Under reduced gravity, turbulent fluid flow is much reduced because of the reduced levitation force. However, recent magneto-hydrodynamic calculations have suggested that under certain conditions turbulent fluid may also be induced under reduced gravity conditions strongly affecting the viscosity values obtained by the oscillating drop method. One critical parameter is the ratio of the surface oscillation amplitude to the sample diameter. Another parameter, which may affect the measured viscosity values is the strength of the positioning field. Parabolic flights provide about twenty seconds of reduced gravity which entails that specimen need to be heated with maximum power into the liquid phase resulting in turbulent fluid flow and large sample deformation at the end of the heating phase. Thus the question arises about the time delay between the end of heating and the excitation of surface oscillations required to produce accurate viscosity values. The experiment consists of 7 parabolas flown on board an Airbus A 300 ZERO-G on April 8th 2008 (campaign day 1) and 9 parabolas on April 10th 2008 (campaign day 3) with PdsSi samples.

Scientific purpose

It is the goal of the study to identify critical parameters affecting the results of viscosity measurements by the oscillating drop method with relevance for short and long duration microgravity experiments. The viscosity of a metallic liquid is an important thermo-physical property. Under technological aspects, it is used as a parameter in the modeling of industrial casting processes. In this regard, there is much demand by industry for accurate viscosity values for a large variety of industrial alloys. Moreover, the viscosity is of principal interest to metal physics regarding the connection between the atomic structure of the melt, which can be evaluated from scattering experiments, and the resulting macroscopic properties. This connection is also relevant for the thermodynamic model building to predict the viscosity as a function of composition for multi-component industrial alloys. In the experiment, the dependence of measured viscosity values on the parameters listed above shall be systematically investigated in order to identify a critical parameter range for future viscosity measurements by the oscillating drop method on parabolic flights and the International Space Station. In addition it is planned to perform a reference experiments on a TEXUS sounding rocket flight as well as in ground based laboratory by a conventional method. From the basic metal physics aspect, it is planned to perform scattering experiments in the liquid phase for atomic structure determination.

Further information

Associations

- W_PdsSi_2008
- Co-Investigation (Co-Investigator)
- Principal Investigation (PI)
- experiment run of/for (TEMPUS_experiment_run)
 - Parabola01_20080410
 - All TEMPUS experiment runs of W_PdsSi_2008
 - Parabola03_20080410
 - Parabola04_20080408
 - Parabola04_20080410
 - Parabola05_20080408
- Device Usage
 - Highspeed 200 Hz (608x600 Pixel)
 - Loglux 150 Hz (352 x 352 Pixel)
 - ZPY
- Principal Investigation
 - experiment run of/for
 - partOf
 - 08.04.2008 (CampaignDay 1)
 - production
 - sample material of/for
 - PdsSi18
 - Parabola05_20080410

Indirect Associations

Figure 5: The view on an experiment instance in Hypergator

Select a TEMPUS Topic

- Campaign
- Experiment
 - Electrical resistivity experiment
 - Oscillation Drop Method Experiment
 - Solidification Experiment
- Experimental Quantity
- Material
 - Alloy
 - Metal
- Organisation
 - Company
 - Public Institution
 - Institute
 - Space Agency
 - University
 - Research Group
- Parabola
- Person
 - PItempus
- Scientific Programme

Parabola19_20080411

Item data

- Video preview: http://localhost:8080/hypergator/microgator/index.jsp?video=Parabola19_20080411
- campaign day: day 2
- emissivity: 0.16
- melting point: 1190
- parabola number: 19
- process atmosphere: forced gas flow
- sample size: 6.9

Showing file: C:\workspace\hypergator\WebContent\mp\Tempfile1251885097080.avi

Further information

Associations

- Parabola19_20080411
- Device Usage (Radial Measurement Device)
- Principal Investigation (PI Descriptor)
- L.G.
- experiment run of/for (Experiment)
- L_N_2008
- partOf (ensemble)
- production (result)
 - Axial TeVi Video (Parabola19_20080411)
 - FFT file (Parabola19_20080411)
 - FFT input file (Parabola19_20080411)
 - Radial TeVi Video (Parabola19_20080411)
 - TEMPUS Standard Data output (Parabola19_20080411)
 - format description
 - production
- sample material of/for (Material)
 - Ni25Al75
 - material composition
 - Aluminium
 - Nickel
 - sample material of/for

Indirect Associations

Figure 6: The view on a parabola in Hypergator

The Hypergator Application

Hypergator enables surfing through the ontology and its topics, thus accessing data by a powerful and intuitive web interface. By simple browsing, it reveals direct answers to typical questions related to experiments, people, materials and their interconnections. An impression about the GUI is presented in the figures 5 to 7. Crucial features and their benefits are discussed in the following.

The entrance point builds the left navigation bar with an overview about the most important topic types (c.f. figure 5). Here, one can choose to display e.g. all *Campaigns* or all *Experiments*. Subcategories for the topic types exist and are displayed in a tree view. For instance, among *Experiments*, one can choose to display list of all *Oscillating Drop Experiments* which then appears in the middle section.

Clicking on e.g. the specific experiment *W_PdSi_2008* then yields figure 5. In the middle section, one gets presented information about that topic.

Associations to other topics are shown in the right navigation bar. It depends on the topic itself which associations are displayed. In case of an experiment, information about *Principal Investigation* (an association in which a person or a scientific team plays the role of a *PI*), *Experiment Run* (a parabola plays the role of an *Experiment Run*) is displayed.

One can gain information about the directly associated topics by expanding the right navigation bar and thus going deeper into the associations of the associated topics. One thus explores other topics within a defined radius of the selected topic. To make that feature feasible, the radius was restricted to two, i.e. only topics within a distance of two hops from the selected topic are reachable in this view. To avoid circles, only selected associations are displayed in the second level.

Figure 6 shows the view of a *Parabola* in Hypergator. The direct associations show information about *PI*, sample material, etc. One can load a preview video of the experiment run which is downloaded through the Hypertest API and then displayed in the middle window.

When considering the direct association *production* in figure 6, one gets presented an overview of all produced datasets from that parabola. Those are topics themselves and contain information about size, creation date, sample rate, etc. They are identical to a single data file or consist of several files. The *Dataset* topics carry a download script as Occurrence type which downloads the associated file(s) from TEMPUS Hypertest upon request. Videos contain an association to the recording camera. The camera is also a topic and can contain hyperlinks to the internet about manufacturer, user manual, etc.

By expanding the association *production*, one can see that a format description of the dataset *Standard TEMPUS Data output* is available. It contains useful explanations about the measured quantities coming from the Manual Topic Map. By selecting a quantity, one can see in which datasets a measured quantity is present.

If an associated topic in the right navigation bar is considered to be interesting, one can select it. Information about the new topic is then displayed in the middle window and the associations of maximum distance two are loaded into the right navigation bar. Practically, one changes his/her position in the topic map by performing this procedure, hence without assistance of a graphical tool.

Still in the view about the selected topic, one can gain more information about the indirectly associated topics by choosing the tab *Indirect Associations* in the right navigation bar. Basically, like in the former case, it expands all direct associations to a distance of two hops, but now groups all found topics. Grouping in that case means that only distinct topics are displayed.

The screenshot shows the HYPERGATOR interface. On the left is a navigation menu titled 'Select a TEMPUS Topic' with categories like Campaign, Dataset, Experiment, File, Image, Log file, Video, Material, Organisation, Parabola, and Person. The main content area is titled 'S.K./D.B.' and contains a 'Further information' section with 'Associations' and 'Indirect Associations'. The 'Indirect Associations' list includes items like 'Doped-Ge', 'FeHf', 'Si', 'Si - doped', 'Si25Ge75', 'Si50Ge50', and 'Si75Ge25'. A tooltip is displayed over the list, stating 'All Materials of all Parabolas which are Experiment of S.K./D.B.'

Figure 7: All Sample Materials for the PI team S.K./D.B.

To demonstrate the power of indirect associations, consider the example in figure 7 which shows a list of all distinct sample materials the PI team *S.K./D.B* ever used during the DLR parabolic flight campaigns. A dynamically generated tooltip gives a human readable explanation to the currently displayed indirect association.

A far from being complete list of exemplary similar questions which can be answered at a single view is the following one:

- Show me all experiments for which DLR staff serves as principal investigator.
- Show me all different materials of the solidification experiment L_NiAl_2008
- Show me all people which served as Co-Investigator for experiments of F.W.!
- Which organisations have participated in the experiment L_NaL_2008?
- Give me a list about all experiment runs (parabolas) which used Aluminium based materials!
- Which Aluminium based materials have been used so far?
- Which were all used co-components (mixed metals) of Nickel?
- Which parabolas have produced axial videos?

Note that all topics which are part of an answer contain additional information or can serve as new entry points for browsing its associations, respectively.

CONCLUSION AND OUTLOOK

The aim of the paper was to investigate the application of topic map technologies to a productive data system at DLR-MUSC. In this framework, the Web application *Hypergator* was developed which builds on the freely available Ontopia Knowledge Suite. A topic map ontology, which logically reflects the contents of TEMPUS Hypertest, could be developed. The population of the basic topic map was implemented, containing a mechanism to merge external information sources.

A way for visualizing the contents of the topic map was evaluated and put into action. Hereby, the focus was set on intuitively revealing coherences between experiments, materials and their investigators. According example questions were provided.

Domain Experts performed a cognitive walkthrough to accomplish a predefined task for evaluating the additional benefit of the application with respect to information retrieval and knowledge discovery purposes. In a qualitative assessment, the Hypergator application was considered to be a valuable supplement to the existing data archive TEMPUS Hypertest.

For the near future, the data archive will be enhanced with supplemental data and metadata. A fully available service will enable a detailed internal empirical evaluation and serve for further enhancements. It may then be further improved and serve as a valuable tool for the material science group at DLR MUSC.

The results of the present work should be applicable to the 7th European framework programme ULISSE, i.e. for a pre-investigation of the applied technologies. Comprising a larger information pool and more sophisticated ontologies, ULISSE will aim at providing high-level services to establish tools to archive, access, interact with and process data obtained from a variety of multi-disciplinary sources and, in general, to enable the straightforward valorization of data.

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