Scientific Social Objects

The Social Objects and Multidimensional Network of the myExperiment Website

David De Roure
Oxford e-Research Centre
University of Oxford
Oxford, UK
david.deroure@oerc.ox.ac.uk

Sean Bechhofer and Carole Goble
School of Computer Science
The University of Manchester
Manchester, UK
sean.bechhofer@manchester.ac.uk
carole.goble@manchester.ac.uk

David Newman
Electronics and Computer Science
University of Southampton
Southampton, UK
drn@ecs.soton.ac.uk

***Abstract*— Scientific research is increasingly conducted digitally and online, and consequently we are seeing the emergence of new digital objects shared as part of the conduct and discourse of science. These *Scientific Social Objects* are more than lumps of domain-specific data: they may comprise multiple components which can also be shared separately and independently, and some contain descriptions of scientific processes from which new objects will be generated. Using the myExperiment social website as a case study we explore Scientific Social Objects and discuss their evolution.**

Keywords—Scientific Social Object; workflow; Research Object

I. INTRODUCTION

Routine research practice in many disciplines has entered the "Science 2.0" world where we have new mechanisms for sharing [1] and also new objects to share. Research tools produce and consume data, together with metadata to aid interpretation and reuse. We also have the scripts and experiment plans that support automation, and the records that make the results interpretable and reusable. Our new objects include data, metadata, scripts, workflows, provenance records and ontologies; our tools for sharing include the array of collaboration tools that are available on the Web today, ranging from repositories, blogs and wikis to social networking, instant messaging and tweeting. Where researchers come together around these objects they become *Scientific Social Objects*.

In this paper we focus on one of these new objects, the computational scientific workflow [2], as a case study in scientific social objects. Scientific workflow systems are used to conduct automated data analysis, predictions and validations, and have emerged as a key part of today's data-intensive research environment. A workflow itself is a description of a particular process that is enacted by the workflow system, and this description is shared by researchers in order to support reproducible science and to spread knowledge and expertise.

The myExperiment website (www.myexperiment.org) was designed to make it easy to share these workflow objects – a kind of flickr or youtube but for workflows [3]. It has successfully adopted a Web 2.0 approach in delivering a social website where scientists can discover, publish and curate scientific workflows and other objects. While it shares many characteristics with other Web 2.0 sites, myExperiment's distinctive features to meet the needs of its research user base include support for credit, attributions, licensing and privacy. Since its launch at the end of 2007, myExperiment has over 4000 registered users, thousands more downloading public content, and with nearly 2000 workflows it provides the largest collection available. It is, however, characteristically a 'boutique' site with a specialist audience.

We propose that workflows, and myExperiment as a resource, provide a useful case study in scientific social objects. Workflows are indeed social objects that are shared and used by researchers – they are the cause and/or subject of a collaboration, leading to links in the social graph. Significantly they are composite objects containing heterogeneous components which can be shared separately and independently. Since they capture process they are also prescriptions for the creation of other objects. These two aspects distinguish them from a social object such as a photo or collection of photos.

The next section illustrates the workflow as a social object, and in Section III we describe the multiple interlinked networks in myExperiment. We then explain how these can be explored through myExperiment's SPARQL query interface in order to support further study. Section V characterises a future scientific social object that we call a *Research Object*. Finally we outline current work in the Wf4Ever workflow preservation project.

II. WORKFLOWS AS SOCIAL OBJECTS

Workflows form connections between people in many different ways. Within the context of the myExperiment site these collaborations around workflows are asynchronous, with researchers collaborating around a workflow over a period of time. While some of this collaboration occurs within groups and between friends, it also occurs on an ad hoc basis.

First it is useful to understand the anatomy of a workflow: it is a precise, executable description of a scientific procedure – a multi-step process to coordinate multiple tasks, like a script. Each task represents the execution of a computational process, such as running a program, submitting a query to a database, submitting a job to a computational facility, or invoking a service over the Web to use a remote resource. Data output from one task is consumed by subsequent tasks according to a predefined graph topology that orchestrates the flow of data. The tasks might be local or they may occur remotely hosted by third parties.

myExperiment is supported by UK JISC and the UK Engineering and Physical Sciences Research Council (awards myGrid EP/G026238/1 and e-Research South EP/F05811X/1). Wf4Ever is funded by the Seventh Framework Programme of the European Commission (Digital Libraries and Digital Preservation area ICT-2009.4.1 project reference 270192).

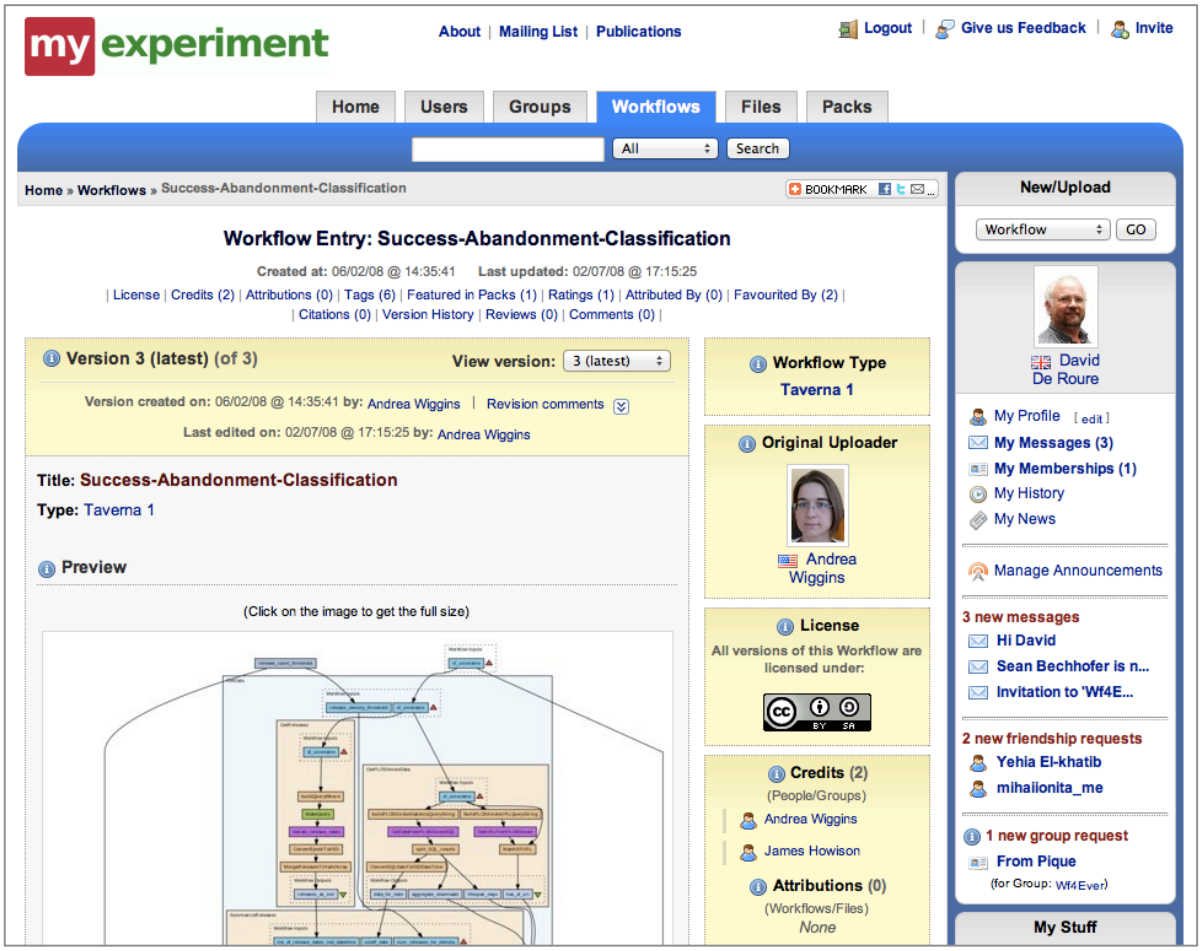


Figure 1. myExperiment website, showing a workflow (left) with its 'social metadata' (middle) and the user's social network (right).

The following scenarios illustrate three typical interactions that come about through workflows as social objects:

1. A researcher makes a runnable workflow publicly available on myExperiment and publishes its URI in a paper. Readers find and use the workflow, perhaps creating a new version which credits the original creator. They might also contact the author for help in using the workflow or to provide feedback.
2. A researcher finds a workflow by searching myExperiment and needs help in its use. They can see who created the workflow, with which groups it is shared and by whom it is favourited or rated.
3. A researcher tries to use a workflow but there are difficulties with a particular task within it. They search for other workflows which use the same task in order to find others who may be able to help. They may then publish the repaired workflow.

These scenarios demonstrate that myExperiment provides multiple routes of connection between people around the workflow as a social object. In the first two cases the workflow connects author and users; in the latter case it is a task within the workflow that connects people.

We also note that workflows are not the only social objects; for example, a scientist may be analysing data and may bring both workflows and other scientists together around that data. Some other objects are identified in the next section.

III. The Networks

myExperiment has a multidimensional network that links people and the objects that they share, and some of those objects are themselves networks as is the case with workflows. Rather than treating this as one big network, here we suggest six categories of network that are superimposed in myExperiment and interlinked by the workflows as social objects.

A. Friends, groups, ownership and credit

myExperiment provides notions of friends and groups, familiar from other social websites. These are the main social graphs of myExperiment and clearly evident in the interface, which is illustrated in Figure 1. The groups have administrators, and visibility and sharing of objects can be finely controlled. As well as being owned by people and groups, explicit credit is given to those who were involved in creating objects – this consideration of credit and attribution is critically important in the scientific context.

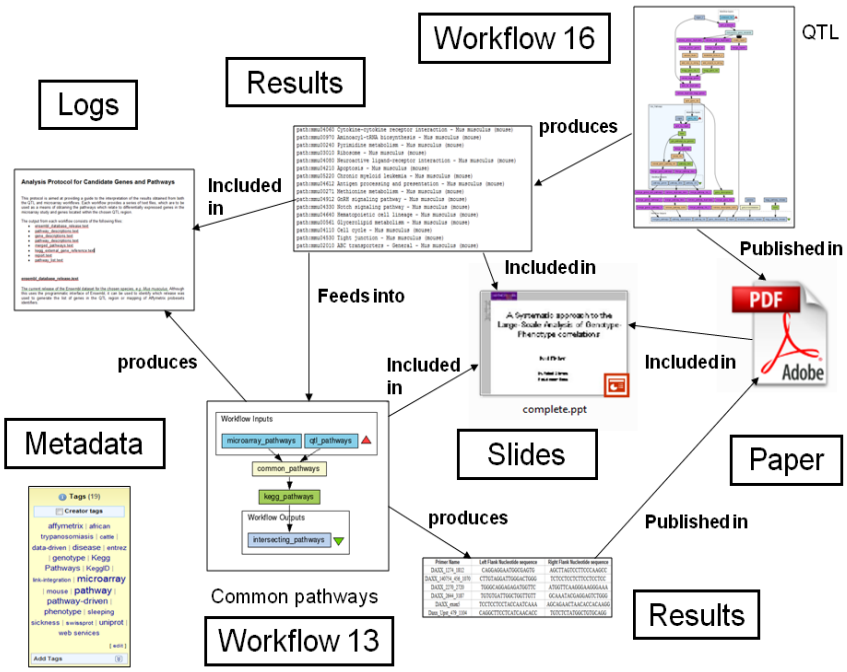


Figure 2. A myExperiment pack with annotated relationships.

B. *Workflows*

A workflow can be viewed as a network of tasks, any of which may also appear in other workflows. Additionally a workflow can call another workflow as a task, and data can flow from one workflow to another (inputs and outputs may also be typed so that they can be matched up). Hence there is a 'workflow network'.

Furthermore the workflow consumes and produces data, and so a workflow execution ('run') can produce a provenance graph that describes the sources of information and processes involved in producing a particular output. As a record of a particular experiment, the provenance graph could itself be a social object.

C. *Packs*

myExperiment users were quick to recognise that a workflow can be enriched as a social object by bundling it with some other pieces which make up the "experiment". Hence we developed support for *packs* – collections of items, both inside and outside myExperiment, which can be shared as one package. For example, a pack might contain workflows, example input and output data, results, logs, PDFs of papers and slides (see Figure 2) – such a pack captures an experiment and is reusable and repurposeable. Approximately 10% of the contributions to myExperiment are packs.

A pack is also a network – it is essentially a bundle of annotated URIs with relationships between them. Packs together form a 'pack network' by pointing at each other, by sharing components or by being shared.

D. *Tags and other annotations*

Annotation of Social Objects, through tagging, reviews and favouriting by multiple users, leads to another superimposed network on the site. Folksonomy-based tagging creates an emergent network of social objects linked by common tags, while we also have controlled vocabularies and some semi-automated tagging as part of the workflow curation process. The act of tagging is seen as significant and tags have an owner attached.

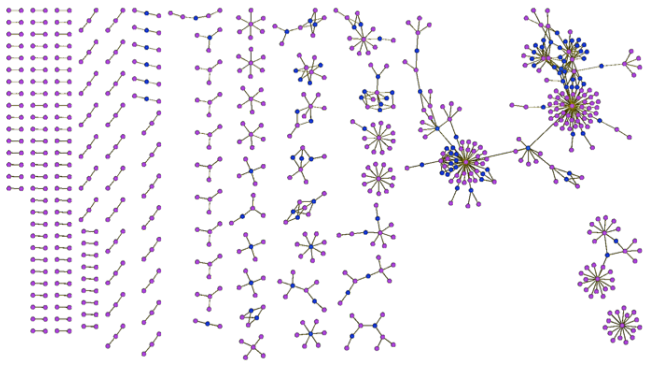
E. *Citation network*

myExperiment's network is also interlinked with external networks, as illustrated by case 1 above. Workflows and packs on myExperiment are referred to by URIs which then appear in research publications; the publications are themselves linked by co-authorship and citation networks. Hence the social objects on myExperiment participate in these bibliographic networks.

This network is only partially stored on myExperiment but it is important: we track it carefully by running queries to identify myExperiment citations and then logging these, as well as inviting people to inform us of publications. myExperiment links both in and out of external repositories, and there is ongoing work integrating with the EPrints (www.eprints.org) and dlibra (dlibra.psnc.pl) digital repository systems.

F. *Service network*

A great many of the workflows on myExperiment make use of remote web services and thus form a network of services, which itself has been the subject of analysis [4]. These services are entities in their own right, many stored in myExperiment's sister site, the BioCatalogue (www.biocatalogue.org), which provides a community-curated registry of Web Services in the life sciences [5]. A task in a workflow links to a service description in the BioCatalogue and hence into the associated network of users, service providers and curators.



```
SELECT ?w ?u
WHERE {
?w mebase:has-current-version ?v.
?v mecomp:executes-dataflow ?d.
?d mecomp:has-component ?c.
?c rdf:type mecomp:WSDLProcessor.
?c mecomp:processor-uri ?u.
}
```

Figure 3. Querying and visualising the services network using the SPARQL endpoint and the Cytoscape network analysis tool.

IV. Querying the Networks

The networks described above are published in RDF (Resource Description Framework) and follow Linked Data practice. We have found that myExperiment's SPARQL endpoint provides a useful interface for exploring these networks as it is straightforward to query the graphs and to obtain results in various formats for subsequent processing.

Every myExperiment entity, whether it is a Workflow, Pack, User, Group, etc. has its own *Non-Information Resource* URI to identify it. The structure of myExperiment RDF is defined by ontology modules that can be assembled to build the complete myExperiment Ontology [6]. This set of modules borrows classes/properties from several established ontologies including Friend Of A Friend (FOAF), Semantically Linked Online Communities (SIOC), Dublin Core, Creative Commons and in particular Object Reuse and Exchange (OAI-ORE). Depending on the workflow system in question it is possible to access the workflow graph; the majority of myExperiment workflows are in the Taverna [7] system and available as RDF.

All myExperiment's public RDF data can queried at its SPARQL Endpoint, which is implemented using the 4store RDF database and reasoner (4store.org). There is also a tutorial available on rdf.myexperiment.org/howtosparql. It is relatively easy to query the networks described above. For example, Figure 3 shows a visualisation of the services network based on Taverna workflows with the associated SPARQL query. Further queries and visualisations can be found on the myExperiment wiki wiki.myexperiment.org/index.php/Vis.

V. From Packs to Research Objects

As the design of the myExperiment site has co-evolved we observe that packs are becoming a social object in their own right. In some ways they have a role like papers, in capturing materials, method and results and supporting reproducibility. Currently they provide a machine-readable supplement to the academic paper, but as the utility of scientific social objects increases it is interesting to speculate how and when such an object might supersede it.

To consider this evolution we have generalised the notion of packs to a future scientific social object which we call the *Research Object*. Through a series of discussions about the affordances of these social objects[1] we propose the following dimensions [8].

- *Reusable*. The key tenet of Research Objects is to support the sharing and reuse of data, methods and processes. Thus our Research Objects must be reusable as part of a new experiment or Research Object. This is black box reuse as a whole or single entity.
- *Repurposeable*. Reuse may also involve the reuse of constituent parts of the Research Object, for example taking a study and substituting alternative services or data for those used in the study. To facilitate such a disaggregation and recombination, Research Objects should expose their constituent pieces.
- *Repeatable*. There should be sufficient information in a Research Object for the original researcher or others to be able to repeat the study, perhaps years later. Information concerning the services or processes used, their execution order and the provenance of the results will be needed.
- *Reproducible*. To reproduce (or replicate) a result is for a third party to start with the same inputs and methods and see if a prior result can be confirmed. Reproducibility is key in supporting the validation and non-repudiation of scientific claims.
- *Replayable*. If studies are automated they might involve single investigations that happen in milliseconds or protracted processes that take months. Either way, the ability to replay the study, and to study parts of it, is essential for human understanding of what happened.
- *Referenceable*. If research objects are to augment or replace traditional publication methods, then they (and their constituent components) must be referenceable or citeable.
- *Revealable*. The issue of provenance, and being able to audit experiments and investigations is key to the scientific method. Third parties must be able to audit the steps performed in the research in order to be convinced of the validity of results.
- *Respectful*. Explicit representations of the provenance, lineage and flow of intellectual property associated with an investigation are needed.

[1] An earlier list of twelve 'R dimensions' can be found in the article "Replacing the Paper: The Twelve Rs of the e-Research Record" on http://blogs.nature.com/eresearch/

Although not explicit in this list, it is the nature of research that these objects need to be interpreted and reused across laboratory, community and disciplinary boundaries, and for this reason it is also constructive to consider Research Objects as *Boundary Objects* [9].

VI. Conclusion and Future Work

Scientific social objects are becoming crucial to data-intensive research, and myExperiment provides a useful case study – a social probe – into how researchers work with workflow objects in particular and their generalisation to packs and Research Objects.

Although workflows are a specific kind of object they may help us understand scientific social objects in general. We believe that some of the aspects of the myExperiment network may be more generally applicable, especially with respect to the composite nature of scientific social objects, inclusion of process descriptions and their executability:

- Treating these objects as aggregations is an important step [10] and packs have demonstrated a significant role in workflow reuse and curation, The Wf4Ever project (www.wf4ever-project.org) is building on the experience with myExperiment, further developing the notion of Research Objects in this context and focusing on workflow preservation. Wf4Ever also features an important strand of activity in recommender systems, which could draw heavily on the multidimensional network in order to assist users in their interactions with scientific social objects.
- Workflows describe process and so do scripts and programs; i.e. software. This means that we may learn from software as a social object, and indeed ideas from open source software development can be applied to workflows, data and the conduct of science itself [2]. The parallel with software has been developed elsewhere in the context of Liquid Publications (liquidpub.org).
- Taking this parallel a stage further, we note that workflows, packs and Research Objects are in some sense 'executable' and hence have parallels with the idea of executable papers which has been championed by the publisher Elsevier in their 'Executable Paper Grand Challenge' (www.executablepapers.com). This suggests a class of 'executable social objects' which are machine-processable.

Thus myExperiment, and workflows as social objects, provide a contribution to the debate about the future of research communication. We invite others to join in the analysis of the myExperiment networks and hope that it may further the study of scientific social objects.

[2] See Michael Neilson's article "The Future of Science" on http://michaelnielsen.org/blog/the-future-of-science-2/

Acknowledgements

We are grateful to all our colleagues and collaborators in the myExperiment and Wf4Ever projects, and Prof Iain Buchan of University of Manchester for his conception of Research Objects. The example Pack in Figure 2 is due to Paul Fisher.

References

[1] B. Shneiderman. Science 2.0. Science 7 March 2008: **319** (5868), 1349-1350. doi:10.1126/science.1153539.

[2] Y. Gil, E. Deelman, M. Ellisman, T. Fahringer, G. Fox, C. Goble, M. Livny, L. Moreau and J. Myers. Examining the challenges of scientific workflows. IEEE Computer, 40:24-32, Dec. 2007. doi: 10.1109/MC.2007.421

[3] D. De Roure, C. Goble, and R. Stevens. The design and realisation of the myExperiment virtual research environment for social sharing of workflows. Future Generation Computer Systems, 25(5):561-567, 2009. doi:10.1016/j.future.2008.06.010

[4] W. Tan, J. Zhang and I. Foster. Network Analysis of Scientific Workflows: a Gateway to Reuse. IEEE Computer, 43(9): 54-61, 2010. doi:10.1109/MC.2010.2622010

[5] J. Bhagat, F. Tanoh, E. Nzuobontane, T. Laurent, et al. BioCatalogue: a universal catalogue of web services for the life sciences. Nucl. Acids Res. (2010) 38 (suppl 2): W689-W694. doi: 10.1093/nar/gkq394

[6] D. Newman, S. Bechhofer and D. De Roure. myExperiment: An ontology for e-Research. In: Workshop on Semantic Web Applications in Scientific Discourse in conjunction with the International Semantic Web Conference, October 2009, Washington DC, US.

[7] D. Hull, K. Wolstencroft, R. Stevens, C. Goble, et al. Taverna: a tool for building and running workflows of services. Nucleic Acids Research, 34(suppl 2):W729-W732, 1 July 2006. doi: 10.1093/nar/gkl320

[8] S. Bechhofer, J. Ainsworth, J., Bhagat, I. Buchan, P. Couch, D. Cruickshank, et al. Why linked data is not enough for scientists. In IEEE Sixth International Conference on e-Science, pages 300-307, 2010. doi: 10.1109/eScience.2010.21

[9] S.L. Star and J.R. Griesemer JR. Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. Social Studies of Science 19 (3): 387–420. doi:10.1177/030631289019003001

[10] Pepe, A., Mayernik, M., Borgman, C., and Van de Sompel, H. From Artifacts to Aggregations: Modeling Scientific Life Cycles on the Semantic Web. Journal of the American Society for Information Science and Technology, 61(3), pp. 567-582. doi:10.1002/asi.21263