arXiv Technical Infrastructure Workshop: Synopsis & Recommendations

Cornell University Library
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Introduction

The arXiv team is undertaking a series of surveys and workshops to help us create a cohesive vision for the future of arXiv and seek major funding for implementation over the next few years. On April 28-29, 2016, a technical infrastructure workshop was held to brainstorm and refine a set of possible technology options for the re-implementation of all or parts of arXiv, and to provide a solid foundation for additional development. Appendix B presents the agenda and Appendix C provides a list of participants. This report summarizes the discussion issues and presents recommendations for the arXiv team. The synopsis includes sections on architectural choices, technology candidates, moderation system and workflows, and funding. It also includes a set of recommendations related to organizational model, resources, and partnerships. The outputs of the workshop will be used to develop a technology plan for arXiv that will allow it to support existing functionality, and for the development of new functionality that aligns with the vision. An important component of this process is to identify partners and funders, and assemble a team with technical and project management skills to carry out such an ambitious project.

Architectural Choices

The workshop framed the discussion of rearchitecting arXiv around a spectrum of possibilities:

- Do nothing: Despite very high user satisfaction with arXiv in its current state, the consensus is that this is not a viable option.
- Incremental: Maintain the status quo as a baseline, but make selected changes over time. This would be undesirable in the long term since continuing on this path could inhibit taking a fresh view of requirements.
- Midpoint: Develop a new architecture using modern design, but potentially incorporate existing modules (e.g., TeX engine) and external components. (Referred to as “hybrid modular integration”).
- Complete rewrite: INSPIRE completed a rewrite (based on Invenio 1). ADS has a beta rewrite operational. DSpace tried and failed on a complete rewrite 3 times. The Fedora 4 rewrite succeeded.
- Replacement: Find an existing system that could be used or customized to replace the entire existing codebase.

We discussed a number of technical scenarios that fall within this spectrum. Participants reflected on the pros and cons of each scenario based on their overall knowledge and

experiences in similar situations. Appendix A presents our options and assesses their pros and cons. Five scenarios are summarized in the following sections.

1. Adopt a Similar System

Adopting a similar system would involve identifying possible off-the-shelf (turnkey) systems or systems that could otherwise be adapted to meet arXiv's requirements.

Finding a system that is easily modifiable and extensible would have the benefit of requiring less new development. Other important benefits include shared maintenance and security updates, potential access to community support, and ongoing refinement of the underlying system. This is especially the case if we are able to leverage the knowledge and development efforts of a system's wider community.

It is also unclear how the migration to a new system would best work. The wholesale switchover of a monolithic system (i.e. arXiv) would likely pose more difficulties than a gradual introduction of new components to a new, more hybrid system. Any changes in the data model would add the burden of keeping it synchronized with the old model. Software examples:

- Invenio 3 (as a complete solution rather than using components of the framework)
- Open Journal Systems (OJS)
- Ambra (PLoS)

2. Rebuild Using Generic Open Source Software (OSS) Stack

The Ruby/Rails and Hydra stacks are heavily used within CUL and peer libraries. There exists strong community around these technologies. This approach would be oriented to selecting an open source stack that can be used for many types of applications, mostly by means of being able to customize or extend functionality as needed. Ideal use of such a stack would be to make changes that can be generally useful and contributed back to the open source community to become part of the core software, but also some customizations may be necessary that serve arXiv's unique needs. Further investigation will be required to assess the appropriateness of this approach. Software examples:

- Hydra/Fedora 4/Sufia
- Ruby/Rails

3. Adapt a Known Framework for Scientific Communication

This approach is similar to the OSS stack scenario, but with better alignment with the needs of scientific communities. Frameworks that are designed for scientific communities may be more likely to be in alignment with the needs of the arXiv stakeholders (e.g., authors, readers, moderators).

Invenio 3 is a modular open source framework with ties to CERN and other institutions that overlap with the arXiv community. It is more modular and less monolithic than its predecessors (e.g., Invenio 1) and may offer some more flexible options for reimplementing some of arXiv's workflows. Substantial development is still needed before it is ready for production

environments. Possible benefits to this approach are that arXiv already has strong connections to this community and that it's early enough to establish collaborative work through partnerships.

The Open Science Framework provides open source software to address scientific research processes and workflows, broadly, but is less specifically focused on scientific publication. The scope may not be a fit for arXiv's more focused mission.

The arXiv team would need to assess the merit of this scenario more thoroughly. This would involve relating previous experiences with Invenio 1 and better understanding of the OSF approach. Software examples:

- Invenio 3
- Open Science Framework (OSF)

4. Redesign/Rebuild Selected Modules from arXiv Codebase

This approach would be incremental and would maintain the existing arXiv codebase while selectively rebuilding pieces of arXiv. Modules might evolve in-place or be completely rewritten. The disadvantage of this approach is that it would not allow the team to stand back and take a fresh view of what a new architecture could be. It would run the risk of path dependencies to the older codebase that may hamper future innovations. Incremental changes would be made to an old codebase that has numerous dependencies and fragilities.

Rebuilding selected modules from an existing codebase is an approach Oxford and DPLA applied successfully for some of its services. For arXiv, following this path would require a deeper evaluation of its APIs and modules. Software examples:

- Catalyst framework for Perl (already in use)
- Oxford, DPLA approaches

5. Assemble Heterogeneous Modules

This scenario would involve judiciously selecting existing application components and using APIs to integrate/combine them to deliver desired functionality and evaluating existing pieces of code, applications and services. OSS (e.g. Invenio 3, Hydra) and commercial components would potentially coexist with the scavenged components as microservices, with new code being written to integrate and fill in the gaps.

Part of the appeal of a hybrid architecture is in the ability to combine cherry-picked components. A multi-platform environment would also lend itself to loose coupling via good use of APIs. ADS has restructured some parts of its code around microservices. This has allowed them to reuse existing code, but often at the expense of many customizations.

The increased complexity in managing change and testing with multiple codebases can be difficult, however. Adopting OSS and commercial components would require participation in multiple, potentially disparate user communities. Software examples:

- Invenio 3 (selected parts)
- Hydra (selected parts)
- Microservices approaches

Of the major architectural approaches there was broad agreement that it will be best to pursue a modular approach that builds on either an open-source stack or framework. Incremental approaches would not allow the high-level rearchitecting recommended, and a complete rewrite from the ground up would be costly and risky. The two strongest candidates are: Invenio 3 framework & Ruby on Rails, possibly leveraging Hydra (based on Fedora 4) and/or other gems.

Technology Candidates

Within the various architectural choices there are still a number of technology choices for the components of arXiv. The following sections summarize discussions about a few key components.

Search

arXiv's current search is based on an old version of Lucene and a custom front-end. Metadata is indexed separately from fulltext; the latter index is wholly maintained by Cornell's CS department, and has been fragile. Software examples:

- Elasticsearch
- Solr
- Blacklight (uses Solr but requires significant customizations)
- Invenio 3 (uses Elasticsearch)

Object Store

arXiv currently uses a "filesystem+" model of storing objects, in which a database supplements a traditional filesystem. One of arXiv's architectural weaknesses is its single database, so it would be beneficial to have a high-availability solution. Updated storage architecture might also be important if arXiv relaxes ancillary materials rules and starts accepting more materials that are large. Software examples:

- MongoDB
- Filesystem+ (hybrid approach)
- Ceph

The question remains whether arXiv should look specifically at storage or repository architecture.

Community and Code

It is unlikely that arXiv as a complete platform would be useful to a wider community, if it were put on Github, for example; arXiv is not a general repository system, but a centralized service that is designed for specific subject areas. It might however be useful to look at modularizing particular components, like moderation or the TeX system, and make those available for reuse.

arXiv is exploring partnerships with CERN, INSPIRE, Max Planck and others. With new services such as citation analysis, should arXiv try to do its own citation analysis or try to integrate services better and not reinvent the wheel? There are off the shelf solutions now for issues that arXiv has had to solve for itself previously.

Moderation System, Policies, and Workflows

The reconfiguration of the moderation system requires that we work closely with moderators. We get involved in about 15% of the 600 daily submissions. How can we continue to scale this human effort? We also need to address moderator preferences if we want these tools to be used. Some tools look conceptually valuable but may not be embraced for supporting daily workflows. For instance, we have a web interface that shows a list of held submissions. But some moderators don't use it. Some only use email and some are consistent web users. There are inconsistencies between moderators. We're hearing from some moderators that the tools are inefficient to scale the work but we don't have their input yet. We will survey the moderators' needs within a few months.

In addition to automated processes, there is a significant level of human moderation and heuristics involved in running arXiv. Paul Ginsparg's expertise has not been captured or documented. We should not underestimate the importance of capturing such expertise as technologies alone would not be sufficient to address important issues. It's not just a set of modern tools, it requires constant human recognition and input to recognize user behavior if we want to constantly improve our quality parameters. Some questions raised include:

- Is constant monitoring and tweaking at this level indeed essential? What would be the quality consequences if the monitoring was looser?
- What makes the moderation system unique?
- Why is it different from PLOS ONE, which has a rich review process?
- Policies and workflows are unique but should the supporting technologies be unique too? It needs to be rapid, distributed, global, and scalable.

Approximately 150 volunteer moderators interact with arXiv via email and web interfaces. Due in part to the daily high volume of submissions, the process is necessarily different from traditional peer review. Despite these differences, it is worth investigating whether some external solutions might be suitable for use or informative. Software examples include Easychair (not open source) & MIT's OpenConferenceWare.

Policy and technological features are symbiotic as they inform each other. The current moderation workflows demonstrate how the arXiv technologies were developed in a customized way to accommodate user communities. For instance, arXiv's classification system is based on communities as it expanded organically and is not based on a schema. Automation is a tool for handling an increasing volume of daily transactions with fixed resources and staff. It also requires formalizing policy to implement technical solutions and offload decision making to clearly defined processes and procedures.

Funding

Although the focus of the workshop was on technological infrastructure issues, matters related to funding often emerged in the discussions. Some key points to highlight include:

- NSF wants innovation and will respond to a vision that is innovation driven. arXiv should not expect to get funding from NSF simply to re-architect. The US federal agency budgets seem to be flat. One potential scenario is funding coming from NSF, NASA and DOE.
- Do we want to do what's compelling from a funding perspective (and engage in unnecessary innovation) or stick to core services? For instance, some funders might get excited about turning arXiv into a social media platform, but users might really balk. The general recommendation is to focus on the core mission, maintain and improve the fundamental systems, and make sure the current system runs well before doing something new. The user study confirms that users are happy with core services.
- CERN is funded by European Commission (EC). If repurposing infrastructure from other domains is a requirement, it could be useful for certain funders. We should consider approaching the EC, and collaborations where NSF could leverage international partnership; think on a global scale.
- There are several foundations such as Simons, Sloan, Moore, Mellon, and Arnold that are investing in developing a scholarly communication infrastructure.
- Specifically from the point-of-view of moderation, if part of the goal is not just to improve architecture, but also how to get funding, which seems innovation-oriented, there's really interesting research that can be done. There exists a massive user community that is very interested in the health and long-term success of arXiv. This could be a good opportunity to get some sort of funding (e.g. IMLS) to do a user study of arXiv and the mod system because we want it to be efficient. If mods are willing to change workflow or be open to a more efficient mod system, that potentially pushes UI research for digital libraries forward.
- Can arXiv be pitched as a general repository framework that might also fit other subject domains? Could innovation around moderation lead to funding? arXiv needs to be informed by a strategic vision of new capabilities, not re-implementing the existing system with a new coat of paint on it. Need to separate deliverables to a funding agency and how it's implemented, one piece at a time.
- Be cautious about funding core arXiv components & services through grants, whether NSF or possibly a European group. Such funds are more for one-time investment and could disappear at any point. Always be mindful of how the service/system will be maintained and developed after the initial development effort. You need to put in place a strong configuration of operational core staff
- This could possibly be 3-year project with a $3-4 million budget: 1 year design and component evaluation, 1 year intense development and testing, 1 year of deployment, configuration, iteration. Incremental is probably the least desirable as a fresh view of overall requirements is needed. Consider the notion of running parallel systems as you

are developing a new one. You can shut off the original arXiv when you are done with migration and testing.

arXiv as Sociotechnical System

In addition to the above recommendations in regard to the architectural choices & technology candidates, the discussion generated several ideas in regard to sociocultural aspects of the operation:

1. Technologies alone will not be sufficient to solve arXiv's problem. There needs to be expertise, vision, & drive. Process & change management strategies really matter, and the transition must be well-managed. The advisors emphasized that it is almost never about the technology, rather it is always about the process. They cautioned not to fixate solely on tech choices.
2. Be careful not to base arXiv's strategies entirely on a bump in funding for 2-3 years. It is not always possible to get everything right the first time around. Mistakes will happen and if you're boxed in, then it could be a funding problem. Keep the options open as much as possible. Testing and iterative development strategies are important.
3. It is important for the arXiv team to pick strategic partners to help share the load. However, the group recognizes that developing a partnership is a non-trivial effort in itself. For instance, arXiv team's Invenio 1 implementation failed because small mismatches turned into big problems. The team underestimated the task of moving the browse component, and was not fully committed with staffing. There was also the need to modify workflows. The lesson learned was that it is not all about finding a logical partnership opportunity but also committing resources, providing oversight and maintaining consistent communication.
4. The project needs a full time software development director to work closely with Jim Entwood, Operations Manager & Martin Lessmeister, Lead Programmer. The director needs to be an experienced architect who is strategic, diplomatic, big-picture thinker, and skillful in communicating with a range of stakeholders. Also critical is filling the Scientific Director position.
5. The advisors reinforced concerns around resources and number of staff. A good strategy is to do away with part-time people as much as possible as such individuals end up with several different commitments with different schedules, making it difficult to focus.
6. It is important to make sure that any replacements for Paul Ginsparg's tools are integrated within the main system as production modules, not as research code.
7. The advisors emphasized that the corpus (papers, usage logs, and applications) is a high-value asset for studying the social aspects and trends in science and needs continued support and additional funding. For instance, maintaining and releasing the TeX engine as a VM or a service would be a great asset to the research community for advancing text mining.

Concluding Remarks

USERS: arXiv is a production service, not a technology experiment. The service needs to be stable; the software under it can undergo changes. Ideally the user only will notice that the UI is faster, sleeker, and responsive with better functionality. What if users don't like the new arXiv? We need to be prepared to respond. For instance, the Inspire team had extensive UI testing with remote video and also the new system is designed in a way the UI can be very quickly adjusted. The arXiv team needs to be prepared to mitigate damage very quickly. Infrastructure improvements should also help underpin efforts to enhance the usability of arXiv. The interface needs to be enhanced based on sound user-centered design principles and guidelines, and will increase ease of use, accessibility compliance and responsiveness.

STAKEHOLDERS: There needs to be a careful stakeholder analysis to understand use cases. There is an ecosystem of scientists, moderators, partners such as ADS and Inspire, related scientific communication initiatives and standards (e.g., ORCID), supporting libraries, advisory boards, etc. In order to set priorities and manage expectations, we need to map the stakeholder types, document the key requirements for each group, and identify priorities. Otherwise, we might get distracted and confused trying to achieve goals that mean different things to different stakeholders.

CODE BASE: It has become clear that no single system can replace everything that arXiv does. A solution somewhere in the middle of the spectrum seems like the most plausible option. The core is what needs to be improved while maintaining simplicity. One key concern is that the code base is 20+ years old. Infrastructure is at risk. Developers newly hired will not necessarily be fluent in the environment. Finding developers who know or want to learn Perl is a challenge. Going forward, arXiv should not rely entirely on Perl.

ARCHITECTURAL OPTIONS: The workshop was extremely useful in helping to lay out options for re-implementing arXiv, and reviewing them in the light of experiences with other systems. Of the major architectural approaches there was broad agreement that it will be best to pursue a modular approach that builds on either an open-source stack or framework. Any new software should be openly developed using modern languages, testing practices, and frameworks to lower development and maintenance costs. The two strongest candidates are: Invenio 3 framework & Ruby on Rails, possibly leveraging Hydra (based on Fedora 4) and/or other gems. Additional investigation will be required to consider these and other options in more detail. arXiv team will begin with an examination of Invenio 3 first as we will be able to leverage the knowledge and development efforts of the system's wider community.

PROCESS MATTERS: The workshops concluded with the advisors stressing that process really matters and managing the transition and putting in place a sound project oversight is as critical as making the right technological choices. As one of the advisors said, "It's almost never about the technology." The arXiv team needs to create a balanced plan that factors in a range of issues extending from architectural choices to sustainability requirements, and from resource needs to skills required to succeed in such an ambitious undertaking.

Appendix A: Pros and Cons of Technical Scenarios

	Technical Scenario	Approach to Make Happen	Software Examples	Pros	Cons
1	Adopt similar system	• Identify plausible turnkey • Identify systems that could be adapted	• Invenio3 • Open Journal Systems (OJS) • Ambra (PloS)	• Not alone; not reinventing • Less new development if system can be modified and extended easily	• May be incomplete or mismatch for arXiv needs • Not clear how to do incrementally vs. wholesale adoption
2	Rebuild using an existing generic Open Source Software (OSS) stack	• Articulate and define motivation for this approach • Evaluate candidate OSS stacks	• Hydra/Fedora4/Sufia • Ruby/Rails	• Community development • May be amenable to a piecemeal or evolutionary approach • Incremental migration from old to new system	• May be too early in process to know how good/bad the fit is • Popular solutions may not improve the situation • Library-centric OSS community (vs. science-centric)
3	Adopt a known framework for scientific communication	• Find out what we do and don't know about the OSF approach • Deeper analysis of Invenio3 due to its close relationship with arXiv and overlapping communities	• Invenio3 Framework • Open Science Framework (OSF)	• Invenio3 is modular and extensible • Invenio3 comes out of scientific community • Learn from Invenio1 experience • OSF platform addresses full research process	• Invenio3 still requires substantial development • Invenio3 is still being tested (integration, scale, performance testing) • OSF primary focus more on workflows, less on publishing

4	Redesign/rebuild selected modules from arXiv codebase	• Deeper evaluation of arXiv APIs and modules • look at projects that have taken this approach • Understand dynamics of the development team culture	• Oxford approach (stepwise evolution • DPLA approach • Catalyst framework for Perl	• Evolve in place • New modules of code can exist within the existing Perl framework	• This does not allow team to stand back and take a fresh look at arXiv • Incremental change is on an OLD codebase • Dependencies and fragilities to navigate
5	Assemble heterogeneous	• Scavenge and evaluate existing pieces (code, apps, services) • New coding to fill gaps • Consider both OSS and commercial components	• Invenio3 (partial) • Hydra (selected parts) • Micro-services approach	• Heterogeneous could be good or bad; not known • Can be hybrid architecture of best of breed components • Allows multi-platform environ; loosely coupled with good use of APIs	• Heterogeneous could be good or bad; not known • Change management on multiple codebases • More complex to test • Temptation to migrate away from generic/core OSS codebase to retrofit • Need for participation in multi- communities

Appendix B: Workshop Schedule

9am-noon Introductions

1. Welcome & general introduction – Oya Rieger (workshop goals, org structure, business model, highlights from SAB/MAB vision setting survey; some early results from the arXiv user study)
2. Overview of the moderation system - Jim Entwood
3. IT overview & discussion – Simeon Warner & Martin Lessmeister

Noon-1pm Lunch

1pm-5pm Discussion moderated by Sandy Payette

1. Goals, Scope, Desired Outcomes (1pm-1:30pm)

a. Review of arXiv user stories

- "arXiv provides [what] to [whom] for the purpose of [why]
- Stakeholders (authors, moderators, readers, sw developers...]

b. arXiv next generation – What is it? What is it not?

c. Tensions and constraints, consider:

- Funding
- Sustainability
- Architectural principles for code - modular, extensible, evolvable, APIs,
- Iv. Expose arXiv data: reusable, open, multiple formats

2. Discussion: Architecture and spectrum of approaches (1:30-2:30pm)

a. arXiv software components (see diagram)

b. Spectrum of approaches (see diagram)

c. Why consider each approach?

    - What are examples of each?
    - What are the risks and benefits of each?
    - What effort/cost/maintenance implications are there?

c. Process for sw development (in-house, multi-institution collaboration, outsource?)

3. Deep Dive – consider essential characteristic of arXiv (3:00-4:30)
    - Moderation system and user experience
    - Author functions and user experience
    - Reader functions and user experience
4. Analysis and Outputs of day (4:30-5:00)

a. Outputs Table (see slide)

b. Summary and set agenda for Friday

<u>Friday April 29, 2016</u>

8:30am-10am Breakfast meeting with Paul Ginsparg (arXiv Founder, SAB member, and Professor of Physics & Computing and Information Science, Cornell University) and the external consultants (not including the Cornell team)

10am-noon
1. Recap Day 1 & Goals Day 2
2. Discussion of potential scenarios – pros, cons, risks
3. Final recommendations, Conclusions and Next Steps

Appendix C: Workshop Participants

Alberto Accomazzi
Principal Investigator
NASA Astrophysics Data System
Harvard-Smithsonian Center for Astrophysics

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Matthew McGrattan
Head of Technical Strategy
Bodleian Digital Library Systems and Services
University of Oxford

Cornell University Library Participants

- Deborah Cooper, arXiv Special Projects Assistant, Meeting Note Taker
- Jim Entwood, arXiv Operations Manager
- Dean Krafft, Director of IT &CTS
- Martin Lessmeister, arXiv Lead Programmer
- Sandy Payette, Director of Land Grant and Research IT Cornell
- Oya Rieger, Associate University Librarian, arXiv Program Director
- Gail Steinhart, Scholarly Communication Librarian
- Simeon Warner, Director of Repository Development and Services, arXiv IT Director