What I learned from 20 years of leading open source projects

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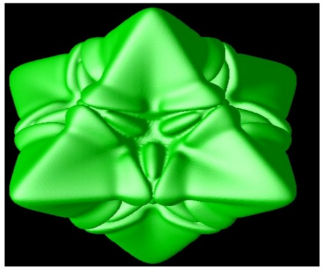
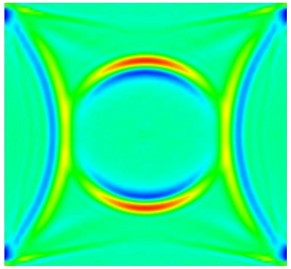
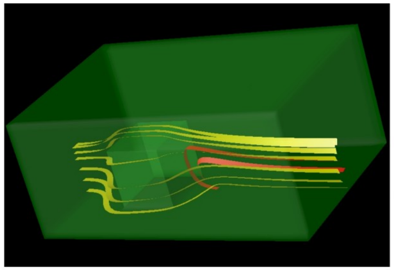
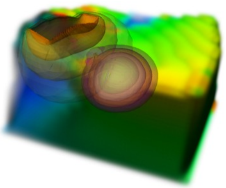
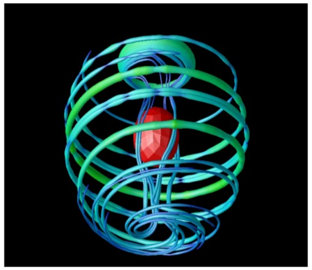
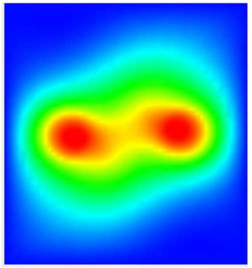
In collaboration with many many others around the world.

Where I'm coming from

My open source, scientific software experience:

- Started the deal.II project in 1997:
  - now 1.5M lines of C++
  - library that provides general finite element support
  - currently 11 "principal developers"
  - ~300 contributors over the years
  - 200+ papers/year that use it

- Started the ASPECT project in 2011:
  - now 150,000 lines of C++
  - simulates convection in the Earth mantle, deformation of the lithosphere
  - currently 9 "principal developers"
  - ~100 contributors over the years

What I learned

Building
– long-term sustainable software
– successful software communities
comes down to this:

It's not about being a "good programmer".
It's really all about (limitations of) people.

Specifically, dealing with human limitations to:
1) learn and work with *complex systems*
2) work with *people* in *complex organizations*

(Humans dealing with) Technical complexity

Managing technical complexity

There is a fundamental difference between
- **where projects start, and**
- **where projects end up.**

Using deal.II as an example. In the beginning:

- Started 1997 by myself: a single grad student
- Wrote 20k lines of code in year 1
- Acquired 2 co-authors in the same lab
- After 2 years:
  - 3 people
  - 100k lines of code
  - no external dependencies
  - no external users
- Website "because we can" in 2000

- This is probably quite typical of many scientific codes in academia and the national labs

Managing technical complexity

There is a fundamental difference between

– where projects start, and

– where projects end up.

Using deal.II as an example. Now:

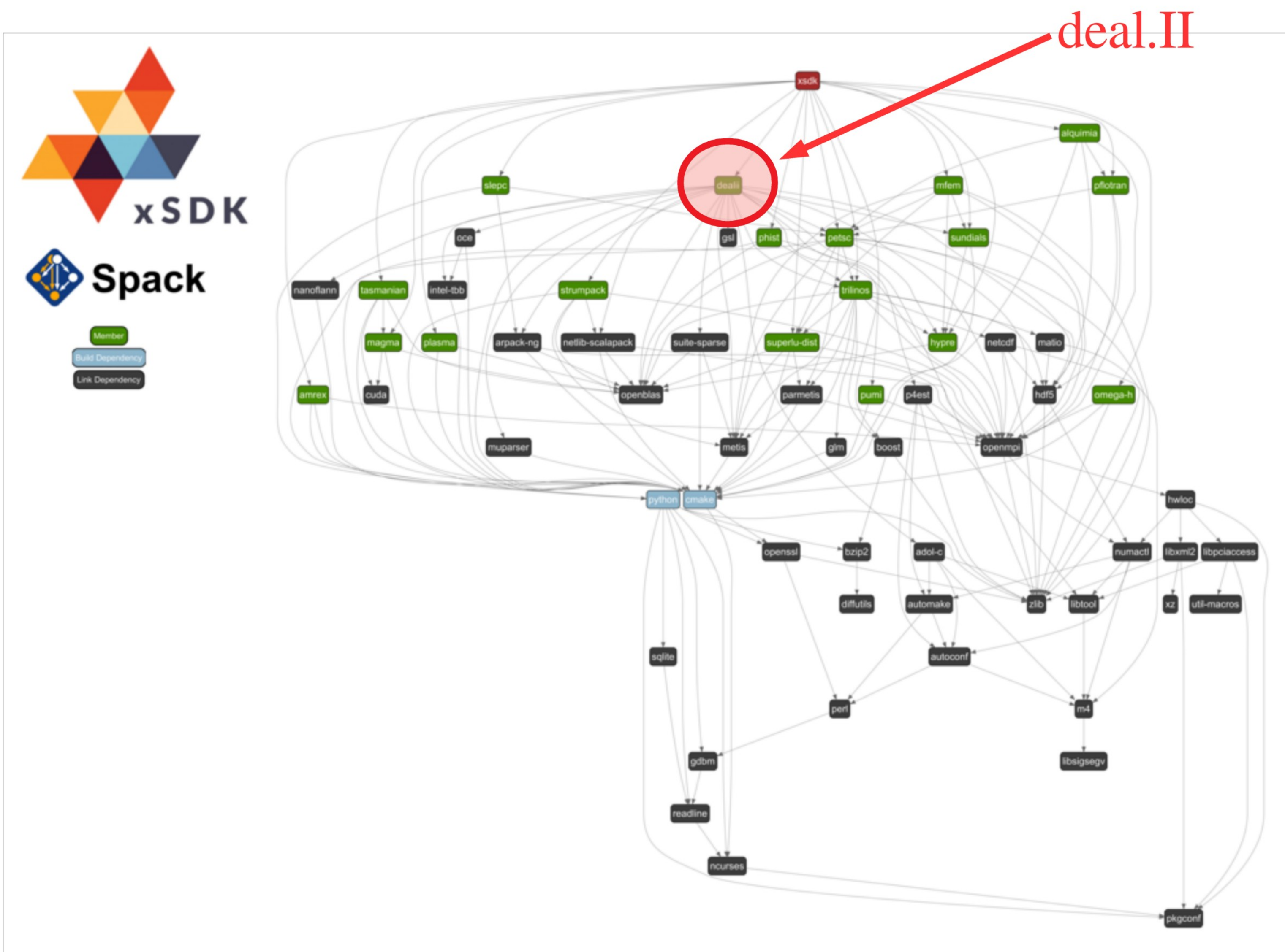
- 1.5M lines of code, grows by 40k lines/year
- 11 principal developers
- 300 contributing authors
- 1200 people on the mailing list

- Used in many individual research projects

- Uses many other packages

Managing technical complexity

Example: deal.II in the context of the xSDK collection



xSDK 0.4 dependency graph

Managing technical complexity

What this means:

- Scientific software today is no longer a "collection of sub-routines" (like BLAS or LAPACK originally were)

- Packages form an "interconnected web" where each builds on others

- Many packages are themselves composed of "modules":
  – deal.II itself
  – Trilinos
  – PETSc

Managing technical complexity

Why are things this way?

- Because no single developer can *know* this much
- Because no single user can *learn* this much

Managing technical complexity

There are costs associated with this:

- Installation complexity
- Different styles of coding, documenting, teaching
- Each dependency is in itself a moving target
- Which developer knows which dependency, and how do we make sure that knowledge is preserved?
  (→ what is the project's “bus factor”?)

Managing technical complexity

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(→ what is the project's "bus factor"?)

From Wikipedia: The "bus factor" is the minimum number of team members that have to suddenly disappear from a project before the project stalls due to lack of knowledgeable or competent personnel.

Studies conducted in 2015 and 2016 calculated the bus/truck factor of 133 popular GitHub projects. The results show that most of the systems have a small bus factor (65% have bus factor ≤ 2) and the value is greater than 10 for less than 10% of the systems.

Managing technical complexity

How do we deal with this:

- Poorly

- We talk about “software design”, which is as much *art and craft* as it is *science* – because we don’t really understand it

Managing technical complexity

How do we deal with this:

- Poorly
- We talk about "software design", which is as much *art and craft* as it is *science* – because we don't really understand it
- We learn about human limitations – *specifically that human time is much more valuable than computer time*:

"We should forget about small efficiencies, say about 97% of the time: premature optimization is the root of all evil."
(Donald Knuth).

"Any fool can write code that a computer can understand. Good programmers write code that humans can understand."
(Martin Fowler)

Managing technical complexity

But, we also have good technical solutions for human limitations:

– We forget → we use autocomplete
– We make mistakes → we write test suites
→ we peer review codes
– We break code → we use continuous integration
– It's repetitive/boring → we use package managers
– Can't keep things in sync → we use in-code documentation

Examples of tools:
– autocomplete: Eclipse, Visual Studio, Qt Creator
– tests: ctest, google test, …
– code review: github
– continuous integr.: jenkins, github actions
– package managers: cmake, spack, linux repositories
– documentation: doxygen

Managing technical complexity

There are also many collections of best practices:

– How to write documentation
– How to write teaching materials
– How to onboard new people
– Coding styles, software patterns, naming conventions, …

Examples:

– Code Complete (Steve McConnell)

– Design Patterns (Gamma et al., also several others)
– Producing Open Source Software (Karl Fogel)

– Look at how other projects write documentation, tutorials, manuals
– Check out BSSw

Managing technical complexity

Summary:

- Building workable scientific software packages has really become about *managing complexity* and *human limitations around complex systems*

- A large amount of time and thought goes into:
  – breaking things into manageable chunks
  – writing documentation
  – writing teaching materials
  – building *infrastructure*

- The difficulty is not with the technical tools, but with the human ability to learn/understand/manage *complex systems*

(Humans dealing with) Human complexity

Managing people

Scientific software has some unique aspects:

- Often part of *research* projects – there are no standard solutions one can look up
- Often built by *temporary employees*:
  – graduate students
  – postdocs
- Often built by *unpaid volunteers*
- Generally built by people without formal C.S. education

This brings some interesting human challenges with it!

Managing people

Regarding temporary employees:

- A lot of responsibility on a few senior leaders:
  – constant onboarding of new contributors
  – a lot of teaching/mentoring
  – importance of code review

- Contributing authors do not feel the same level of "ownership", have other priorities

- Leadership needs to make up for lack of experience/quality

Managing people

Regarding volunteers (1):

- Development directions are sometimes unclear: Functionality grows by what user-developers need, not what the project wants
  → It's difficult to establish "road maps"

- Volunteers can't be treated like employees

Managing people

Regarding volunteers (2):

- A lot of responsibility on a few senior leaders:
  – constant onboarding of new contributors
  – a lot of teaching/mentoring
  – importance of code review

- Leadership needs to provide key infrastructure improvements

- Leadership needs to work on growing the pool of volunteers

Managing people

Regarding the "principal developers"? (1)

- Have to fill many roles:
  – manage technical infrastructure
  – maintain "institutional knowledge"
  – onboard and mentor contributors
  – review patches

  – work on foundational functionality

Managing people

Regarding the “principal developers”? (2)

- Manage their own careers with all of the other demands:
  – as faculty
  – as permanent technical staff

- Obtain funding for their work
- Document the work that is being done

Problem: There are a lot of other demands on principal developers’ time.

But: This is also an awesome job if you enjoy working with people!

Some recommendations

Recommendations

Technical aspects:

- Use the tools that are out there:
  – Eclipse/Visual Studio instead of emacs/vi
  – cmake instead of homegrown installation scripts
  – doxygen
  – github
- Teach the use of these tools

- Read up on best practices (e.g. “Code Complete”, books on software design patterns)
- Teach these best practices

Recommendations

Human aspects:

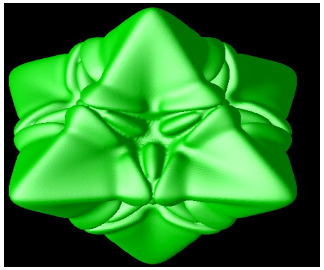
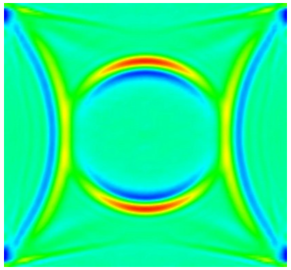
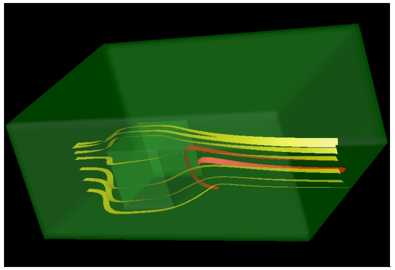
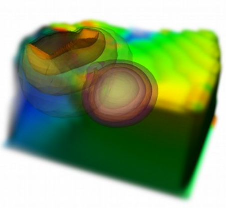
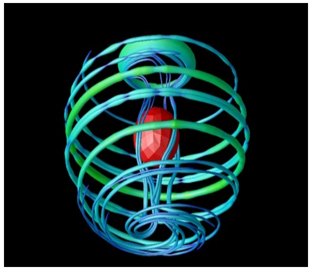
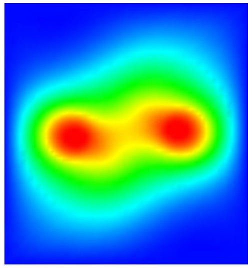
- Commit to a project only if that is compatible with career aspirations

- If you lead a project:
  – Understand where people are coming from
  – Spend the time mentoring
  – Be welcoming and generous with praise

Conclusions

Scientific software packages have become so large that they are *fundamentally different* from small academic codes:

- Managing the limits of humans to understand complexity is the key technical challenge
- Managing the humans in these projects
  – with different skills
  – with different motivations
  is the key human challenge.

More information:

- Wolfgang Bangerth:
  "Leading a Scientific Software Project: It's All Personal"

  Better scientific software (BSSw) blog post, 2019

  https://bssw.io/blog_posts/leading-a-scientific-software-project-it-s-all-personal

- Wolfgang Bangerth and Timo Heister:
  "What makes computational open source software libraries successful?"

  Computational Science & Discovery 6 (2013), 015010

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