RESEARCH REVIEW 2019

Untangling the Knot: Recommending Component Refactorings

James Ivers

Software Structure Enables Our Ability to Innovate

Quickly delivering new capabilities and taking advantage of new technology depend on an ability to evolve software efficiently. The structure of legacy software, however, often fails to support this goal.

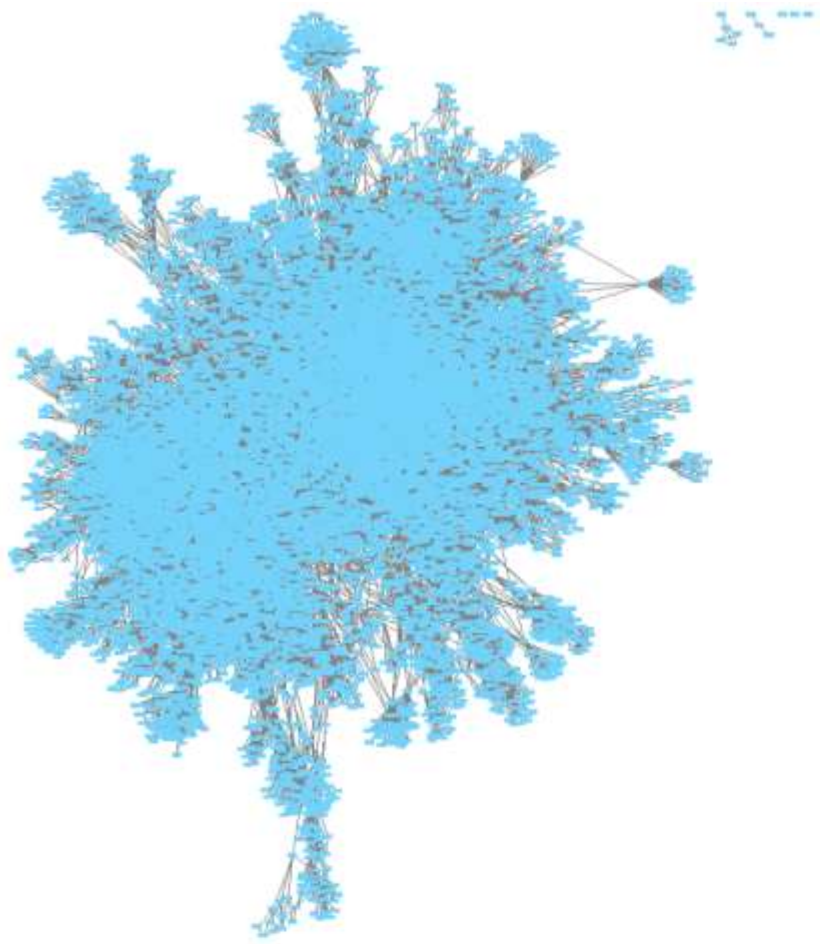
A recent anecdote from a DoD contractor: The estimate for isolating a mission capability from the underlying hardware platform was 14,000 staff hours (development only).

This is representative of a class of changes that involve isolating a specific software capability from its context. Other examples include

- migrating a capability to the cloud
- harvesting a component for reuse
- replacing a proprietary component

Our project will allow the same work to be done in **one-third** of the time.

Software Complexity Is a Driver of the Effort Required



Even modest systems are hard to comprehend, and harder to modify.

- A modest application with only 68K lines of code (LOC) contains more than 10K nodes and 50K relations.
- Making a "simple" change, like isolating the code for deployment as a service, can require reasoning about hundreds of dependencies.

A 2018 survey found that more than **40%** of an average developer work week was spent on "maintenance (i.e., dealing with bad code/errors, debugging, refactoring, modifying)."

https://stripe.com/reports/developer-coefficient-2018

SEI Goal: Create an Automated Refactoring Assistant

Refactoring is a technique for improving the structure of software, but it is typically a *labor-intensive* process in which developers must

- figure out where changes are needed
- figure out which refactoring(s) to use
- implement refactorings by rewriting code

Our goal is to create an automated assistant for developers that recommends refactorings to isolate software, allowing capabilities to be harvested or replaced in 1/3 of the time it takes to do so manually.

- Uses a semi-automated approach
- Addresses all three labor-intensive activities

In perspective, our work would reduce the cost in the earlier example from 14,000 staff hours to 4,500 staff hours—saving the cost of 9,500 hours of development.

Building on Search-Based Software Engineering

By framing software engineering problems as optimization problems, we can use metaheuristic search techniques to automatically find solutions.

- Encouraging work in refactoring focuses on improving general quality metrics[1,2,3]
- Limited but growing interaction with users to capture preferences

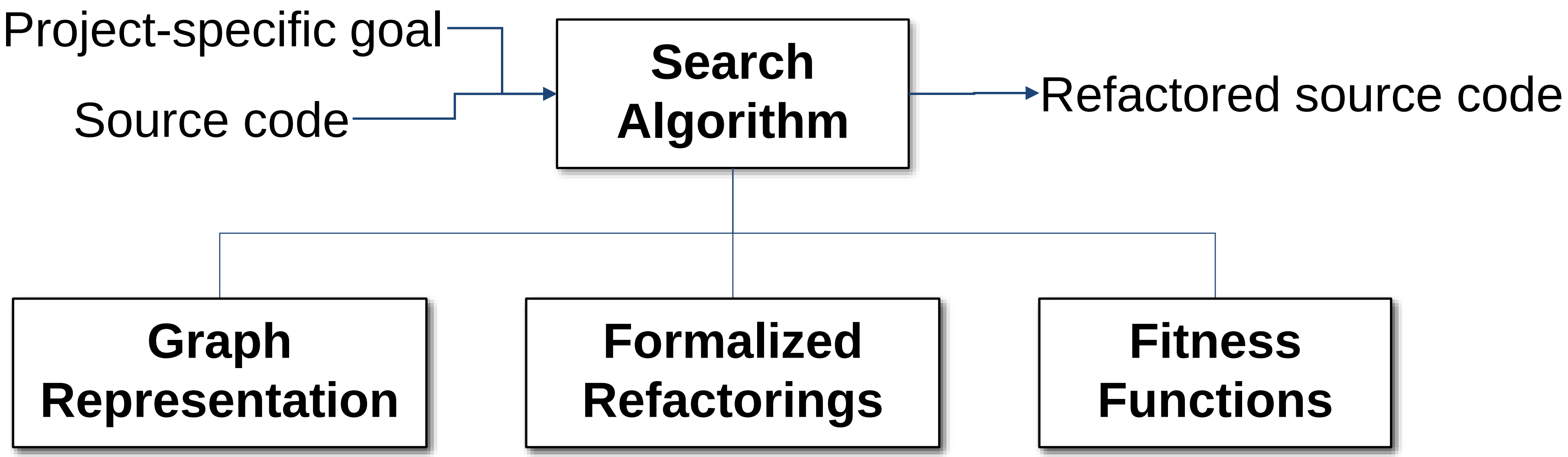
Our innovation

- Focus on isolating software
- Start with user preference
- Define criteria to guide search to practical solutions

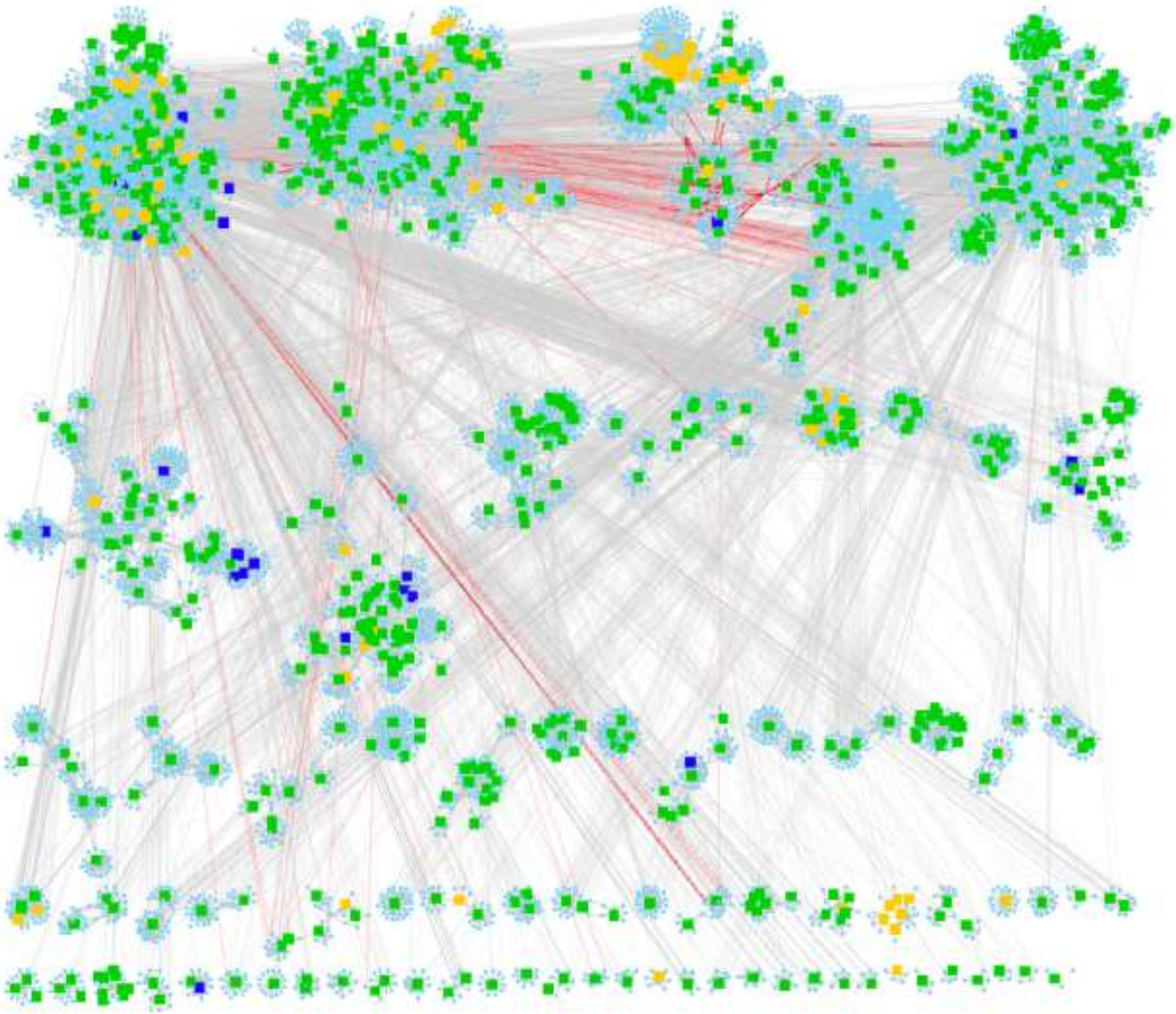
[1] M. Harman & L. Tratt. Pareto Optimal Search Based Refactoring at the Design Level. GECCO 2007: 1106–1113.
[2] M.W. Mkaouer, M. Kessentini, S. Bechikh, M.O. Cinnéide, & K. Deb. On the Use of Many Quality Attributes for Software Refactoring: A Many-Objective Search-Based Software Engineering Approach. *Empir. Softw. Eng.* (2015) 1–43.
[3] C. Simons, J. Singer, & D.R. White. Search-Based Refactoring: Metrics Are Not Enough. SSBSE 2015: 47–61.

Our Approach

We are adapting search-based optimization algorithms to recommend refactorings that isolate software to support harvesting or replacing capabilities.



Problem Framing



Basis: Only certain software dependencies interfere with the goal.

Approach: Focus search on solutions that reduce those dependencies.

- Counting those dependencies is an **objective** basis for fitness.
- Reducing scope of search (by 1 to 4 orders of magnitude) promotes **scalability.**

Problematic Couplings

Problematic couplings are those software dependencies that interfere with achieving a specific goal.

		Problematic Couplings - Relation Type						
Project	Scenario	CALLS	IMPLS	INHERITS	READS	USES_TYPE	WRITES	Total
MissionPlanner	Logger_A	515	0	1	982	255	403	2156
MissionPlanner	Logger_D	25	0	0	9	5	1	40
MissionPlanner	Radio_A	135	0	0	103	30	43	310
MissionPlanner	UI_A	2557	2	2	7269	2085	1493	13408
Duplicati	Logging_D	448	4	2	114	28	0	596
Duplicati	Server_A	105	3	0	235	56	52	451
Duplicati	Server_D	65	4	0	320	22	24	435
ConvNetSharp	GPU_D	529	0	1	495	384	7	1416
SharpCaster	Activity_D	10	0	0	13	3	0	26
eShopOnContaine	Eventbus_D	28	0	0	29	19	0	76
eShopOnContaine	Ordering_A	57	18	31	142	78	51	377
mRemoteNG	Putty_D	6	0	6	32	8	12	64
mRemoteNG	Rdp_A	45	1	1	218	4	16	285
mRemoteNG	Rdp_D	5	0	0	42	30	1	78
		4530	32	44	10003	3007	2103	

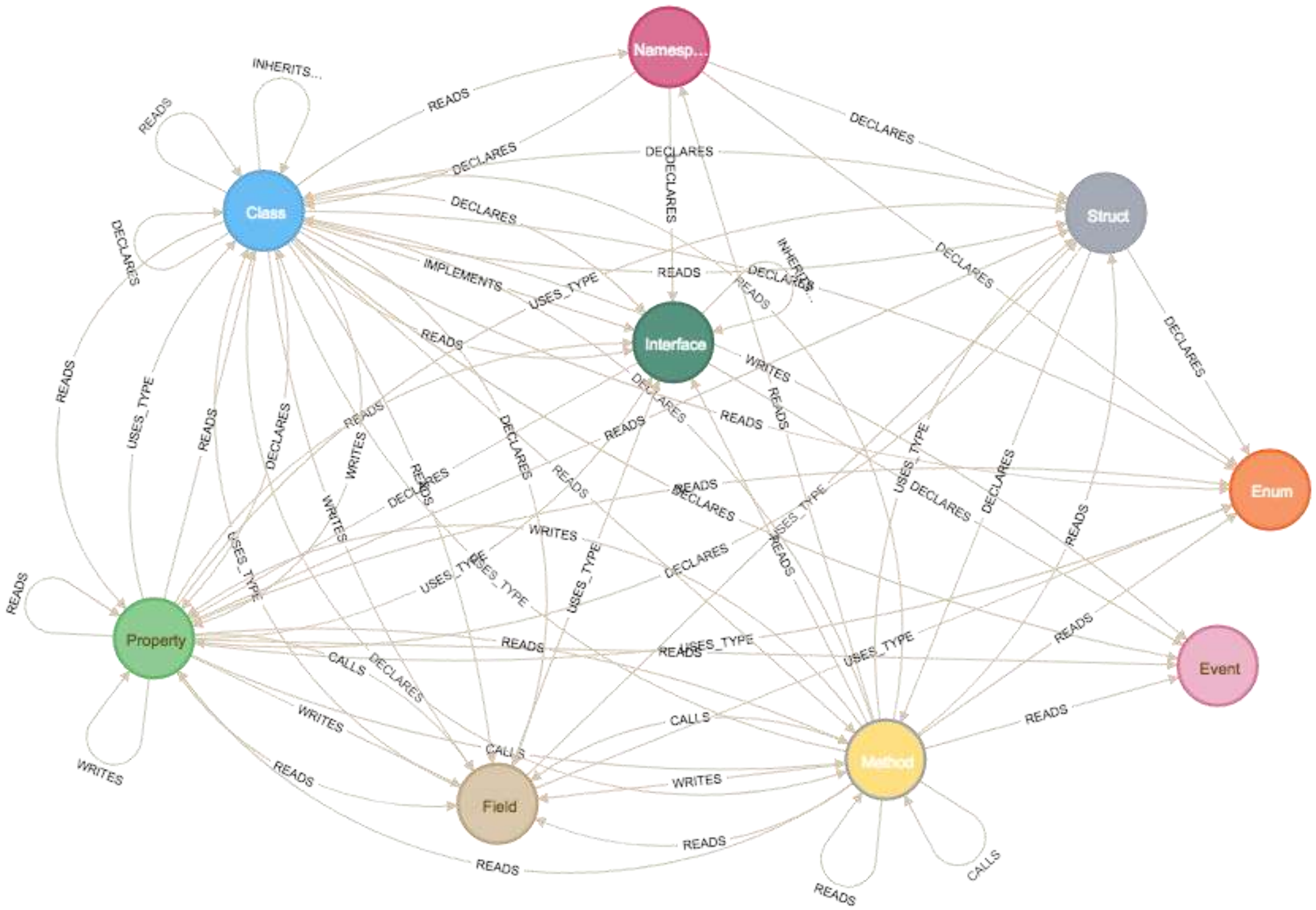
Source: All project data from github.com/open-source

Our prototype automatically identifies these, and we are using this data to drive the research.

Application: Sizing the work to isolate software for a range of scenarios

- Prioritizing software for migration
- Providing input to cost analysis

Graph Representation



github.com/duplicati/duplicati

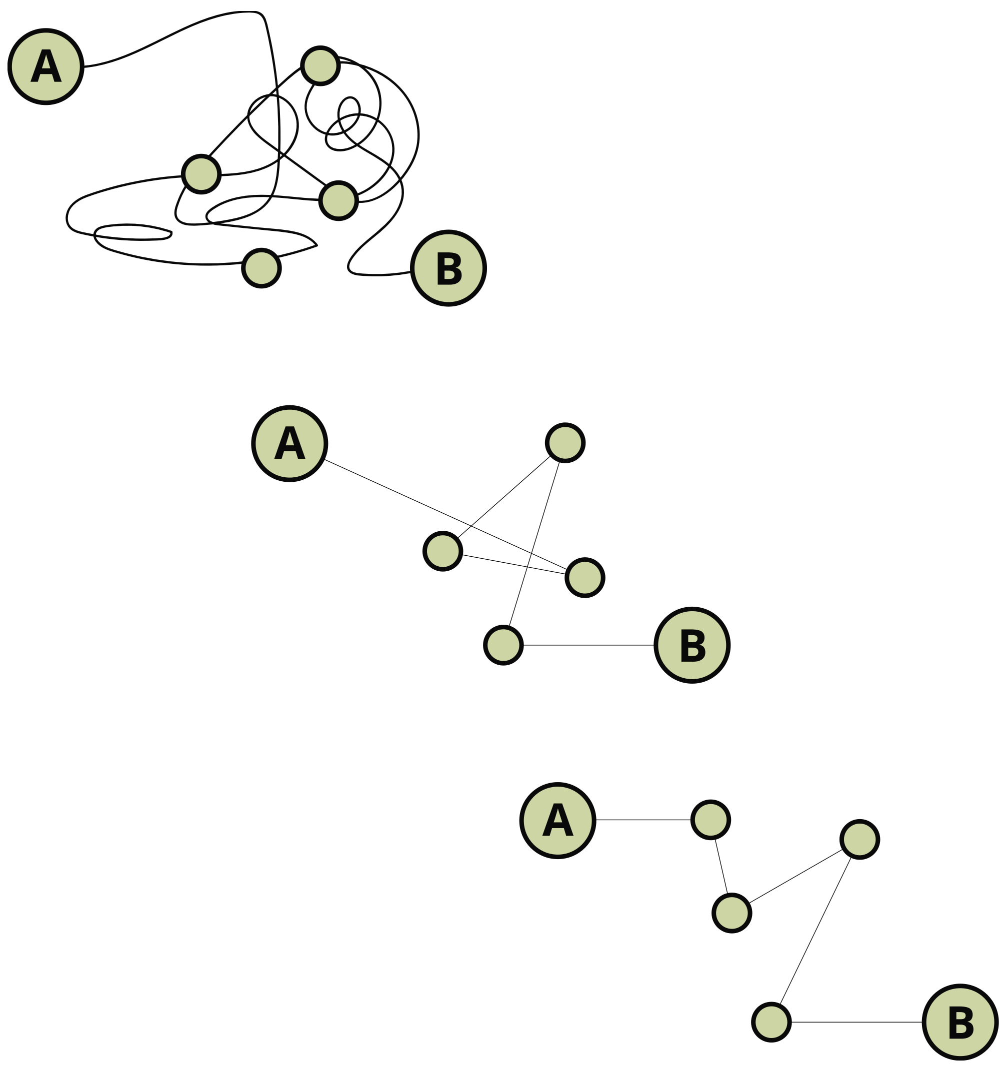
github.com/ArduPilot/MissionPlanner

We use a static code analysis tool to extract structural information from C# source code.

Sample graph sizes

- Duplicati:
  - **68K** code lines
  - **10,194** nodes and **49,620** relations
- MissionPlanner:
  - **756K** code lines
  - **81,790** nodes and **587,542** relations

Formalized Refactorings



Refactorings are the operations that the search algorithms use to explore changes to the graph.

Refactorings involve changes like

- moving, copying, or removing code
- extracting portions of code
- introducing interfaces or intermediaries

We formalize each in terms of a precondition and transformation over the graph.

FY19 – initial set; FY20 – scale up

Of 19,720 problematic couplings in our open source case studies,

- 74.1% can be resolved by at least one refactoring
- 14.0% can be resolved by more than one refactoring

Multi-objective Search and Fitness Functions

Multi-objective genetic algorithms like NSGA-II allow us to employ multiple fitness functions and generate Pareto-optimal solutions.

We are exploring fitness functions to find a combination that yields *recommendations that developers will accept*.

Candidates include

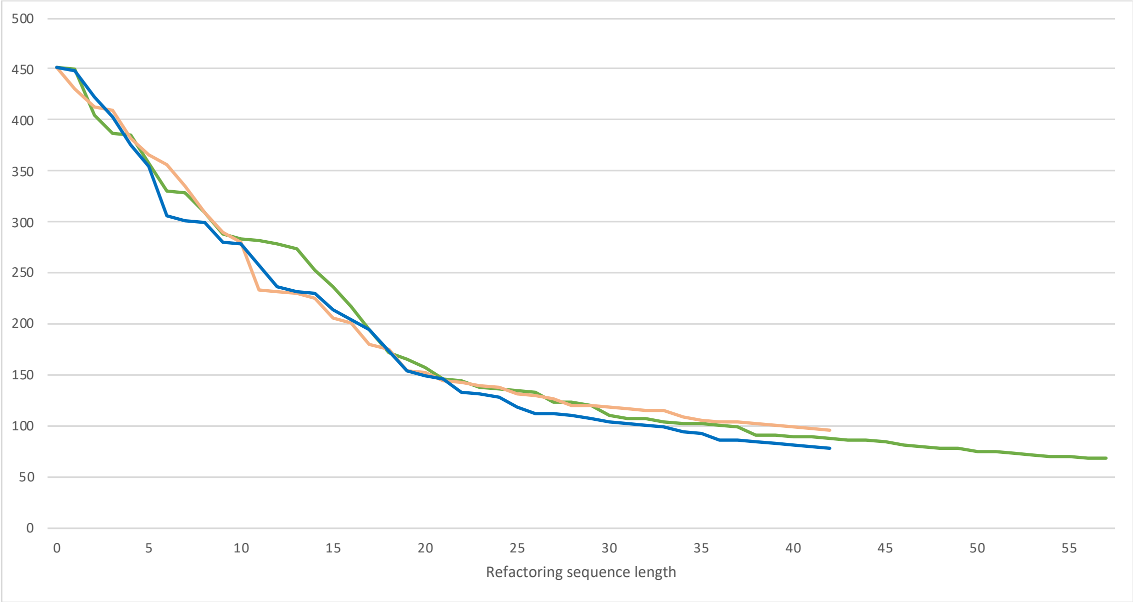
- solving the core problem – minimizing problematic couplings
- reducing work – minimizing code changes and unrealized interfaces
- maintainable code – improving a range of code quality metrics
- understandable code – maximizing semantic coherence

Search Algorithm

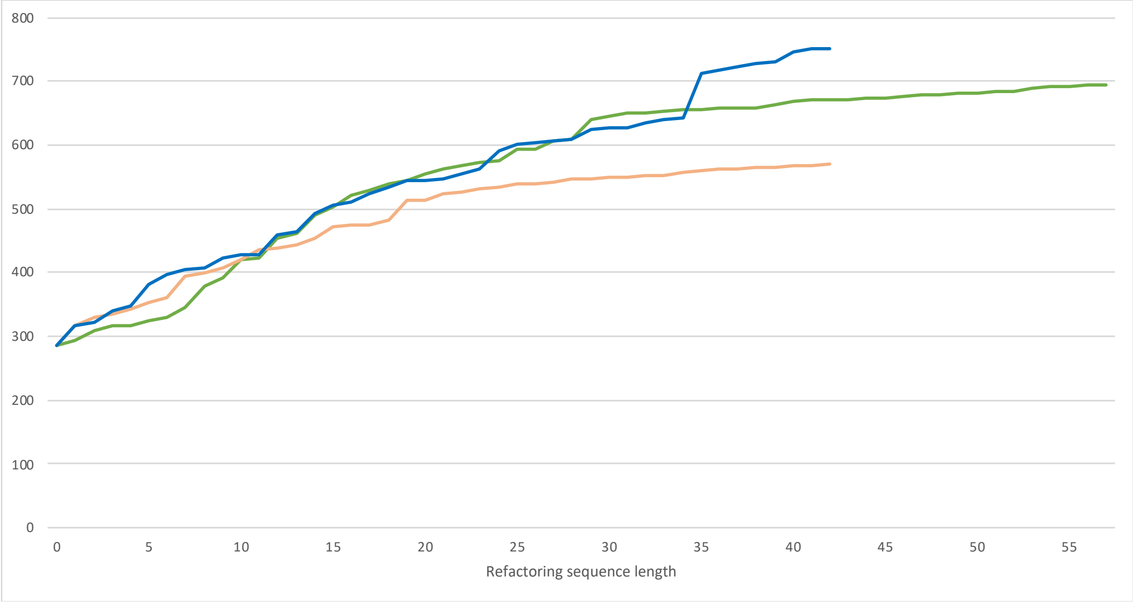
Automated search finds sequences of refactorings that collectively solve as much of the project-specific goal as possible.

FY19 – local search; FY20 – global search (genetic algorithms)

Number of Problematic Couplings



Amount of Code Included in Harvest



Looking Ahead

FY19

- Build out infrastructure: representation, refactorings, fitness functions, and local search
- Assemble open source data and initial analyses
- **Ready to pilot** the ability to size problems for C# software

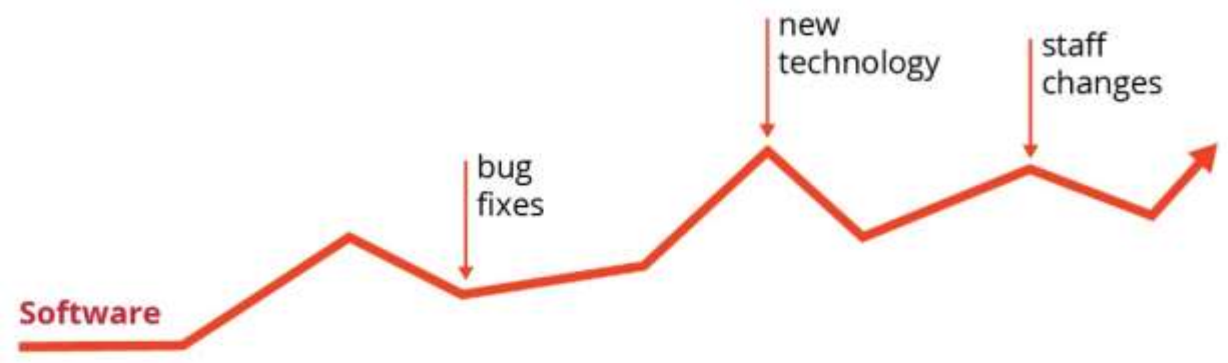
FY20

- Broaden the palette: more refactorings and fitness functions
- Implement global search using multi-objective genetic algorithms

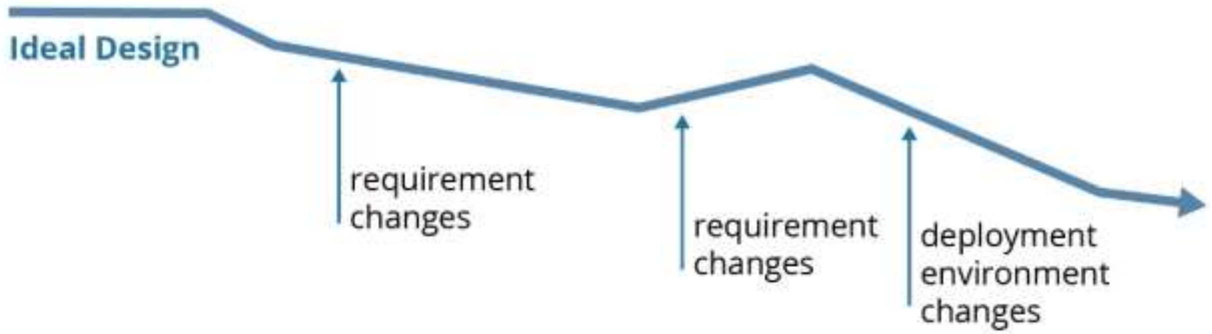
FY21

- Fine-tune search
- Validate with experienced developers
- **Ready to pilot** generation of refactorings for C# software

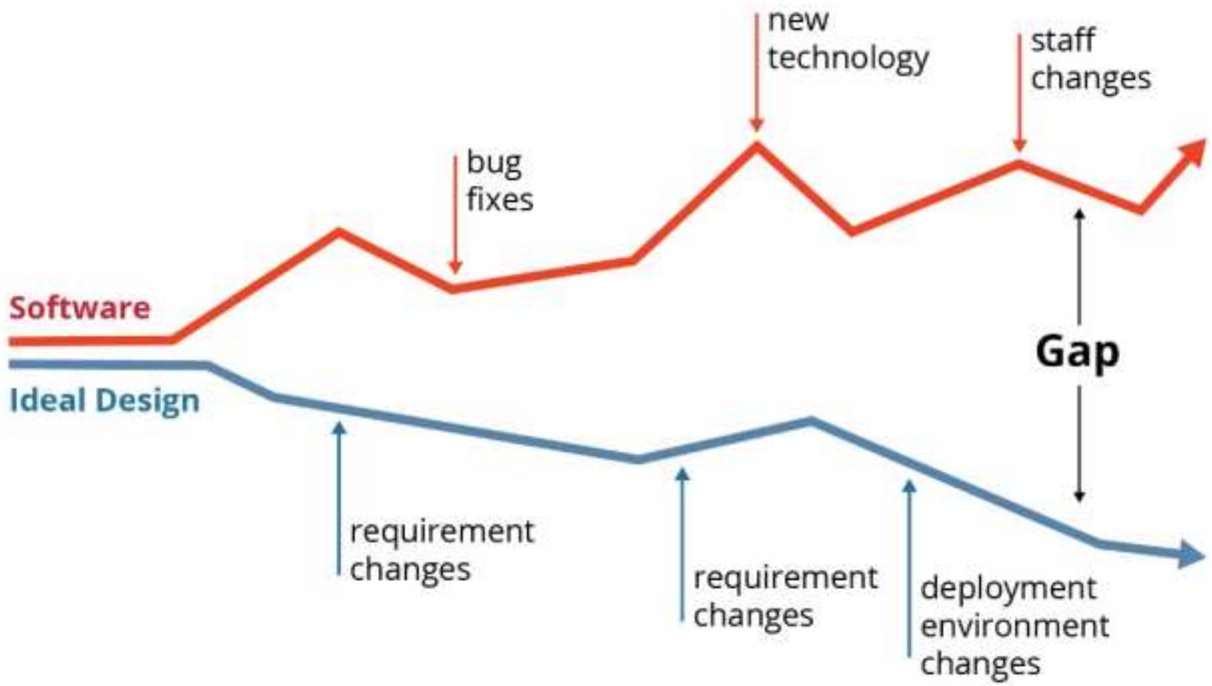
Software Is Constantly Changing over Its Lifetime



What We Want Software to Do Also Changes

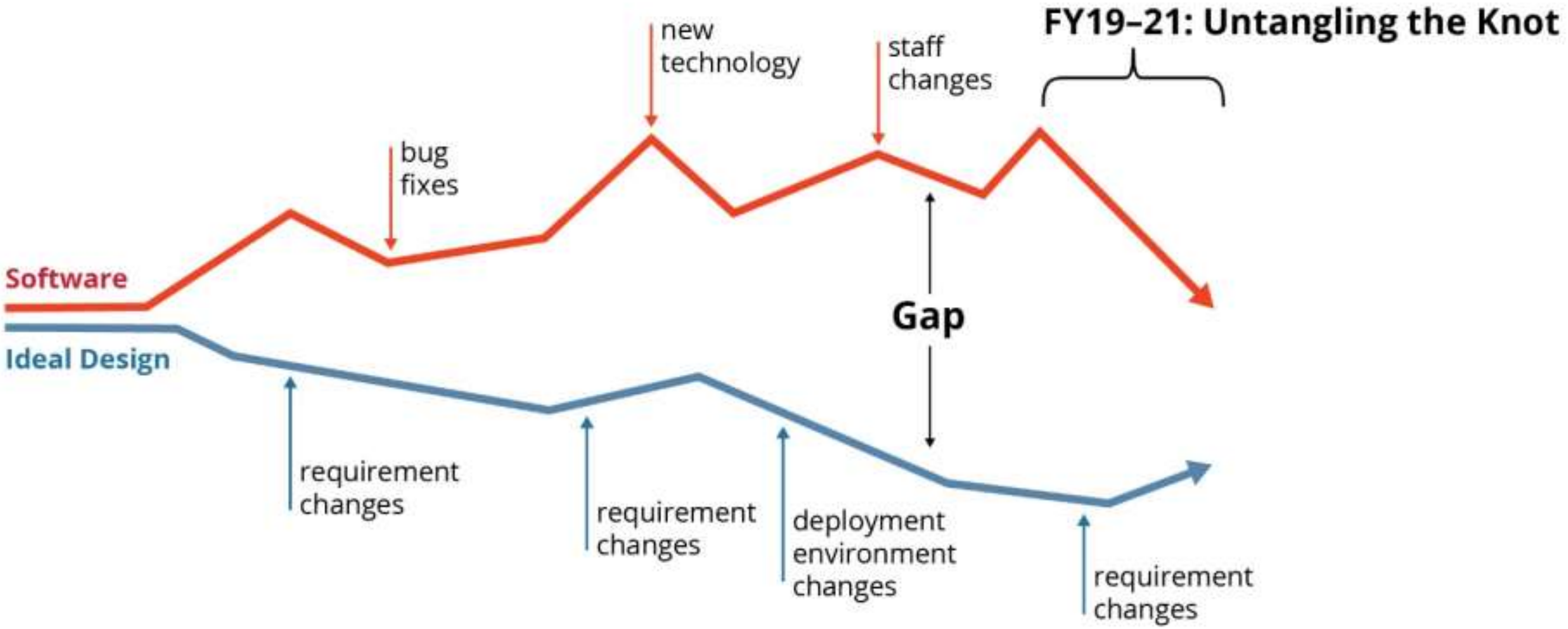


Over Time, Gaps Emerge and Grow



When software structure differs significantly from what is needed, the pace of change and innovation slows down.

Vision: AI for Software Engineering
Automation Can Bring Projects Back into Alignment



Vision: AI for Software Engineering
Automation Can Keep Software Aligned with Needs