Refactoring for End Users

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University of Nebraska–Lincoln

May 22, 2011

In this talk

- End-user software engineering
- Refactoring for web mashups
- Mashup languages create opportunities to extend refactorings
- Speculate how refactoring adapts to other end user domains

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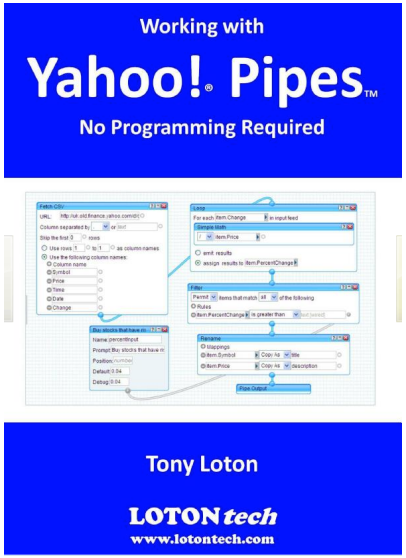
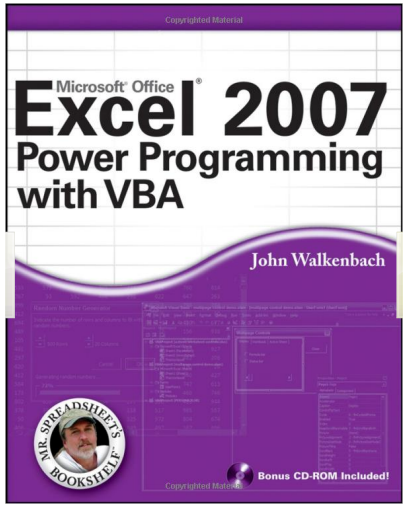
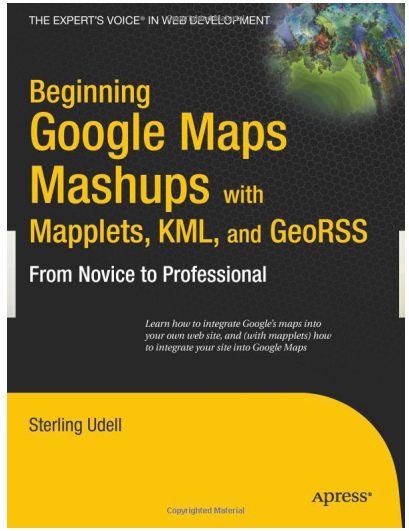
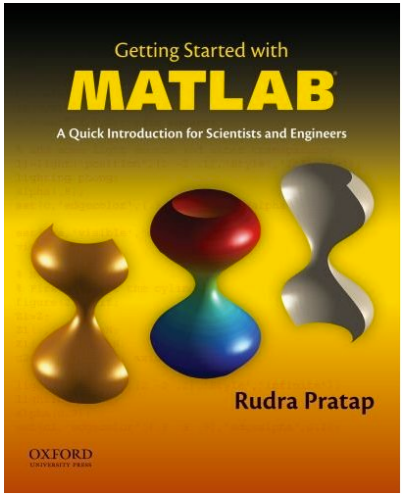
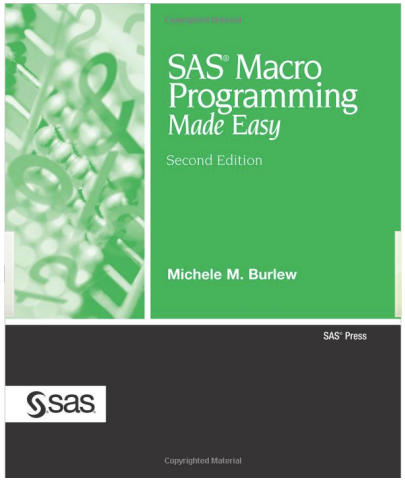
End-User Programming

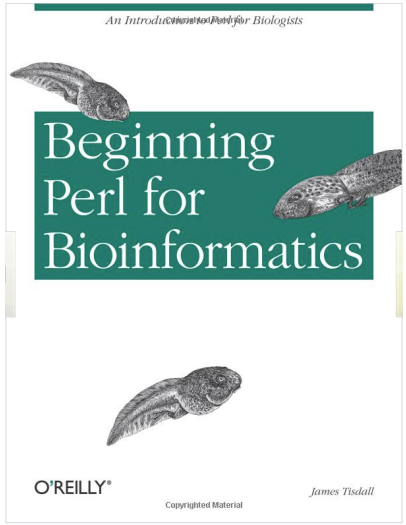


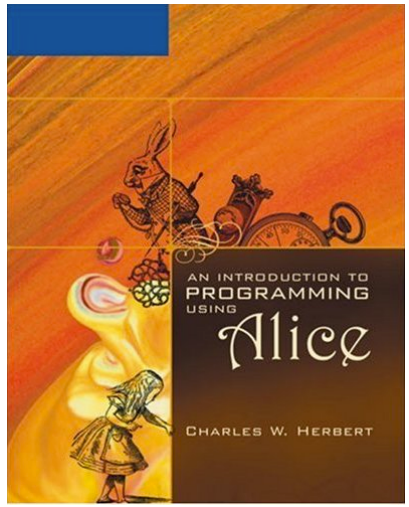












About End-User Programmers

- **There are many** (an estimated 55 million in 2005)
- **Their jobs are diverse** (e.g., accountants, biologists, teachers)
- **They create useful software**, for example:
  - Macros save hundreds of hours in data entry
  - Spreadsheets allow for efficient data storage and computation

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Undermines common assumptions*

- Software is mostly created by professionals
- End users just need good user interface

*Credit to Mary Shaw

Qualitative Differences Between Professional and End-User Programmers

Software Engineering Activity	**Professional SE**	**End-user SE**
Specifications & Requirements	*explicit*	*implicit*
Reuse	*planned*	*unplanned*
Testing and Verification	*cautious*	*overconfident*
Debugging	*systematic*	*opportunistic*

* Credit to Ko, A. et al., The State-of-the-Art in End-User Software Engineering

Challenges in End-User Programming

- **Faults**
  An error in a spreadsheet formula cost a Texas oil firm millions of dollars in an acquisition deal

  Panko, R. “What We Know About Spreadsheet Errors.” Journal of End User Computing Spring 1998.
- **Design**
  Decomposing a problem is difficult for end-user programmers.

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- **Understanding**
  Most learning barriers regarding program understanding were unsurmountable for new programmers.

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Generally, these tasks are unsupported in EUP environments

End User Software Engineering

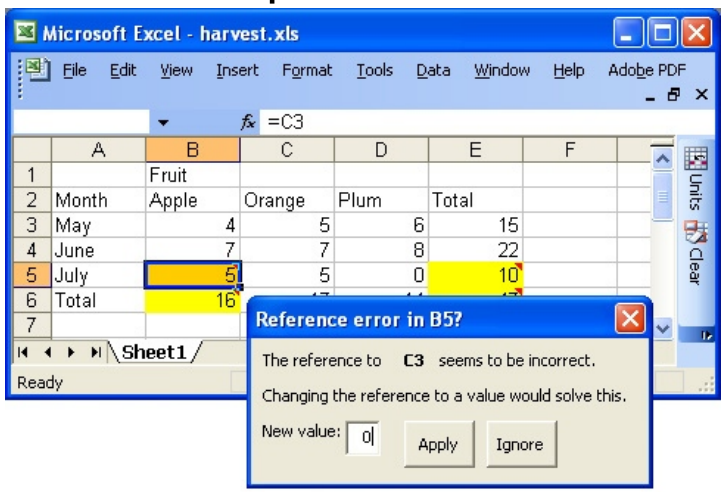
Goal: Better development support for end-user programmers*

- Without requiring training or even *interest* in software engineering
- A holistic approach: no separated tasks, modes, or tools

* Credit to Margaret Burnett

Current End-User Research

UCheck Spreadsheet Errors



Credit: EUSES Consortium `http://eusesconsortium.org/`

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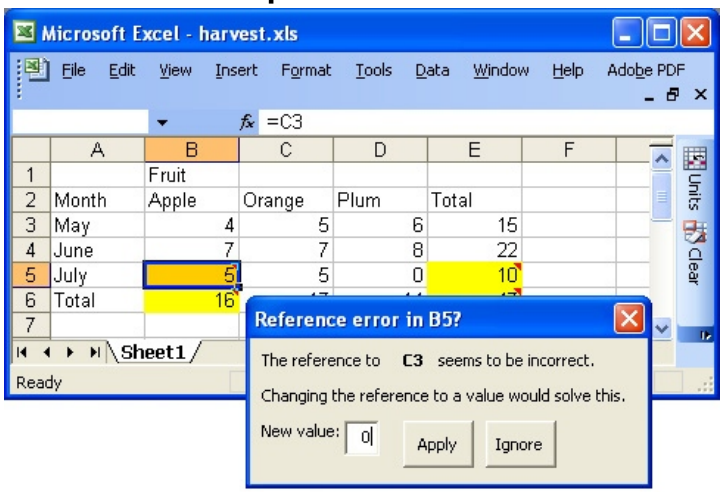
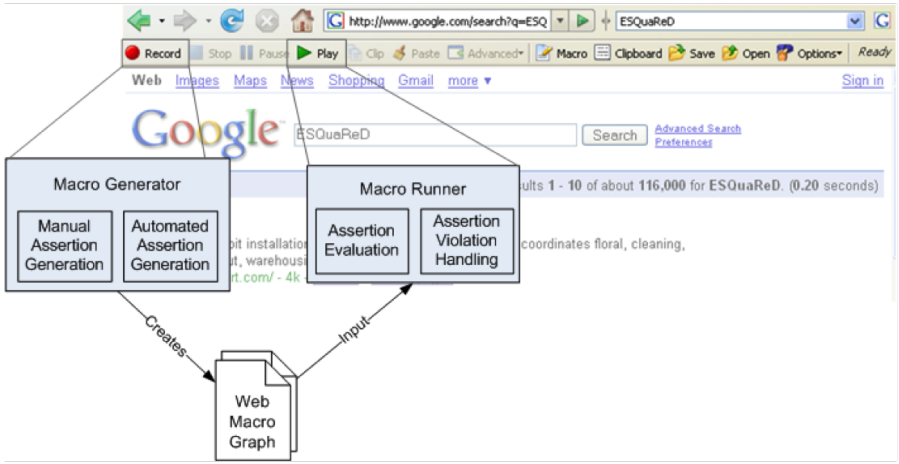


Robofox Assertion Generation



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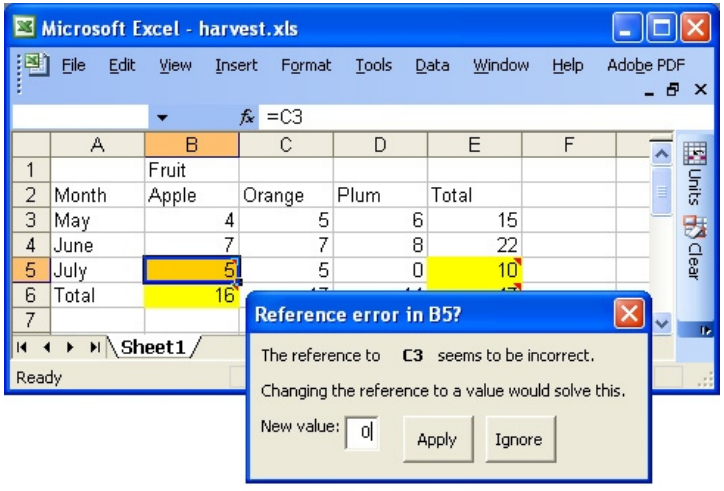

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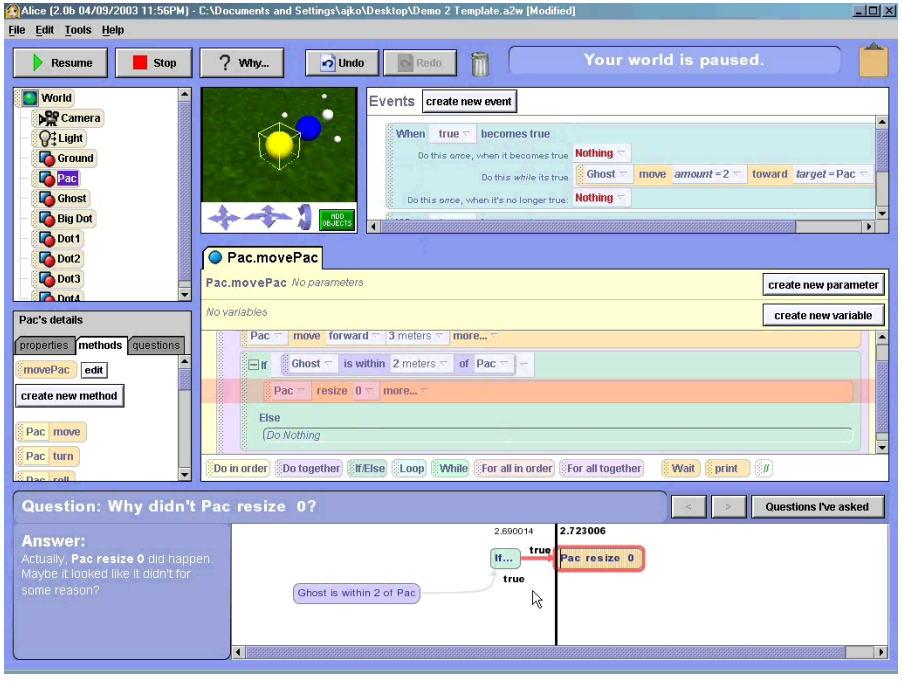

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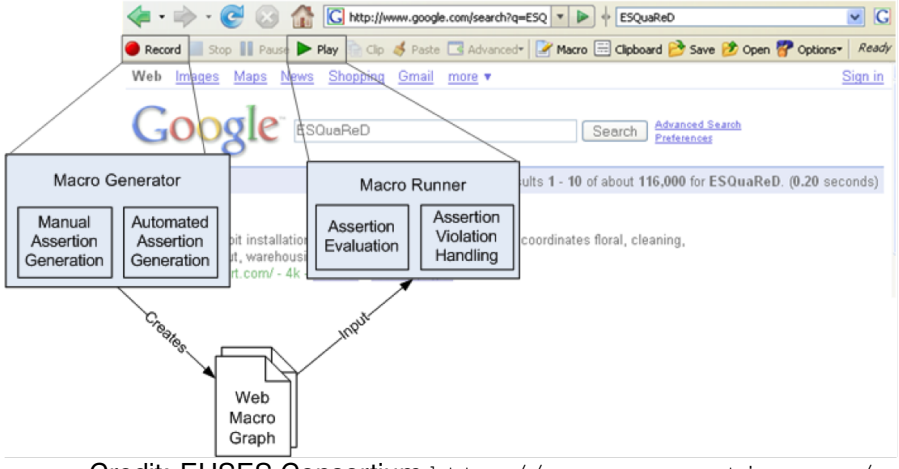

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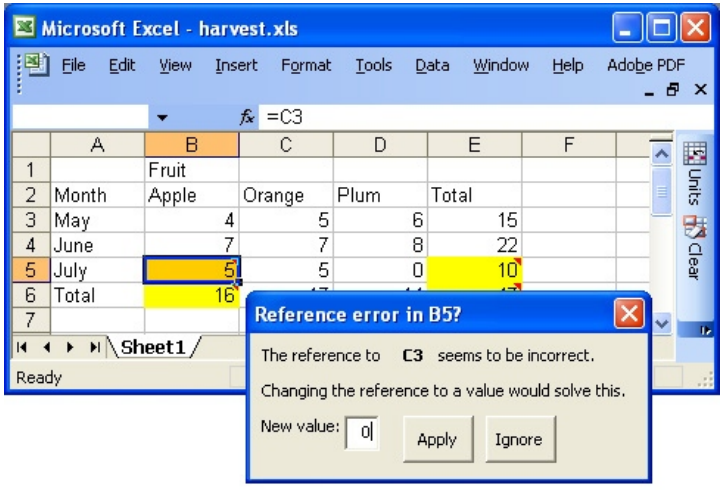

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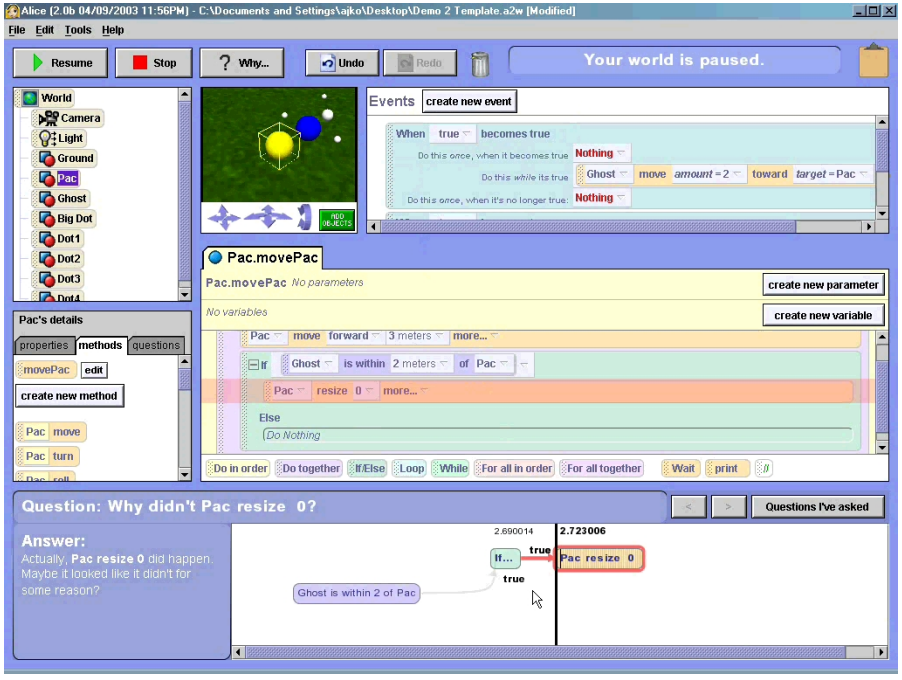

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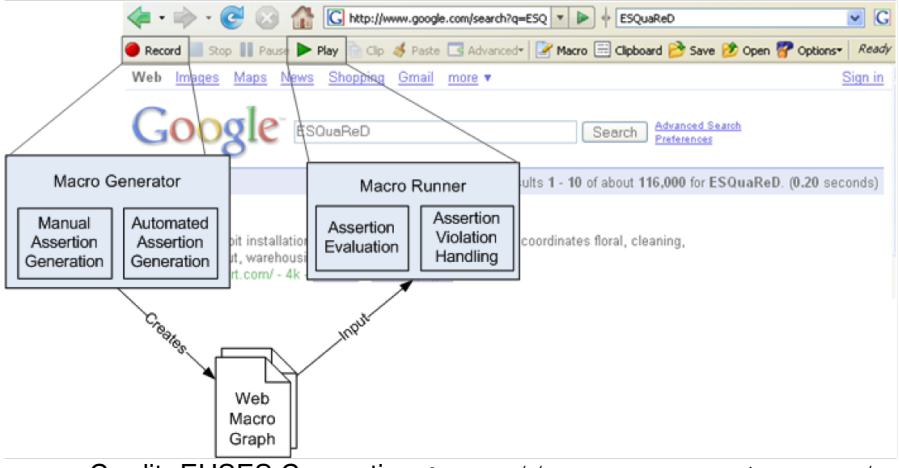

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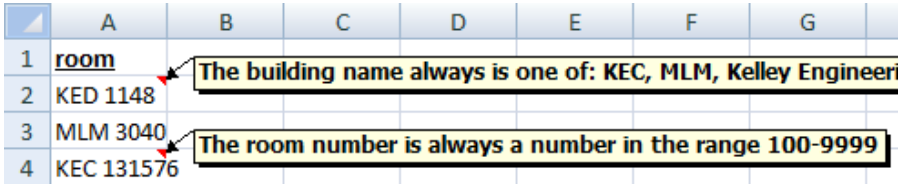
Topes Data Validation



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Why Web Mashups?

Web Mashups

Applications that compose and manipulate existing data sources or services to create new data or service.

Why Study Mashups?

- Many environments (e.g., Apatar, DERI Pipes, IBM Mashup Center, Kivati, Yahoo! Pipes, . . .)
- Potential impact
- Communities

Why Refactoring for Mashups?

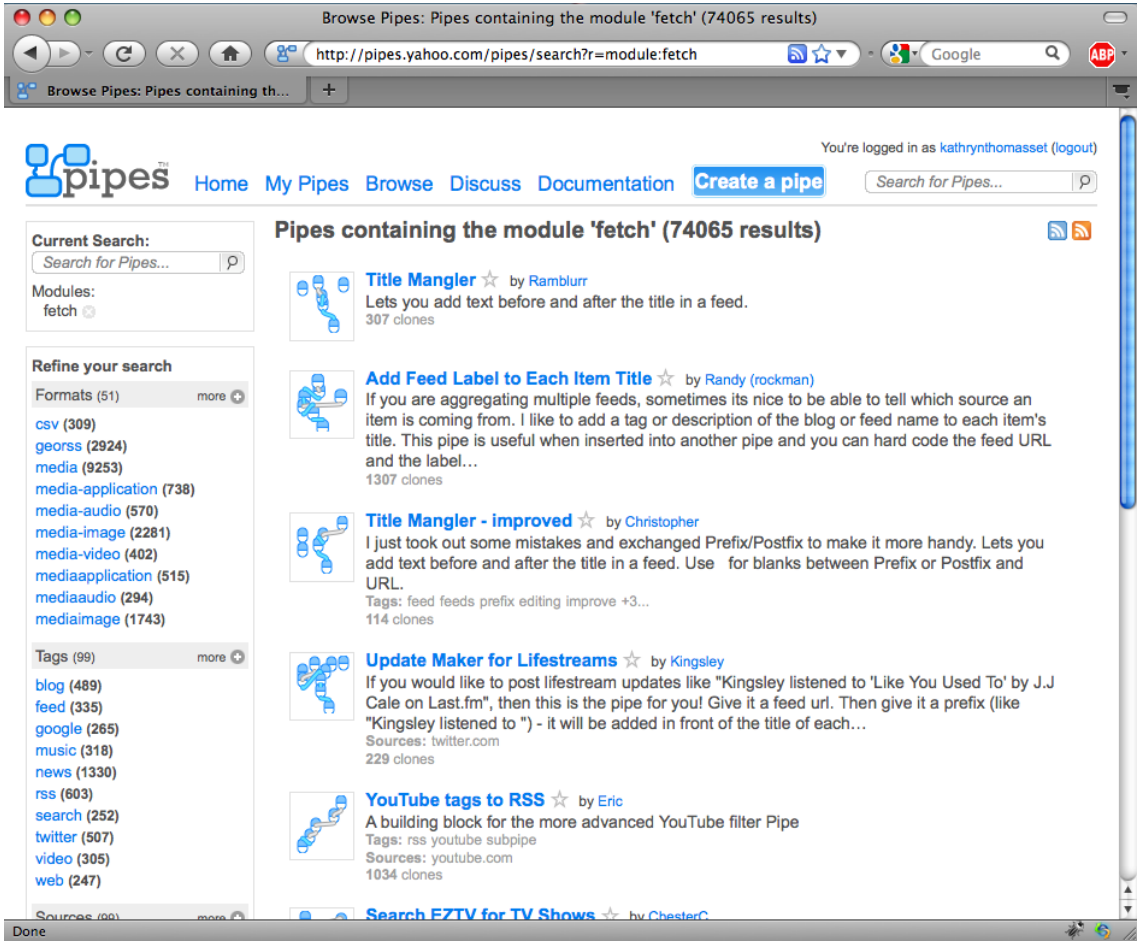
- Mashup programs are littered with code smells
- Smells matter to end users

  Stolee, K.T. and Elbaum, S. Refactoring Pipe-like Mashups for End-User Programmers. ICSE 2011
- Mashup languages are hard for end users to understand

  Zang, N. and Rosson, M.B. Playing with information: How end users think about and integrate dynamic data. VL/HCC 2009
- Maintenance in mashups is common: nearly 24% of Yahoo! Pipes mashups were modified after they were made public
- Reuse then adaptation is common: over 54% of pipes have been cloned, yet only 5% have an exact match

  Stolee, K.T., Elbaum, S., and Sarma, A. End-User Programmers and their Communities: An Artifact-based Analysis. ESEM 2011

About Yahoo! Pipes



- Over 90,000 authors have created mashups
- 5,000,000+ pipes executed every day
- **Large public repository of sample code**

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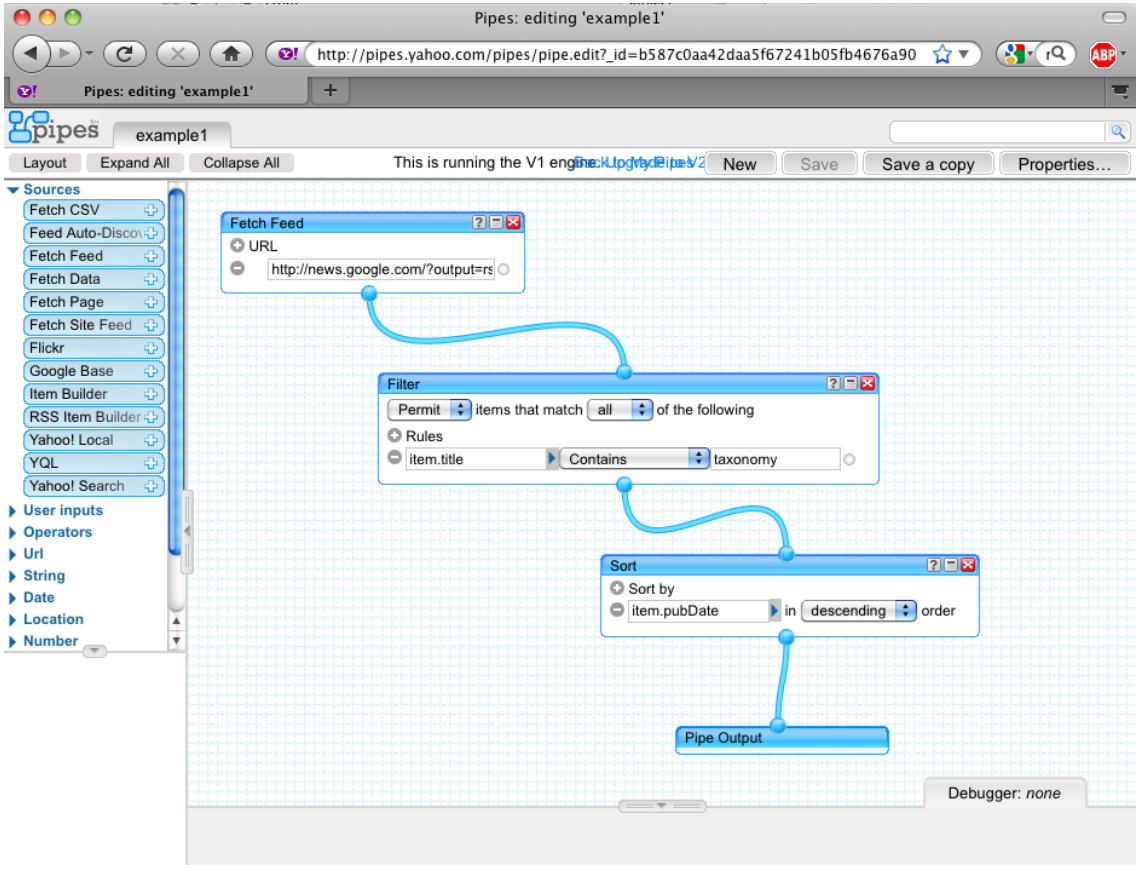

- Visual mashup creation environment
- Within a browser
- Drag and drop interface
- Constrained, yet flexible language

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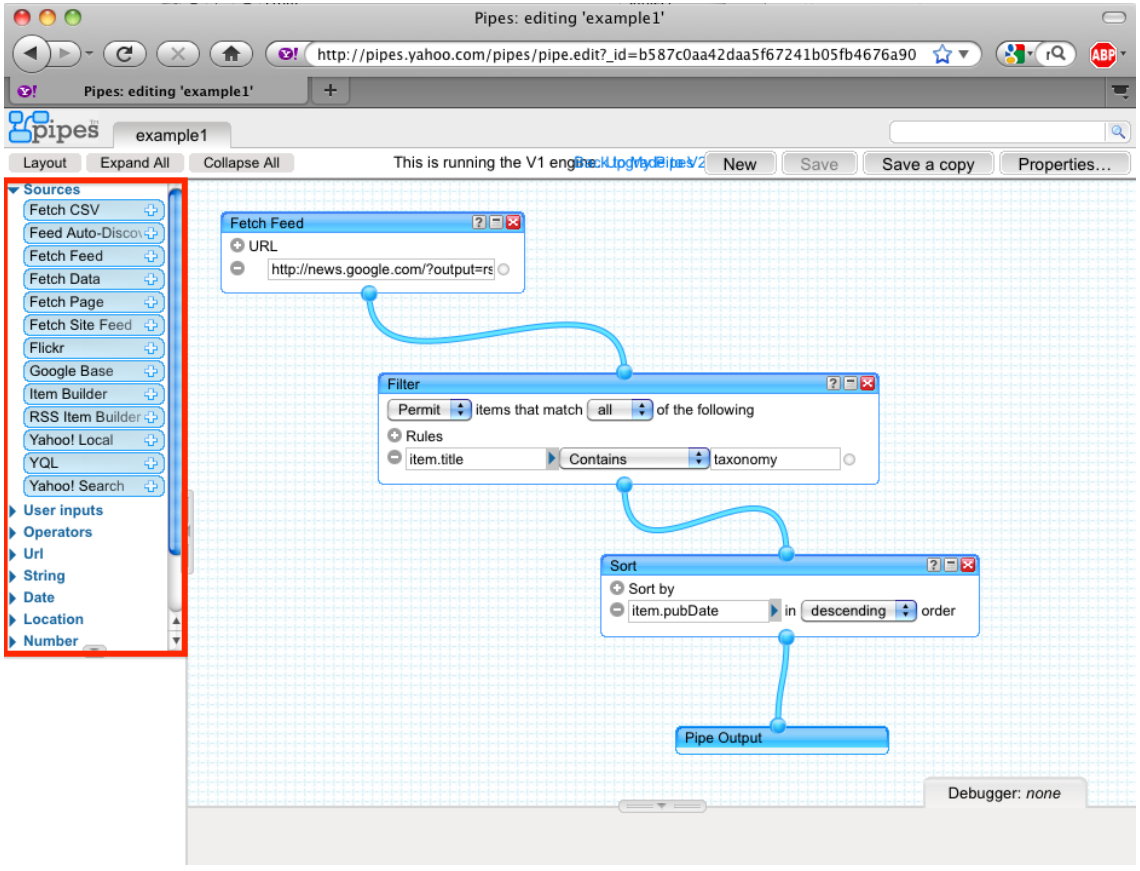

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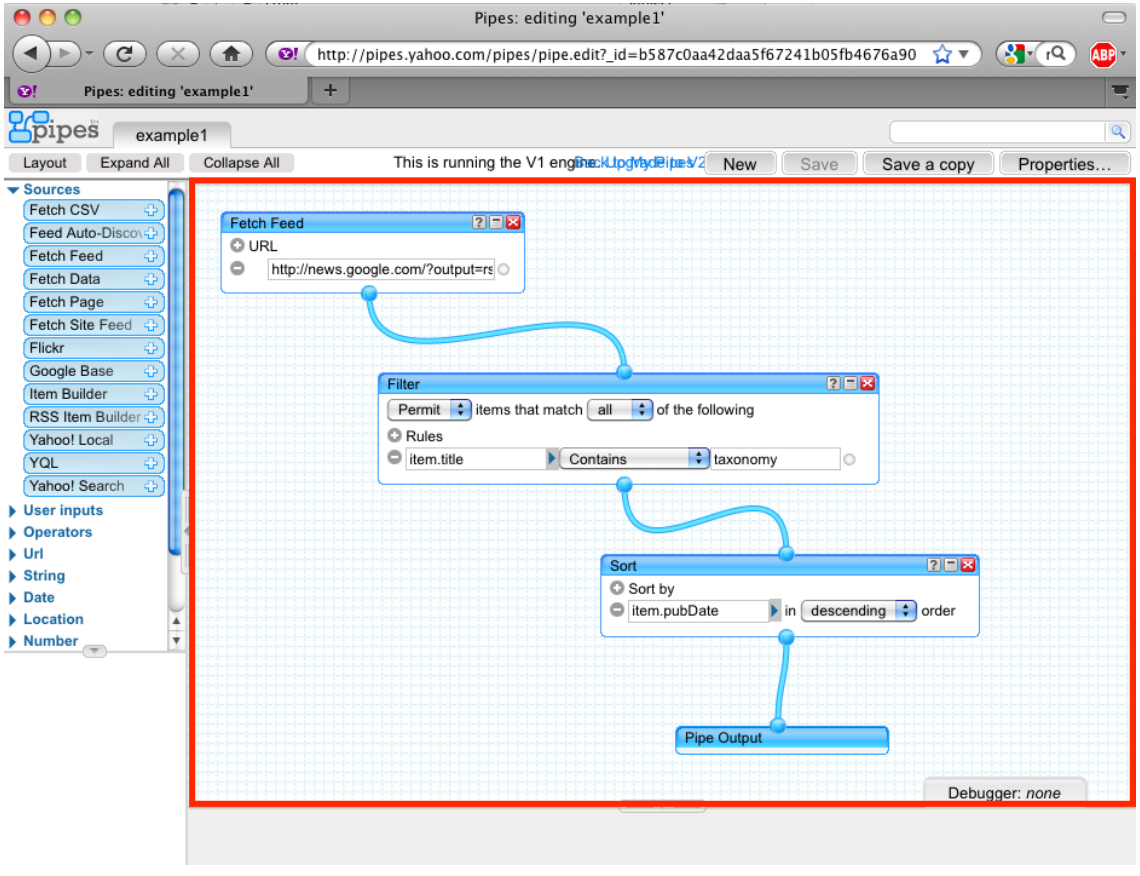

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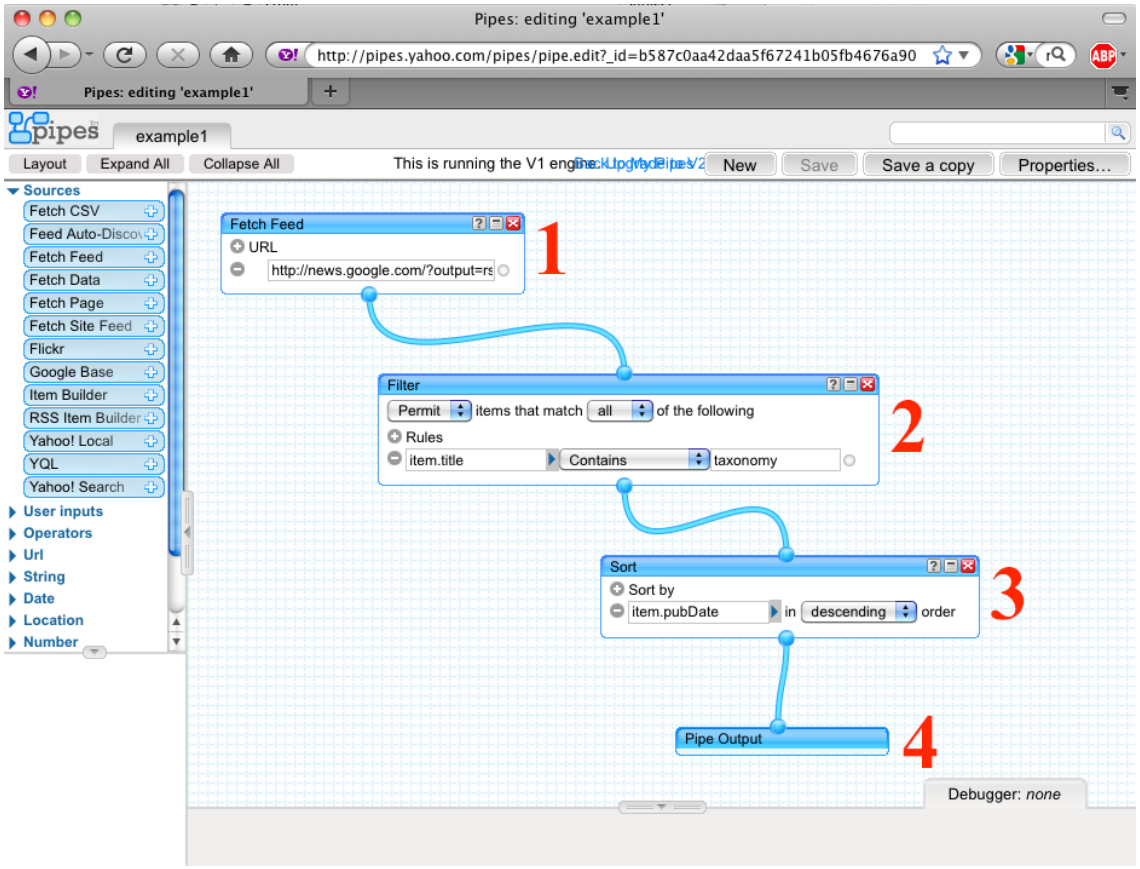

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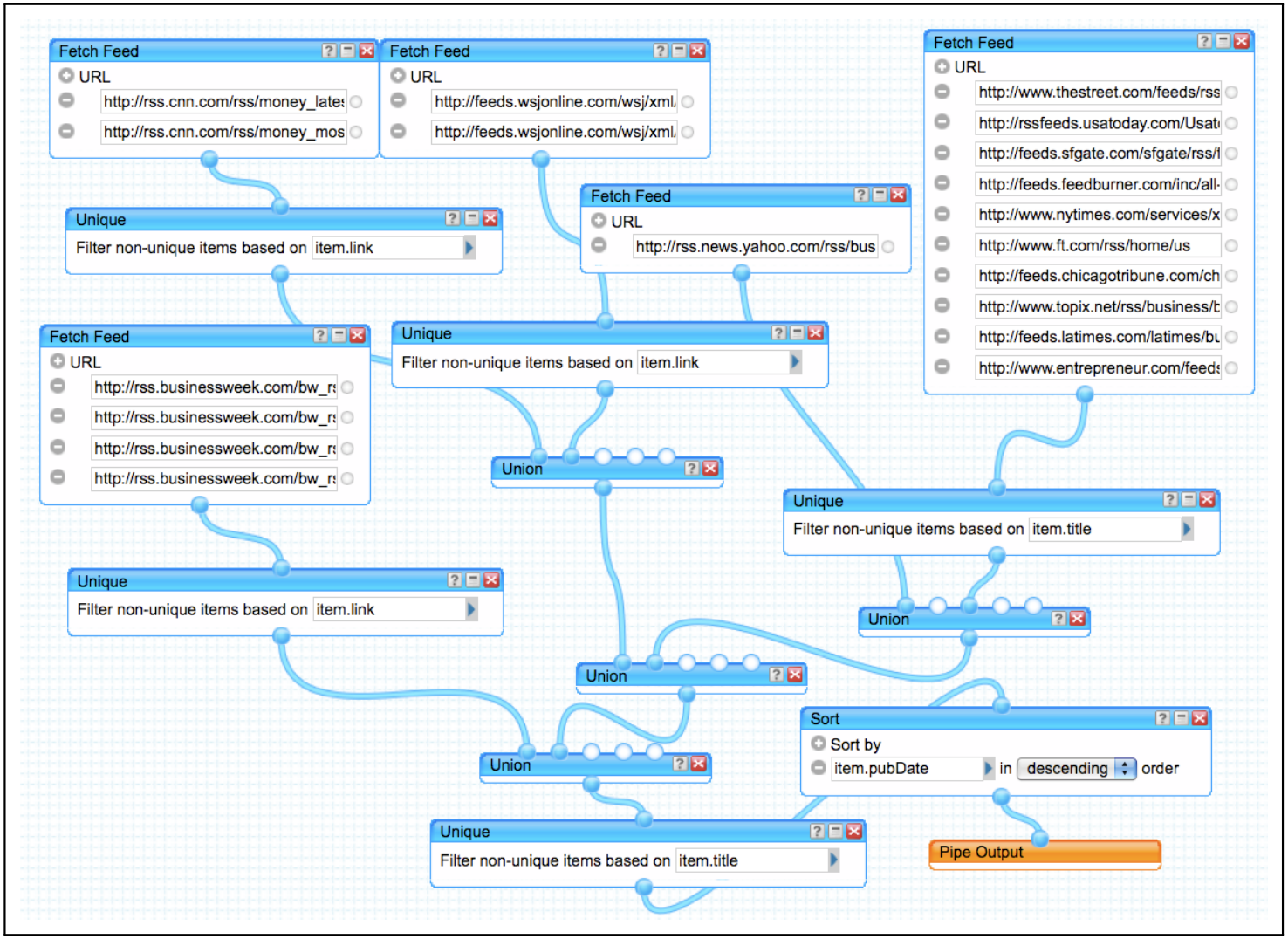
Motivating Example



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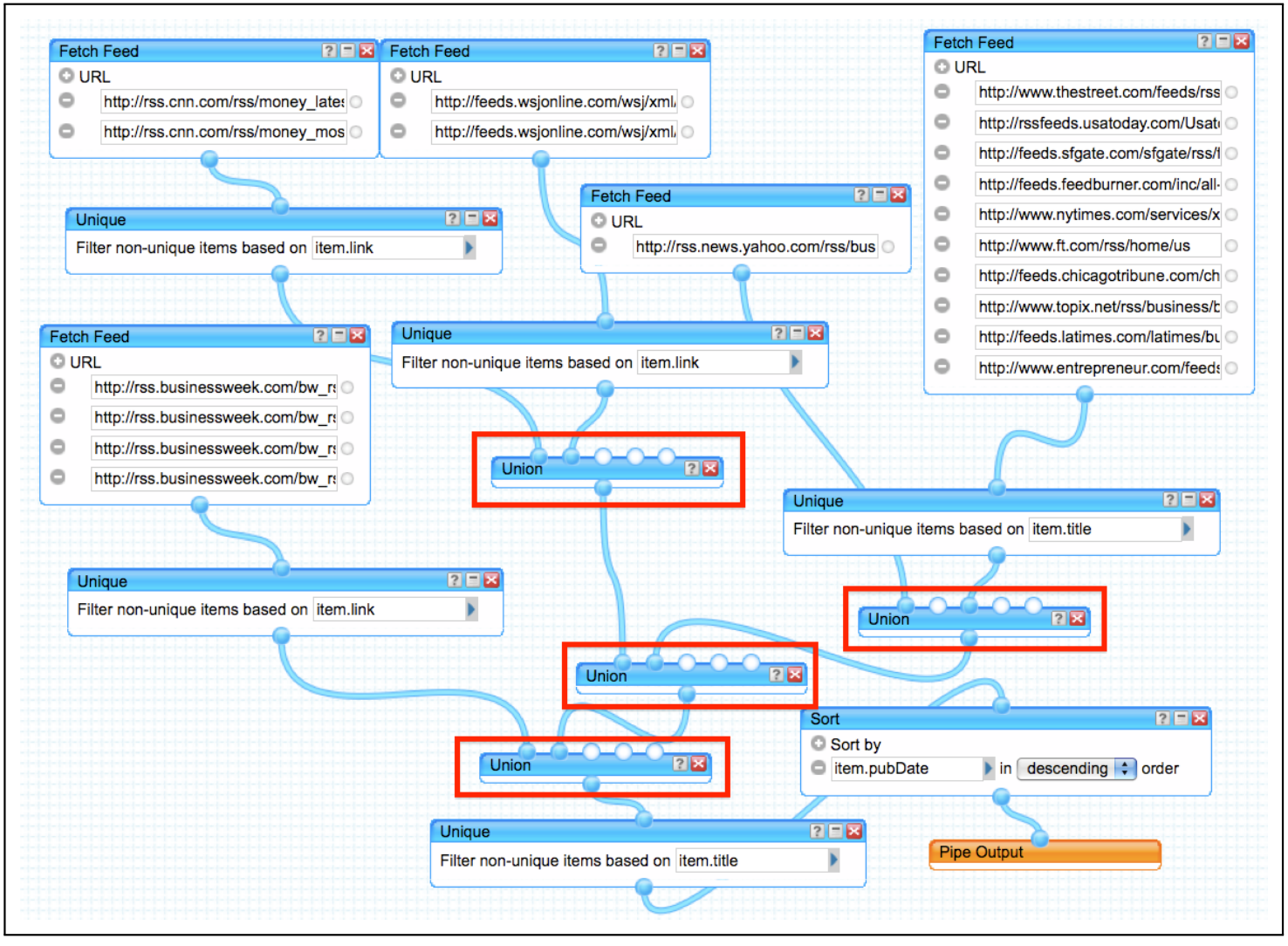

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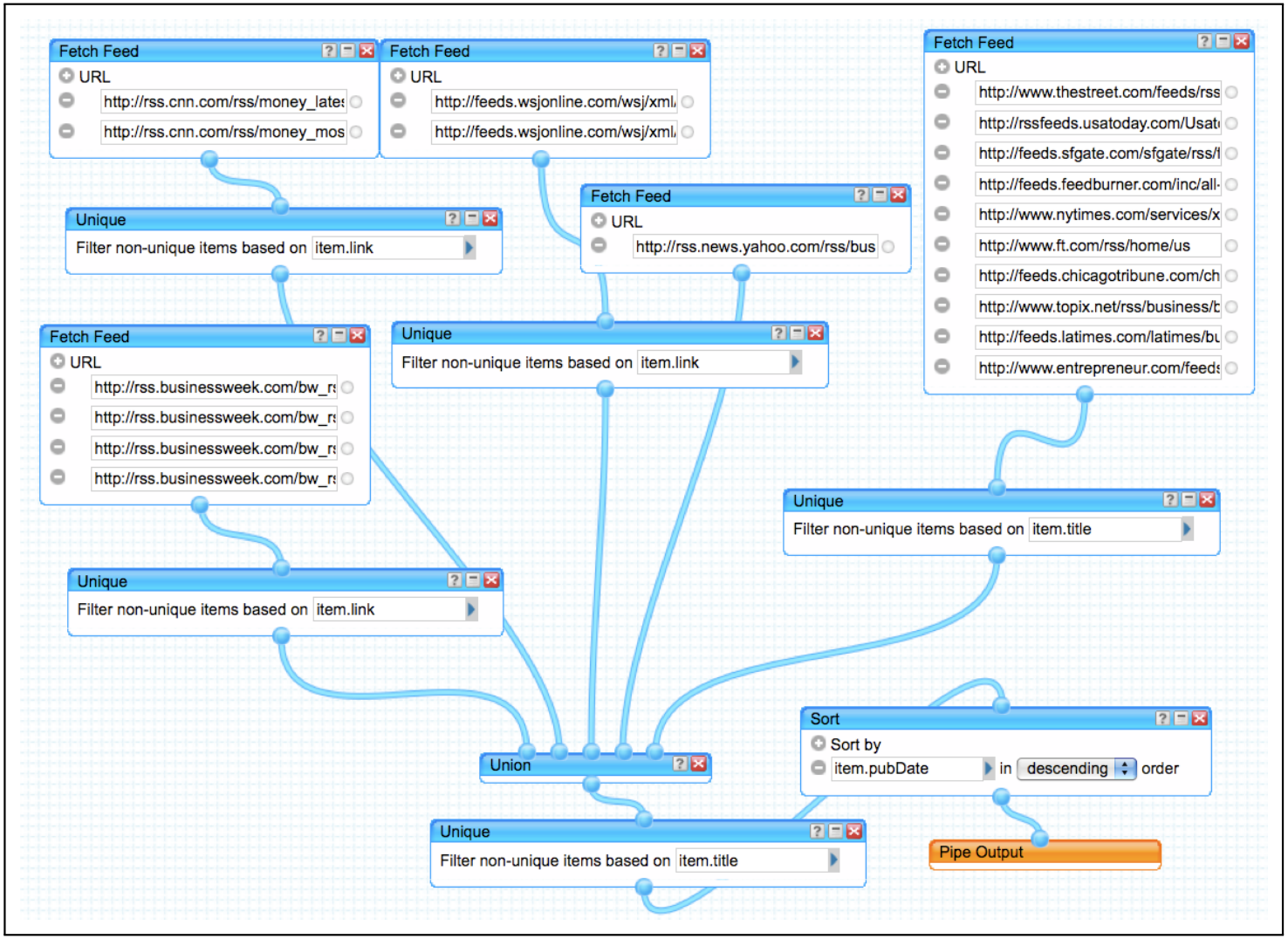

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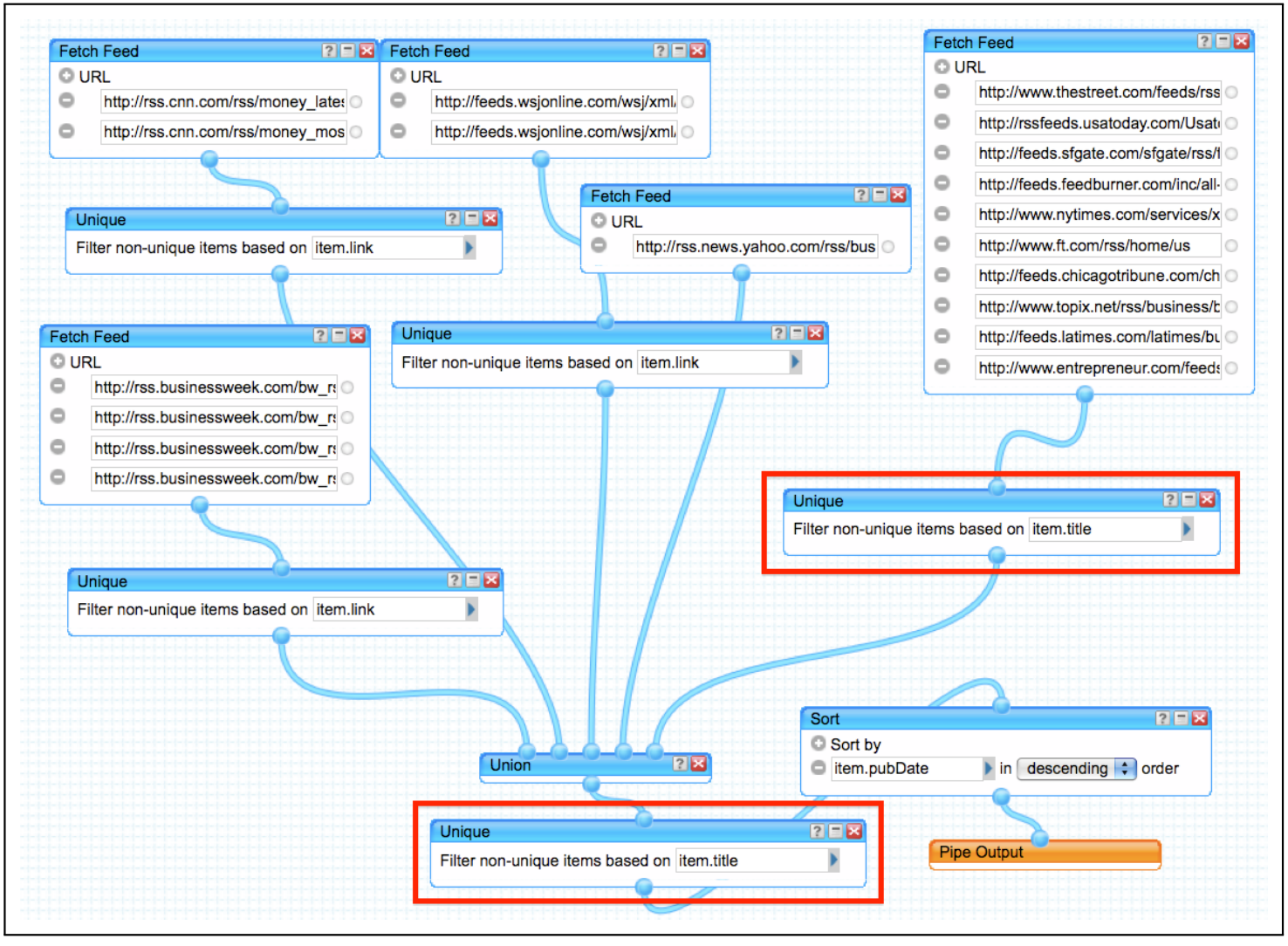

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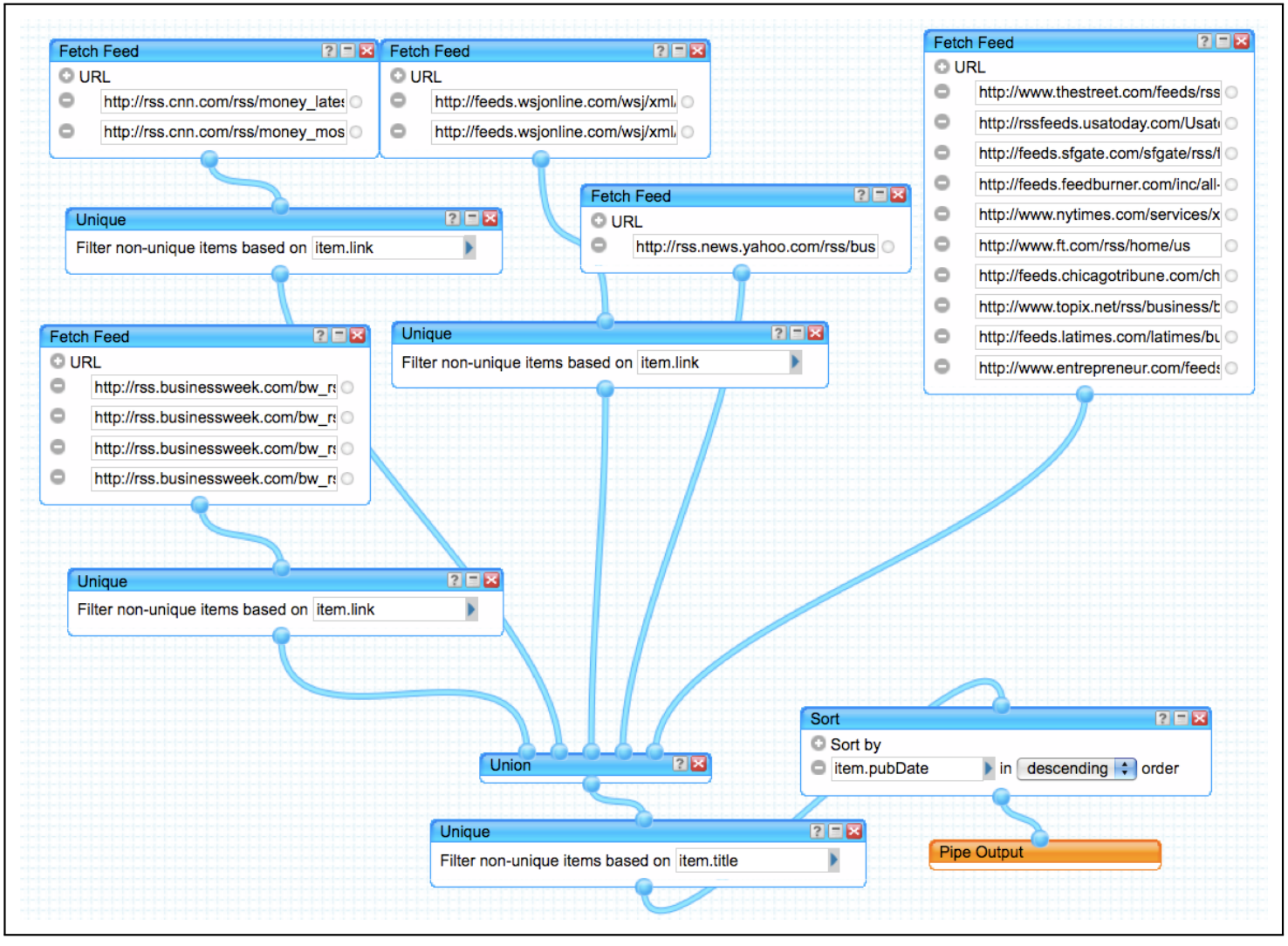

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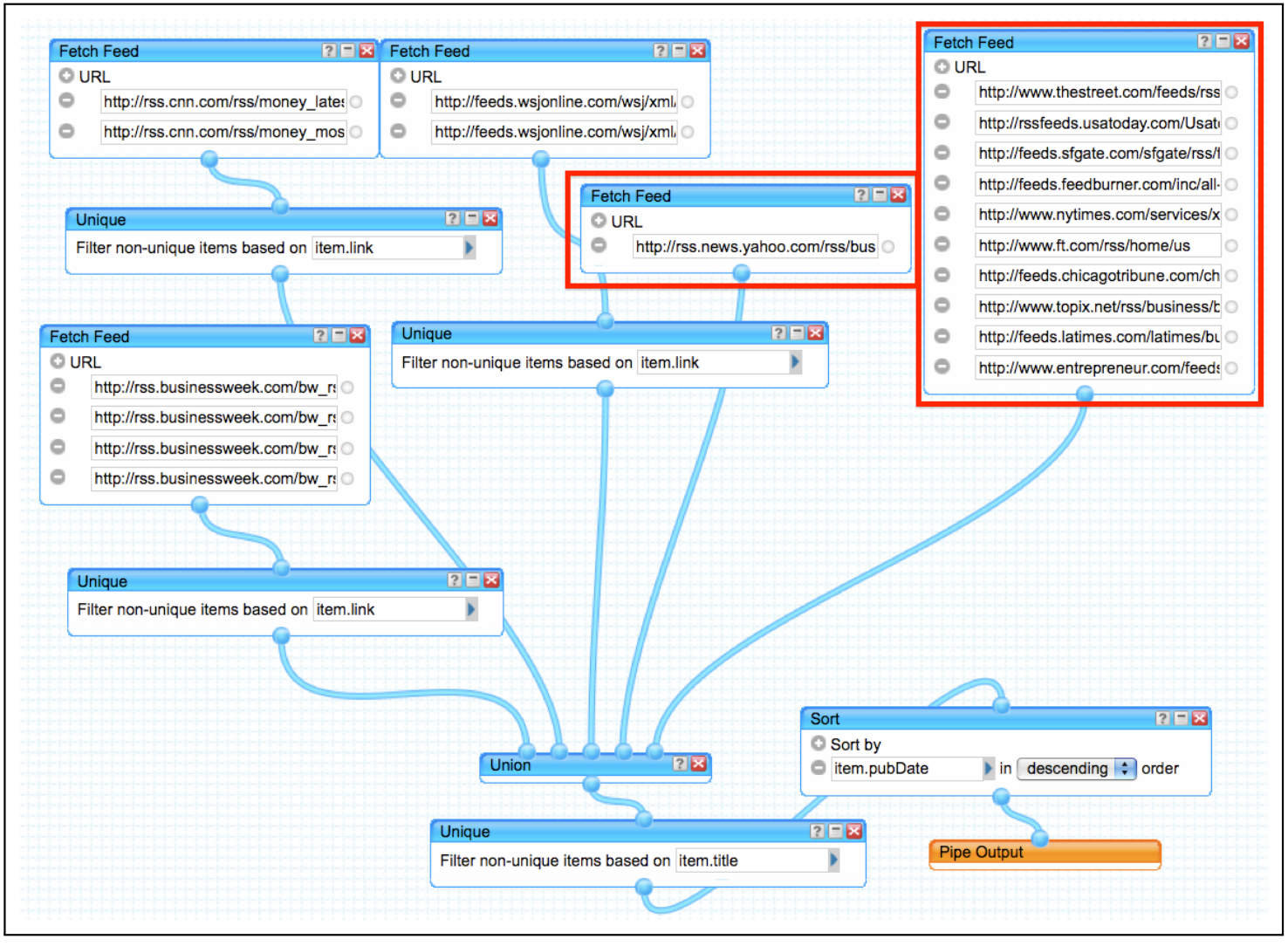

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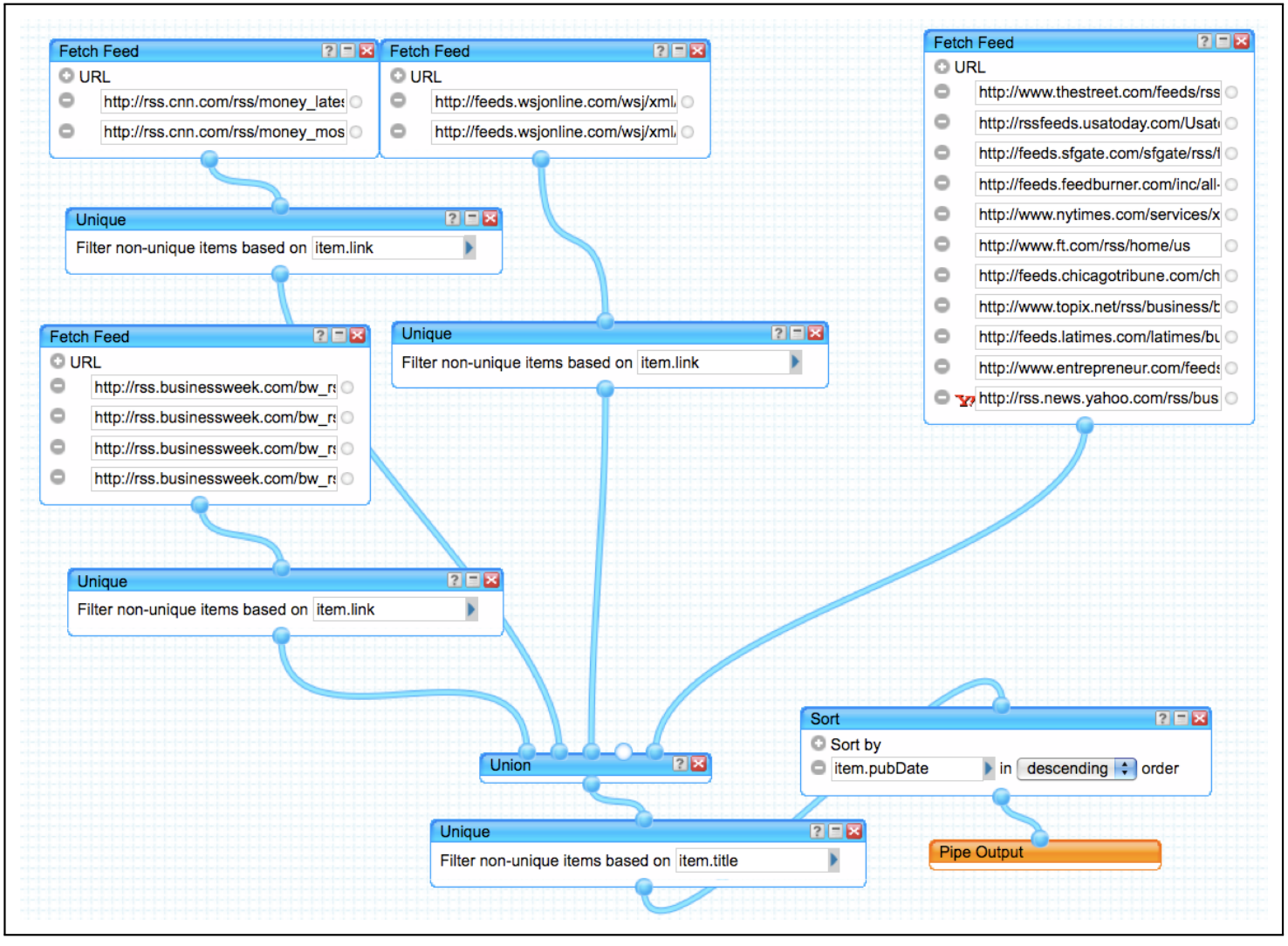

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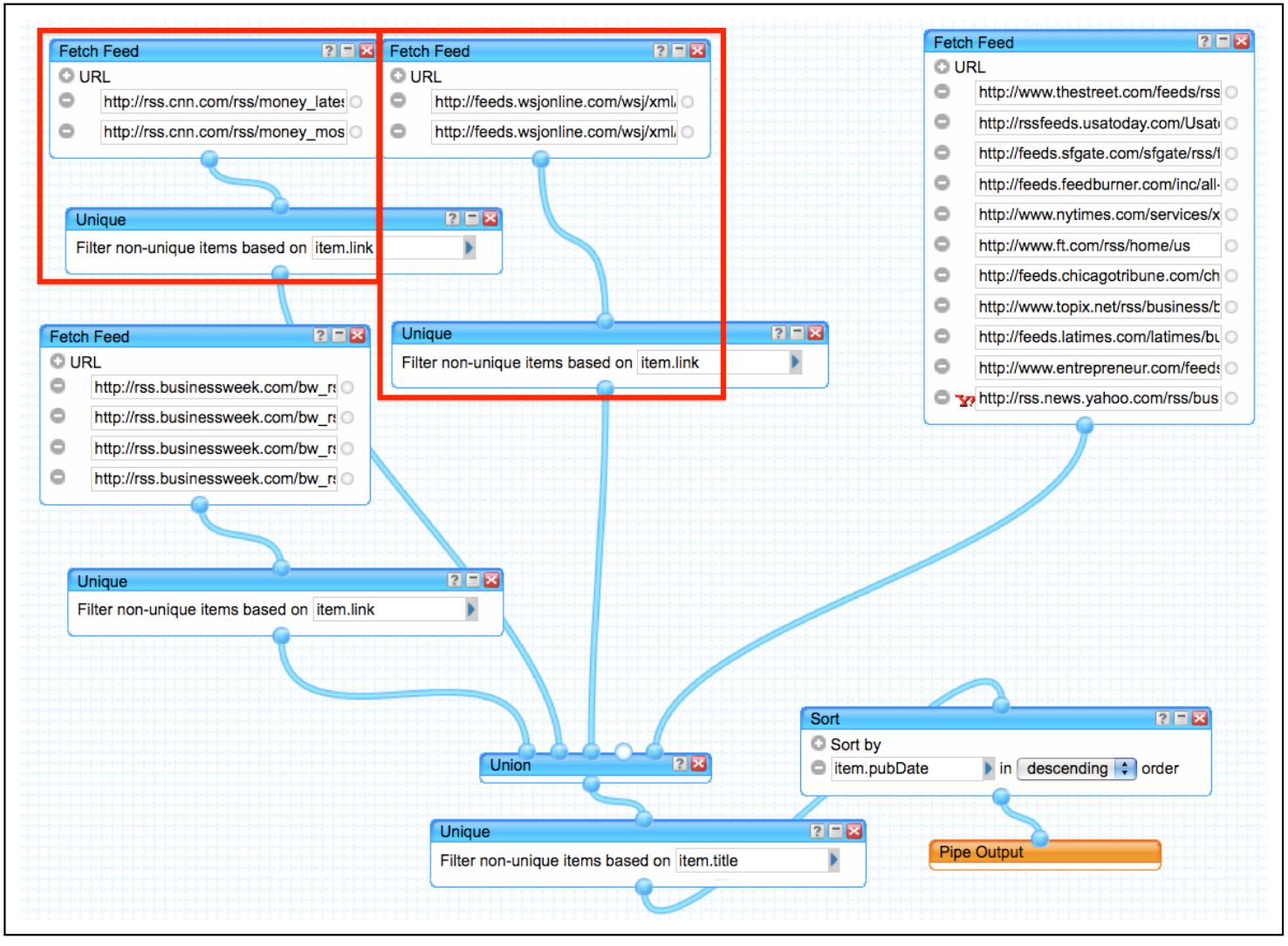

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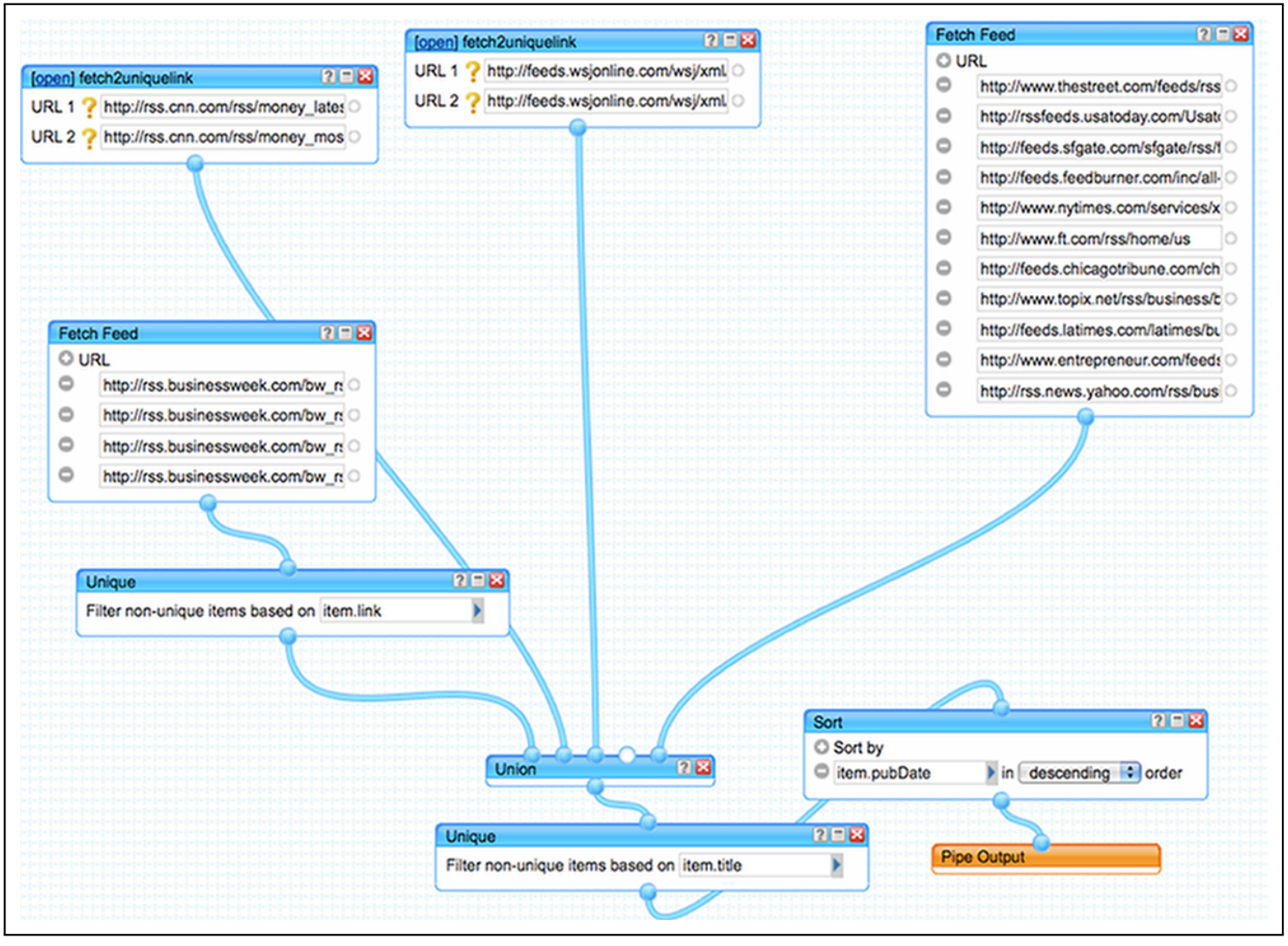

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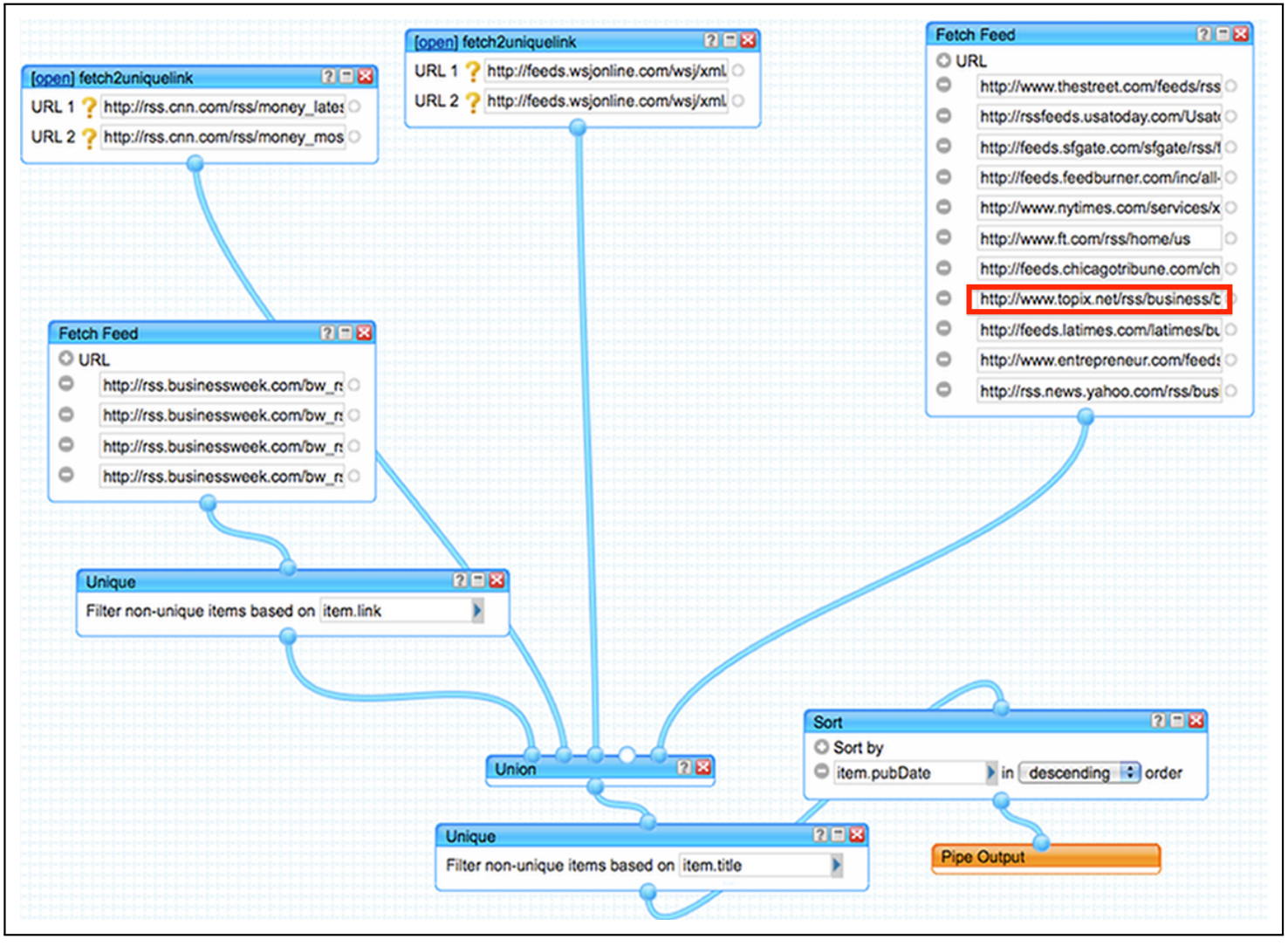

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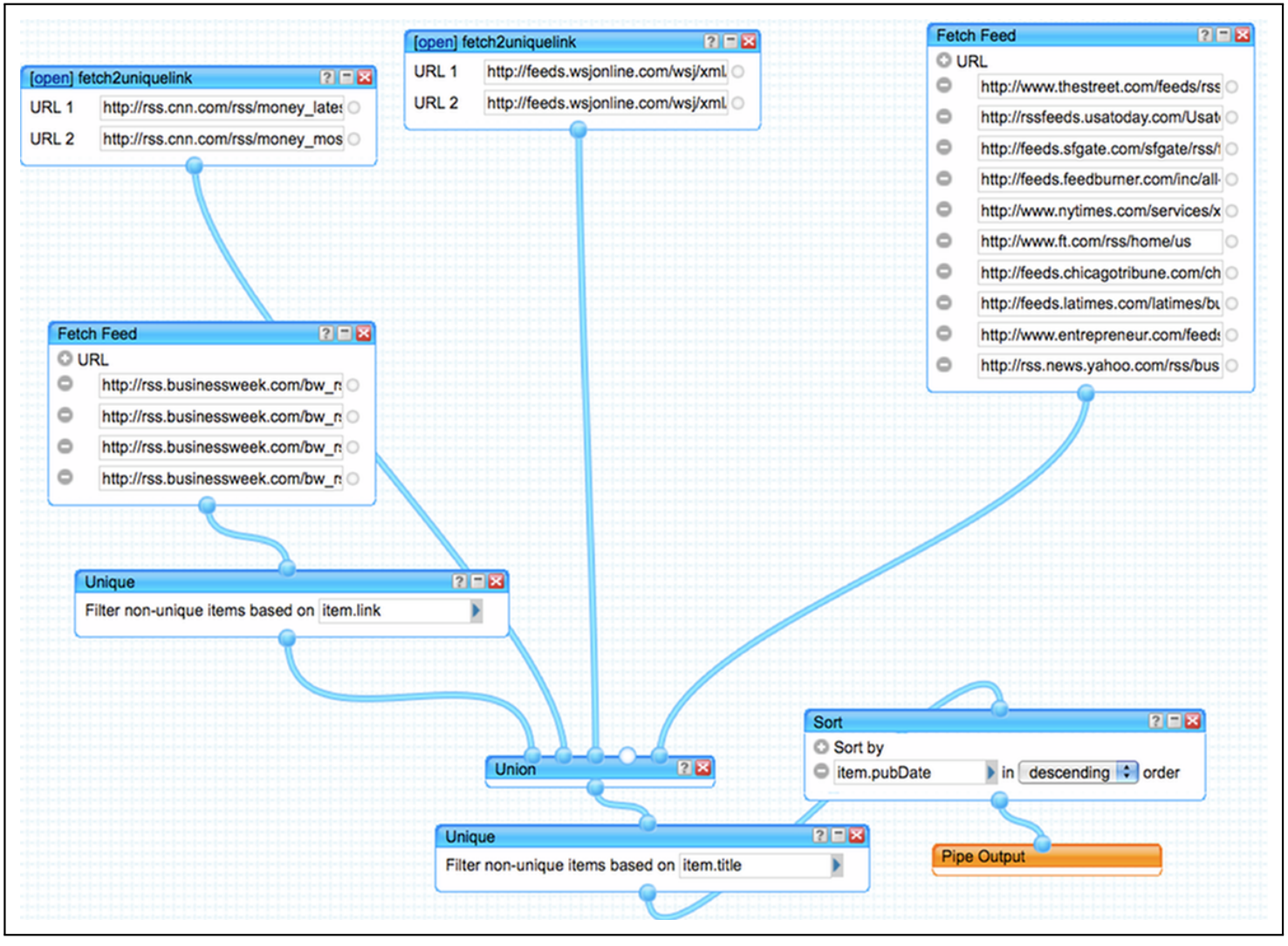
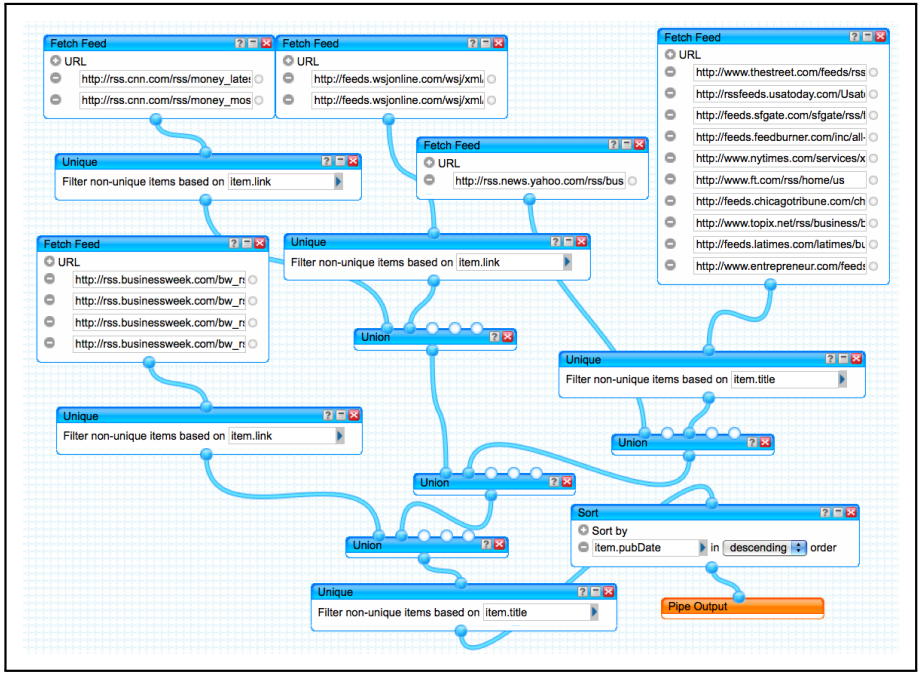


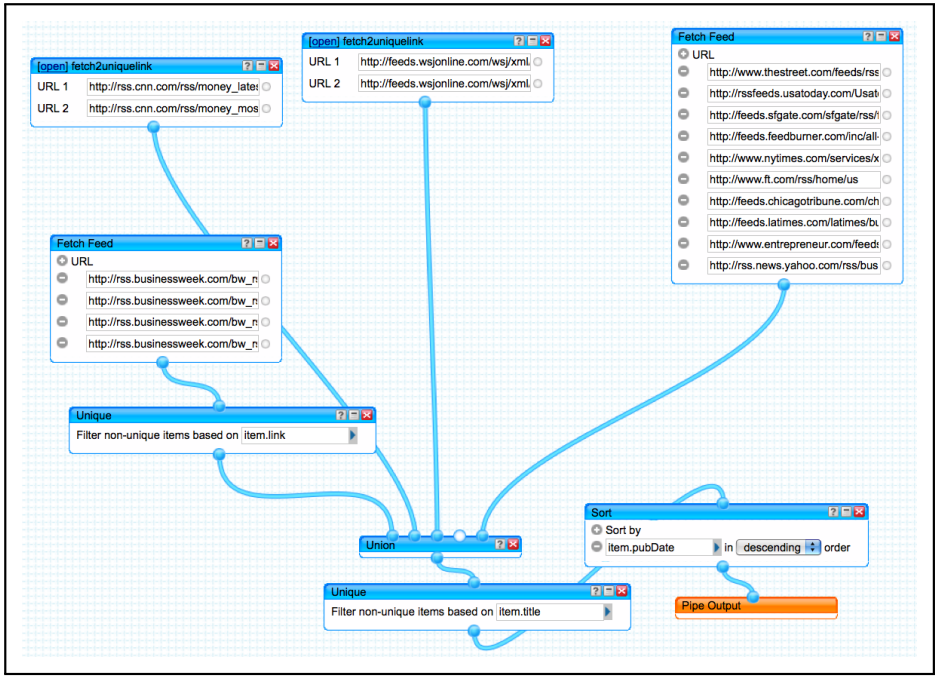
Refactoring in Yahoo! Pipes: Before and After

Before



- Unnecessary modules
- Redundant structures
- Broken data sources

After



- Fewer modules
- More abstract
- All valid data sources

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Smells in Mashups

Code Smell

A deficiency in program code that can make it harder to maintain or more error-prone

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We have defined 10 code smells for pipe-like web mashups

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Refactoring

A semantic preserving transformation on a program for the purpose of removing code smells and improving maintainability

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A deficiency in program code that can make it harder to maintain or more error-prone

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Refactoring

A semantic preserving transformation on a program for the purpose of removing code smells and improving maintainability

We have defined 11 refactorings for pipe-like web mashups

Smell Types

- Laziness – ineffectual or unnecessary components
- Redundancy – duplicate components
- Environmental – external changes cause impact
- Population-Based – deviants from community norms

Smell Types

- **Laziness – ineffectual or unnecessary components**
- **Redundancy – duplicate components**
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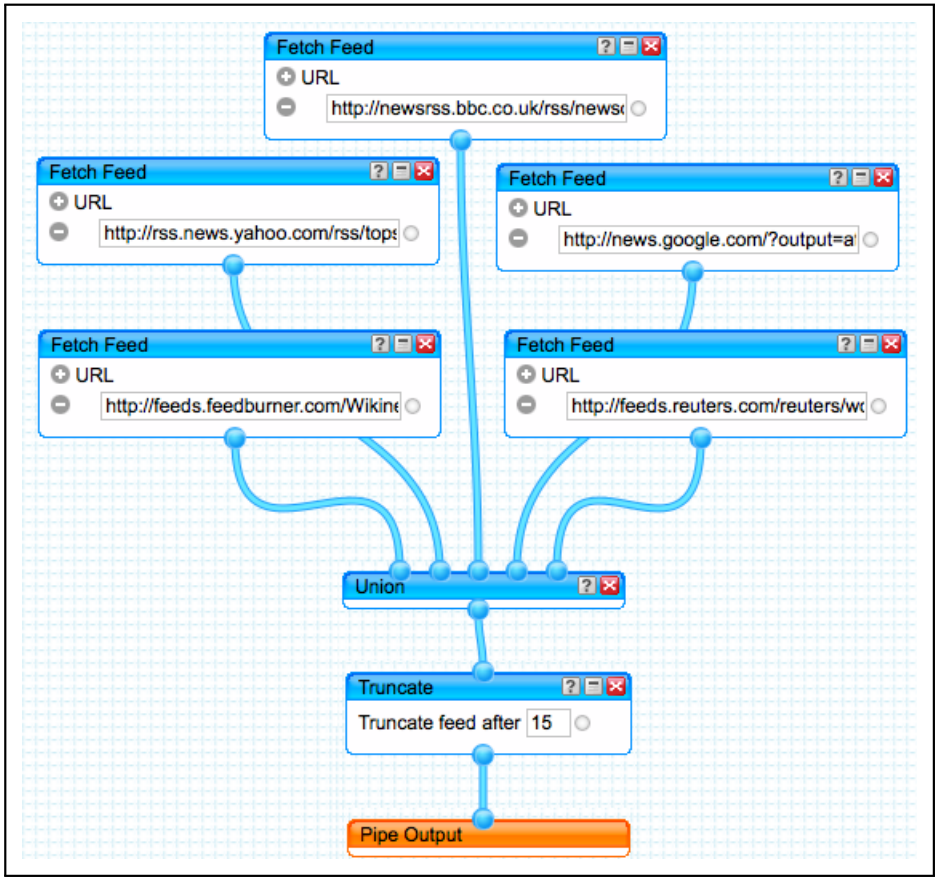
Properties of Languages and Environment

- Flexible and forgiving (e.g., no compiler errors)
- Easy to analyze programs exhaustively

Redundancy and Consolidation

Smell: Duplicate Modules

Similar modules appearing in certain patterns may be redundant and candidate for consolidation.



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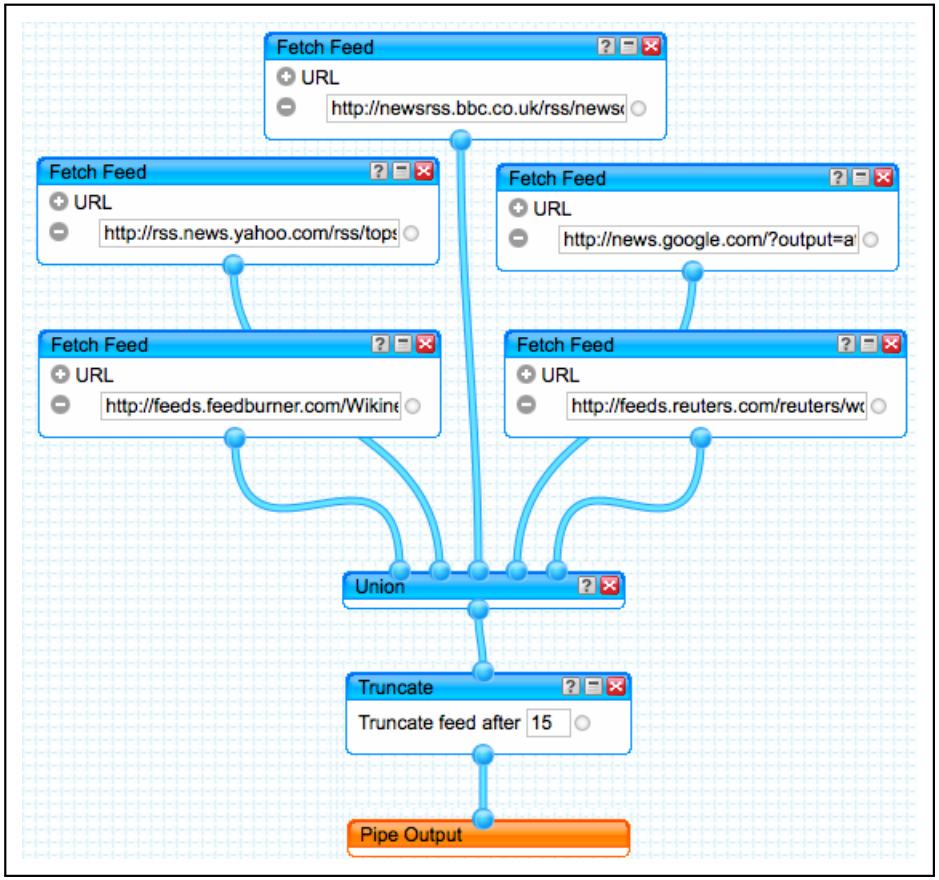
Definition

$$\exists m, n \in \mathcal{M} \mid m \neq n \wedge$$
$$m.name = n.name \wedge$$
$$gen(m) \wedge gen(n) \wedge$$
$$connected\_to\_union(m, n)$$



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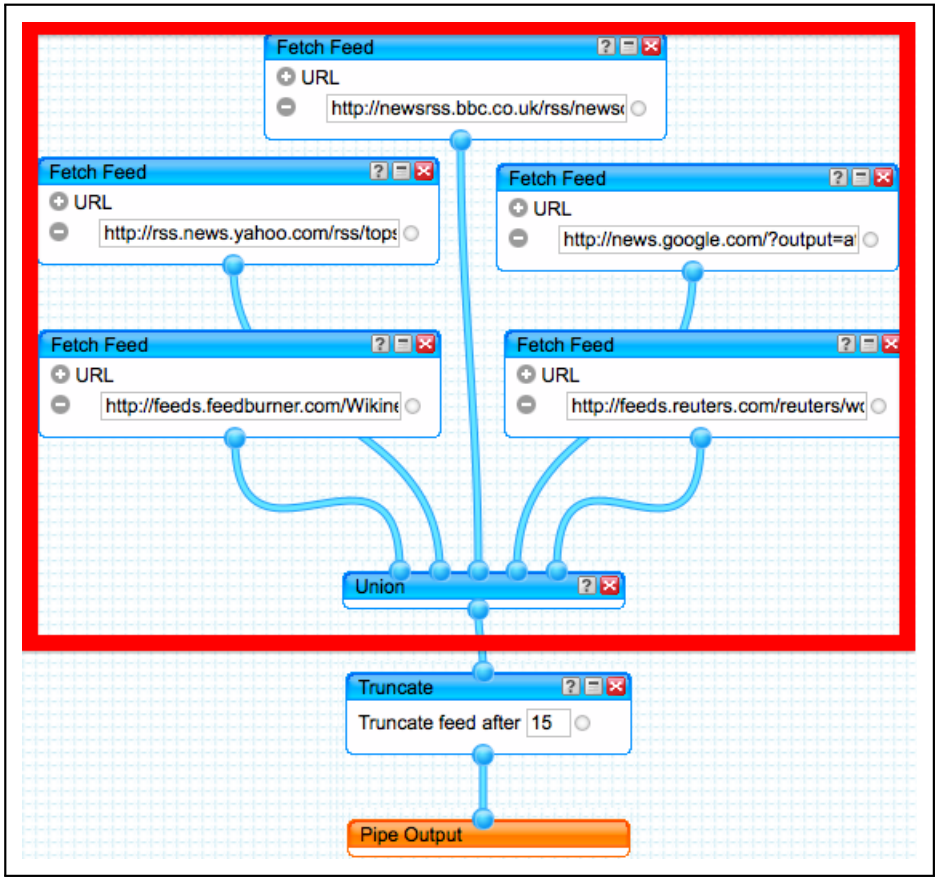


Redundancy and Consolidation

Smell: Duplicate Modules

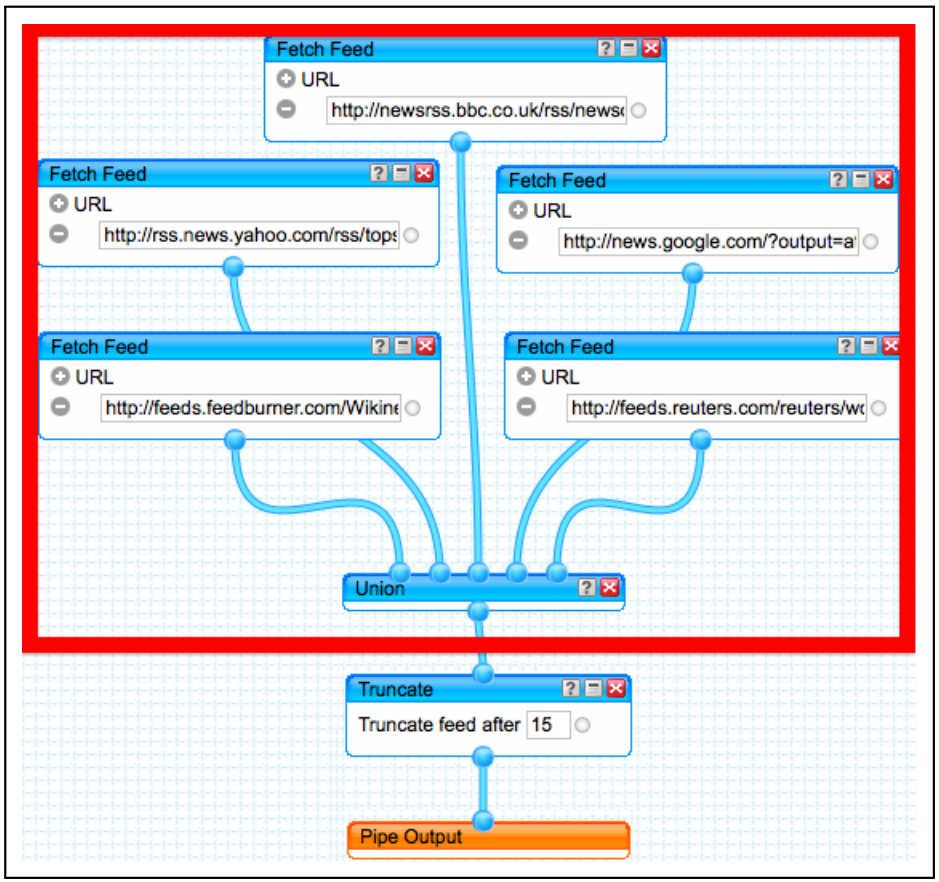
Similar modules appearing in certain patterns may be redundant and candidate for consolidation.

Definition

$$\exists m, n \in \mathcal{M} \mid m \neq n \wedge$$
$$m.name = n.name \wedge$$
$$gen(m) \wedge gen(n) \wedge$$
$$connected\_to\_union(m, n)$$

Why is this Smelly?

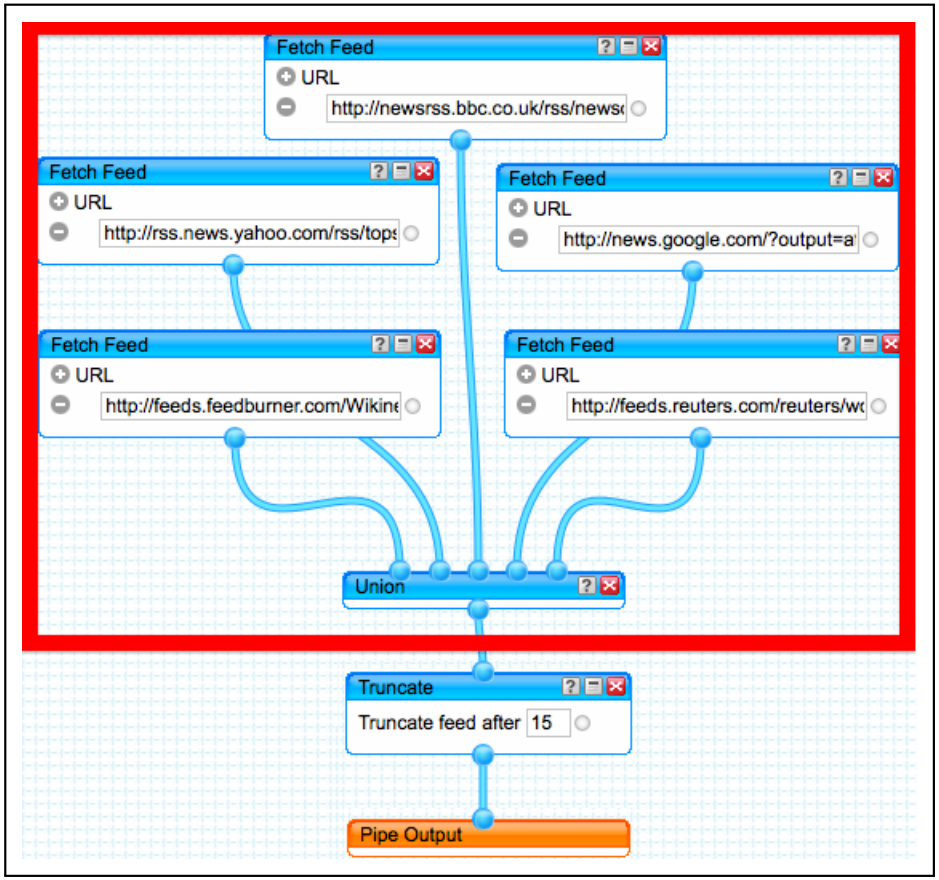
Adds unnecessary complexity



Redundancy and Consolidation

Refactor: Collapse Duplicate Paths

Paths that are aggregated using the same union module can often be consolidated into a single path



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Definition

P_{before}	Joined generators
Params	$Pipe = (\mathcal{M}, \mathcal{W}, \mathcal{F}, owner)$, joined modules m, n
Transf.	$\forall f \in n.\mathcal{F}$ move f to m
	$\exists w \in \mathcal{W} \mid out\_wire(n, w)$ remove w
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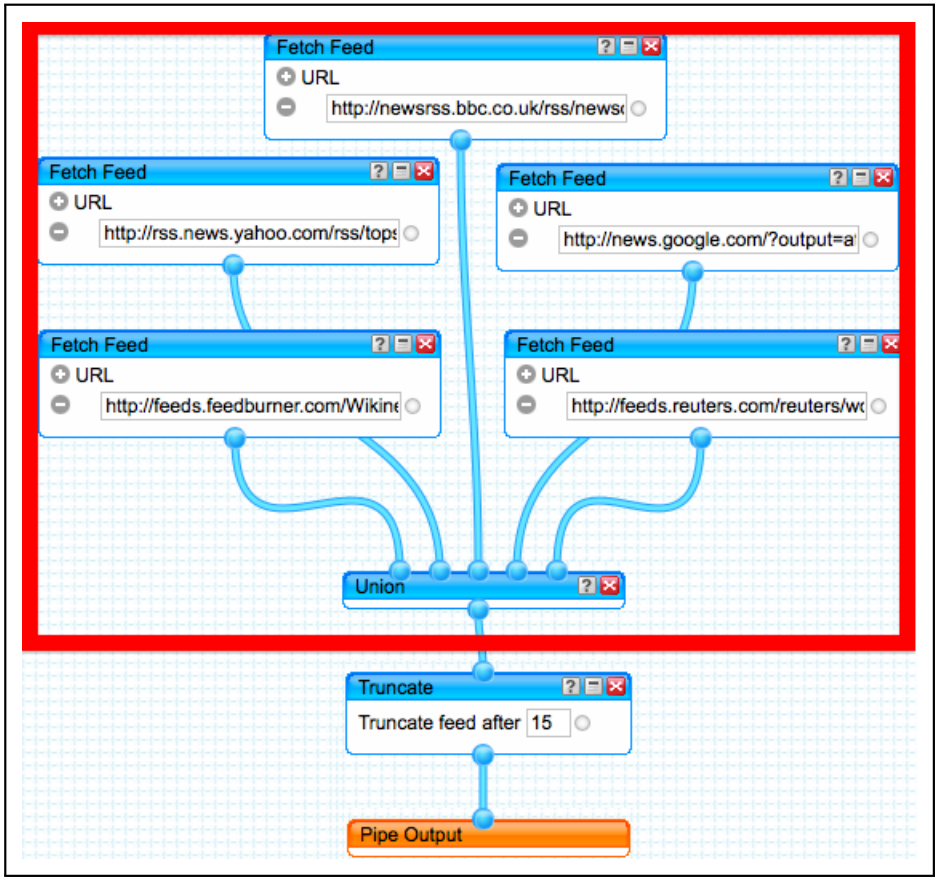
P_{after}	$n, w \notin Pipe$
	$m'.\mathcal{F} = n.\mathcal{F} \cup m.\mathcal{F}$



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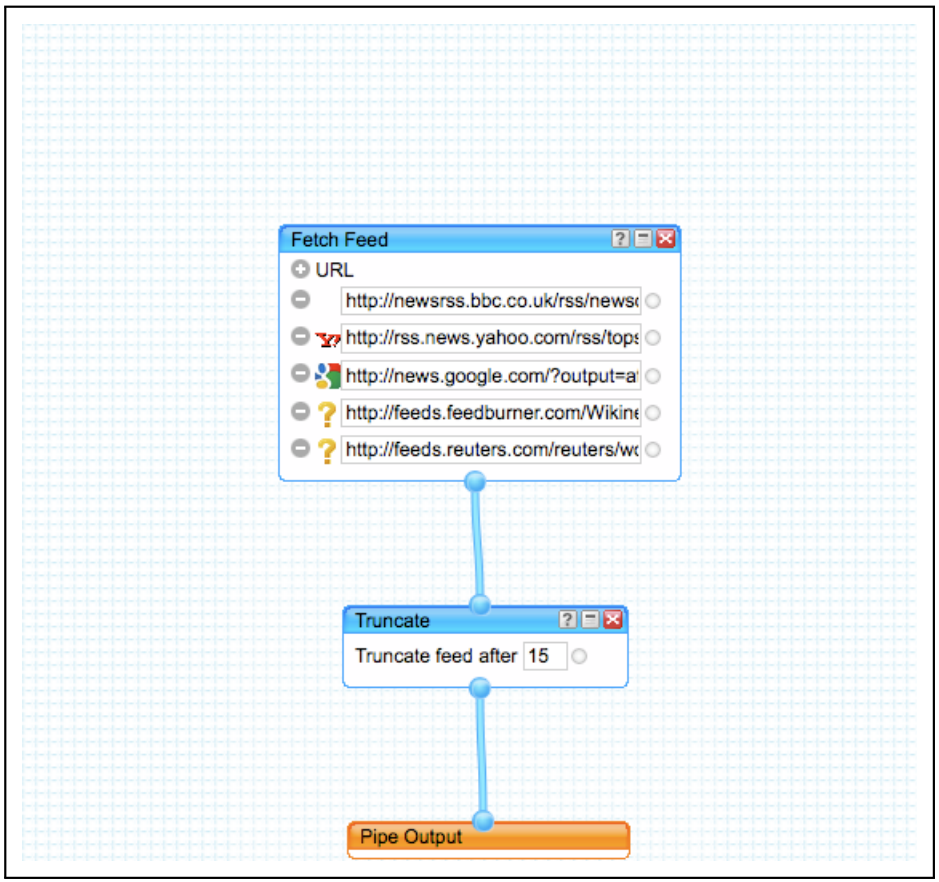
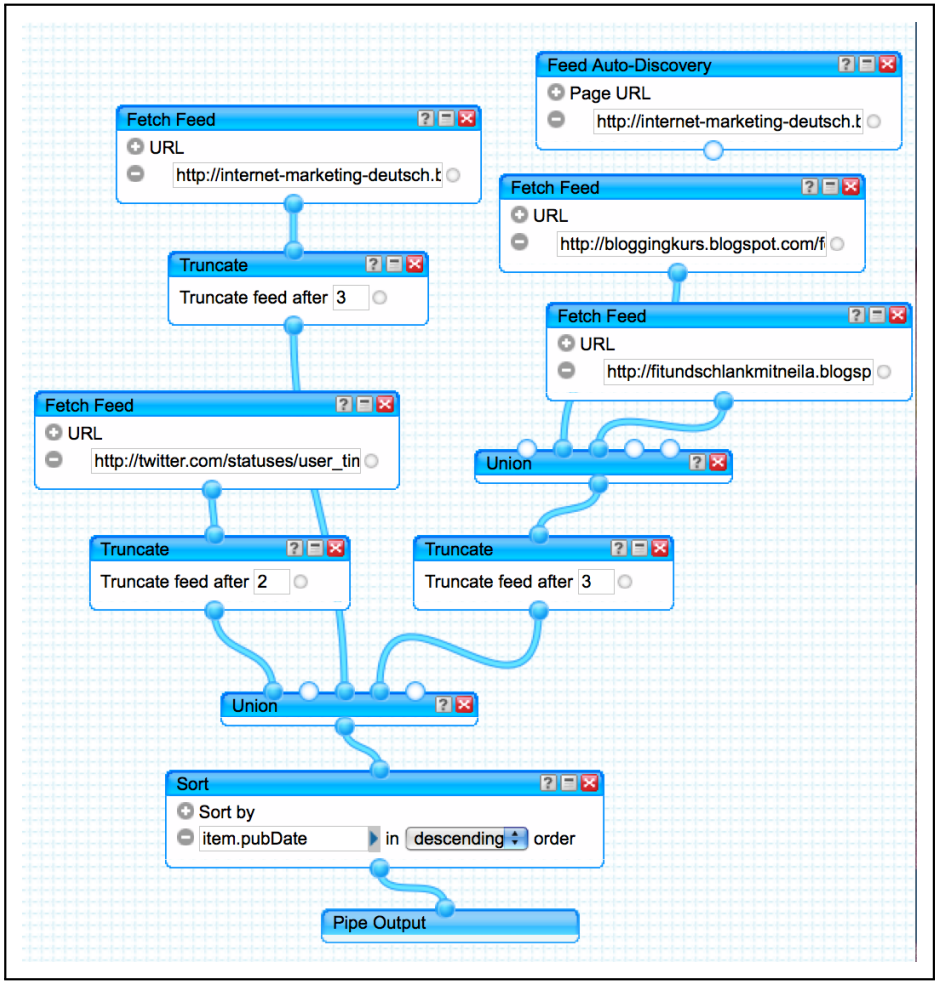


Laziness and Reduction

Smell: Unnecessary Module

A module whose execution does not affect the pipe's output



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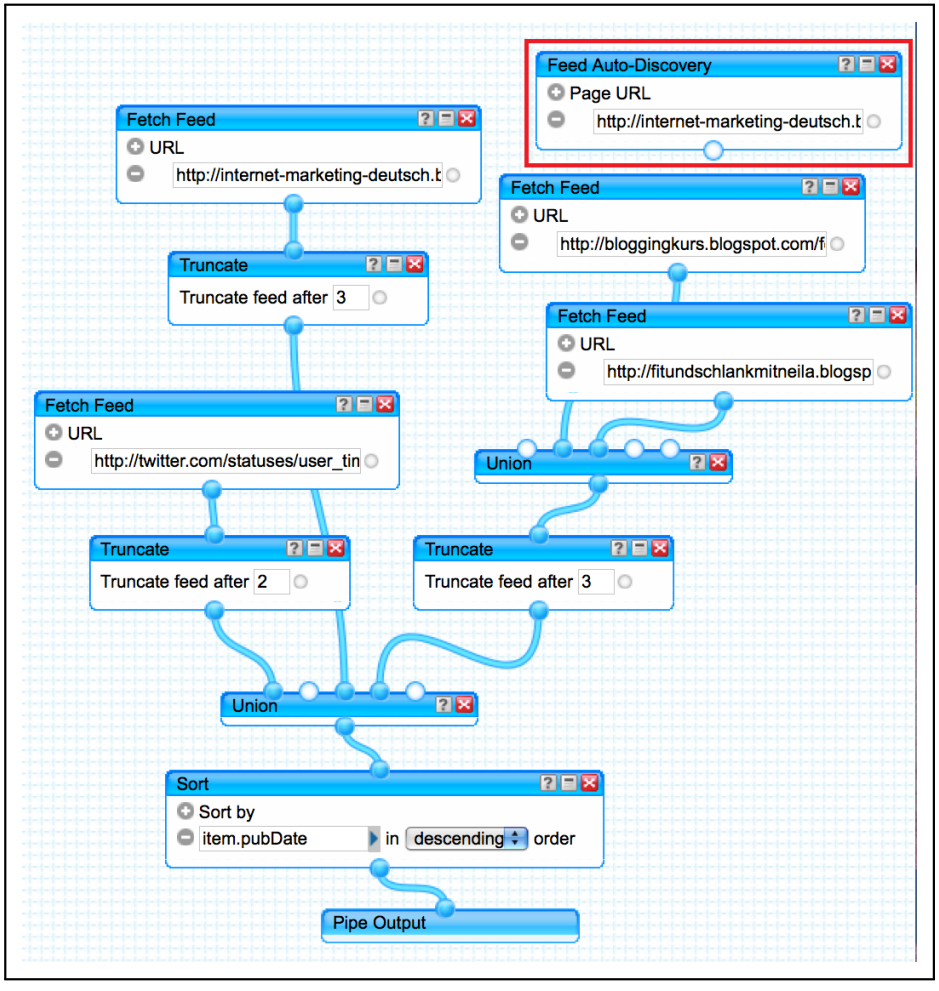


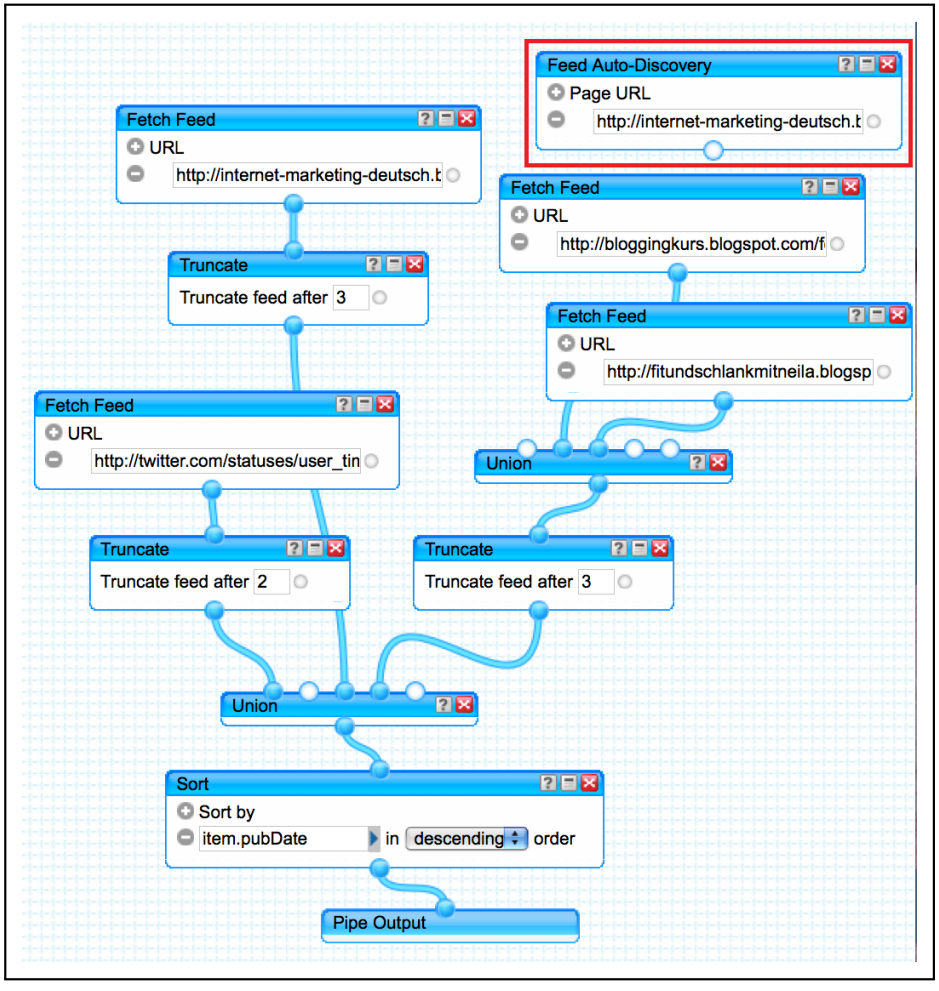
Laziness and Reduction

Smell: Unnecessary Module

A module whose execution does not affect the pipe's output

Why is this Smelly?

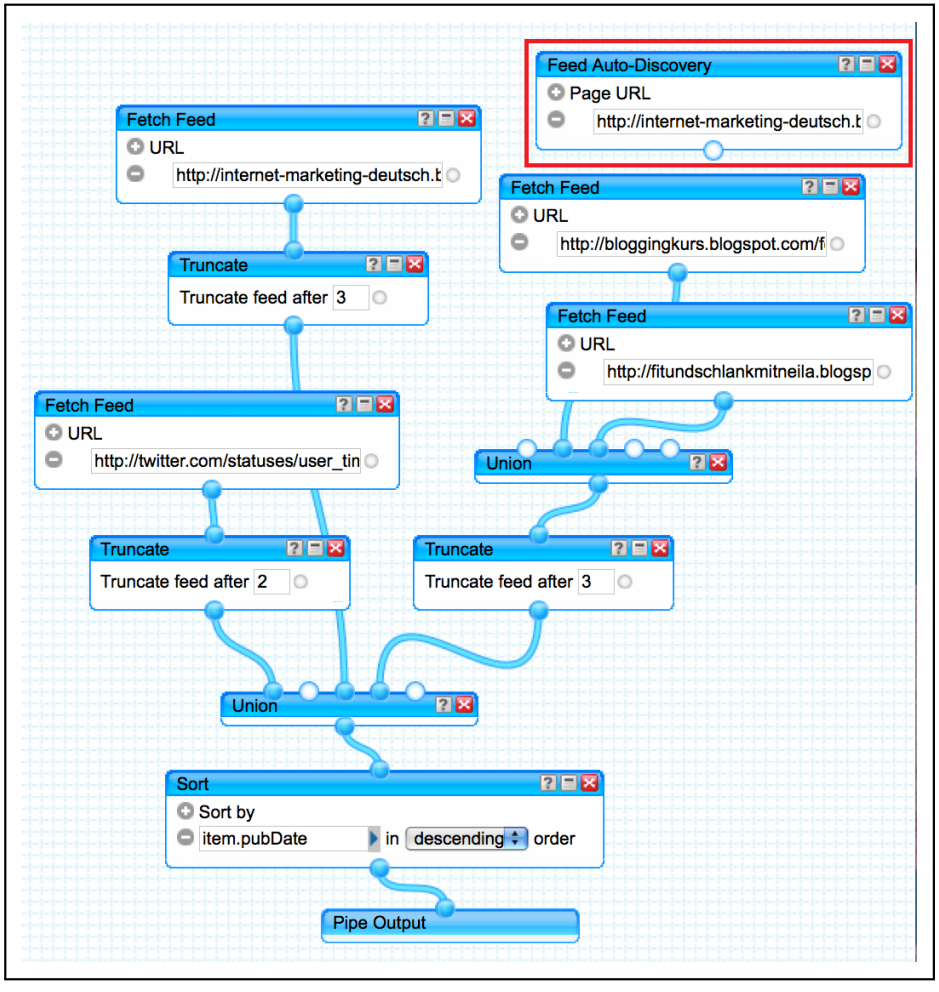
It's dead code



Laziness and Reduction

Refactor: Remove Non-Contributing Module

Modules that do not reach the output and their attaching wires can be removed.



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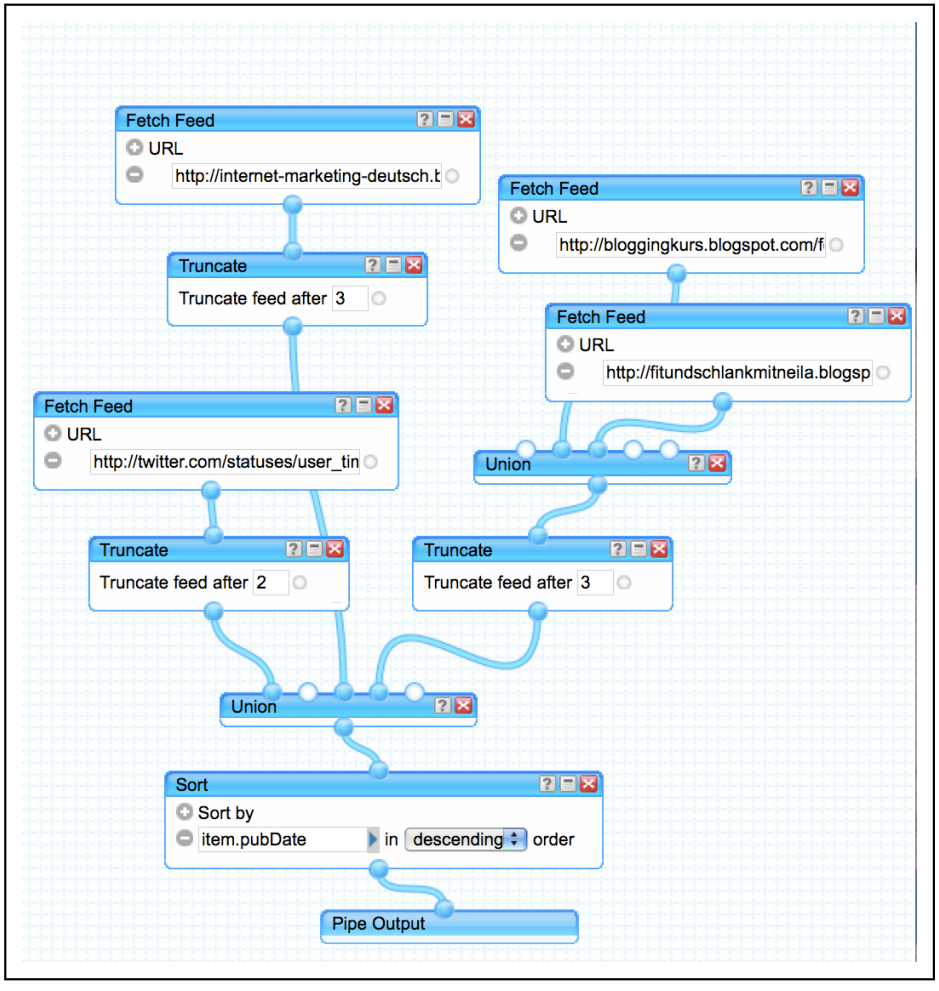
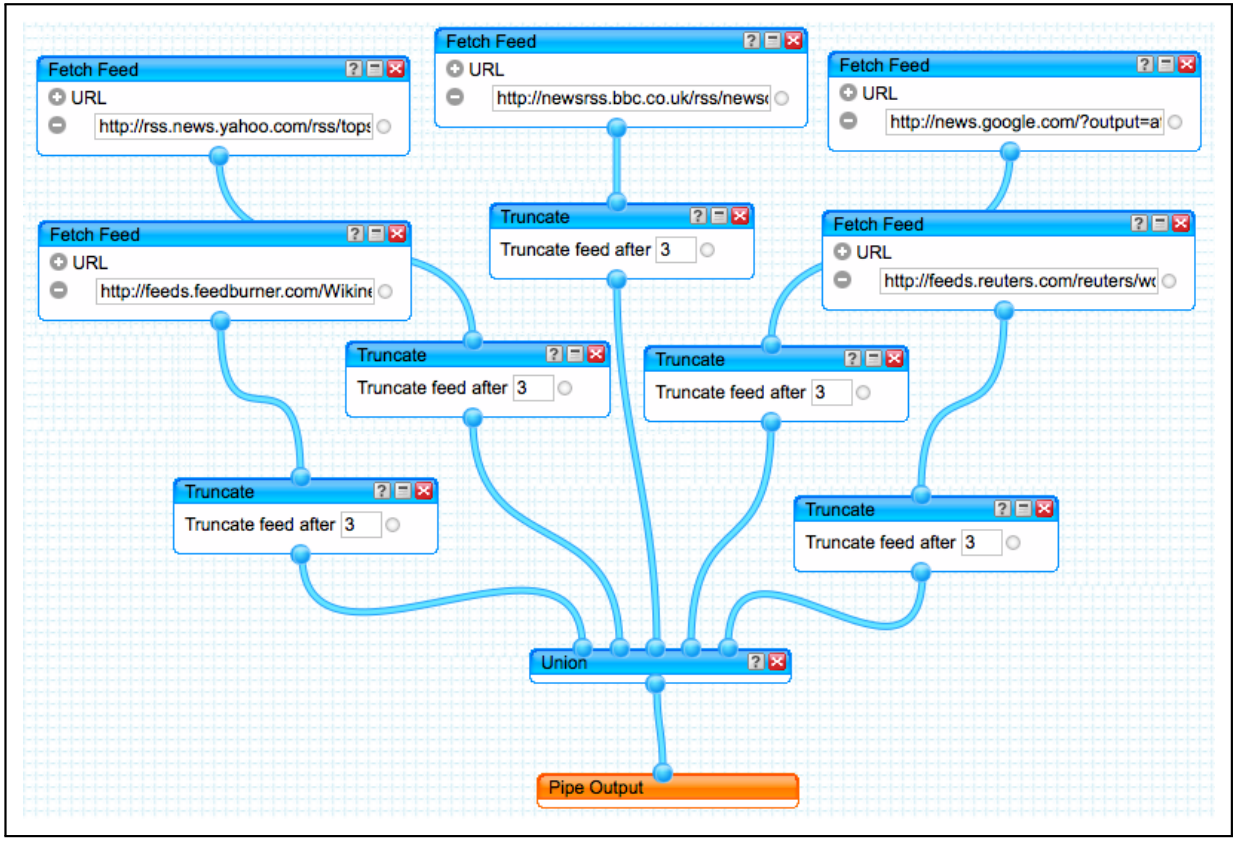


Redundancy and Abstraction

Smell: Duplicated String

A constant string that is used in at least *n* wireable fields in at least *m* modules.



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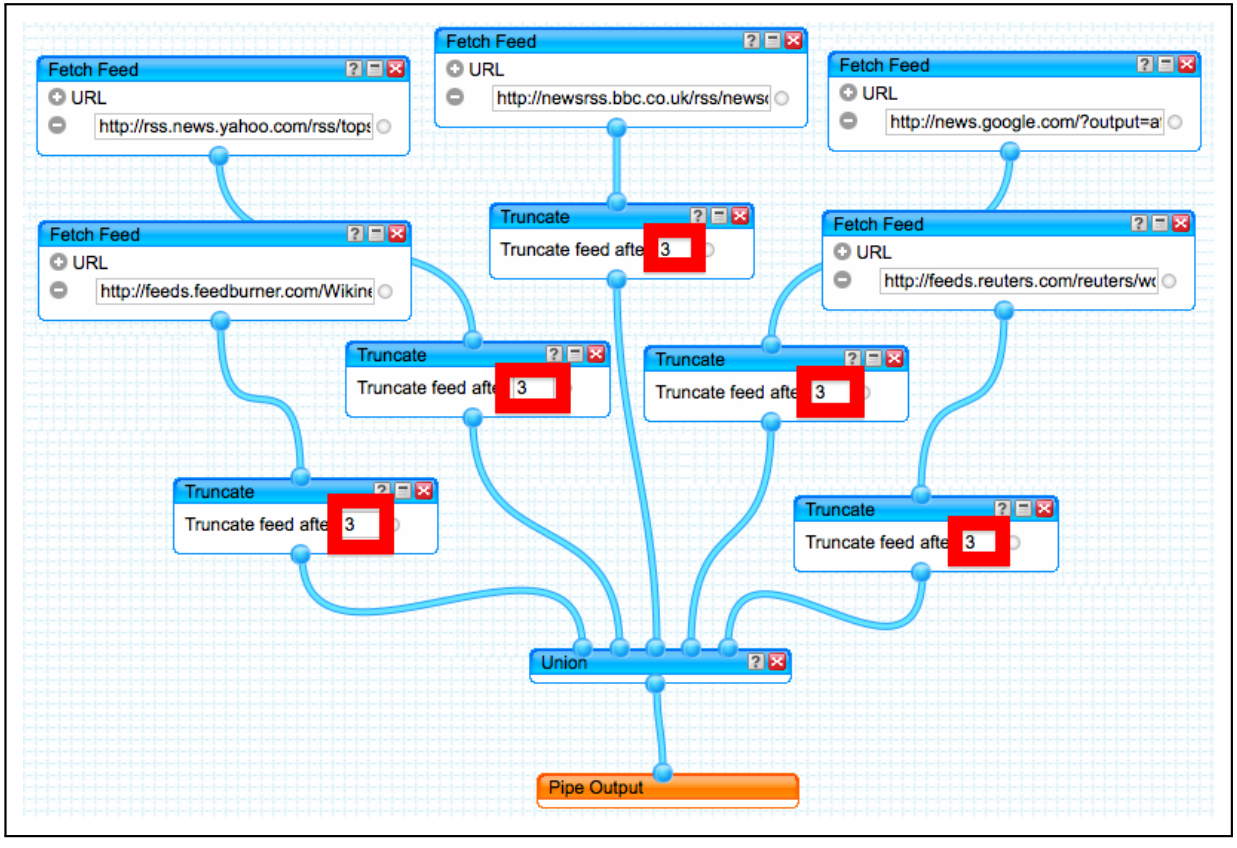

Redundancy and Abstraction

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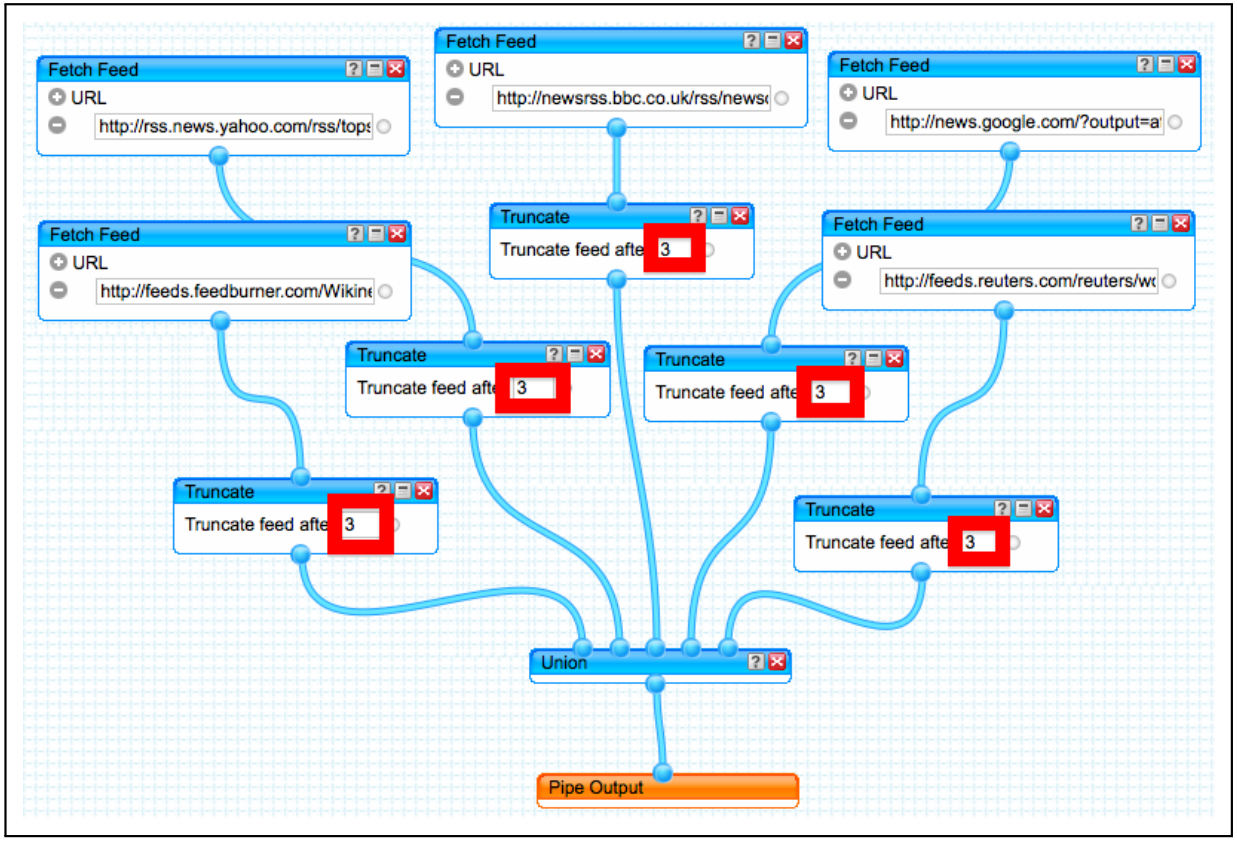
A constant string that is used in at least *n* wireable fields in at least *m* modules.

Why is this Smelly?

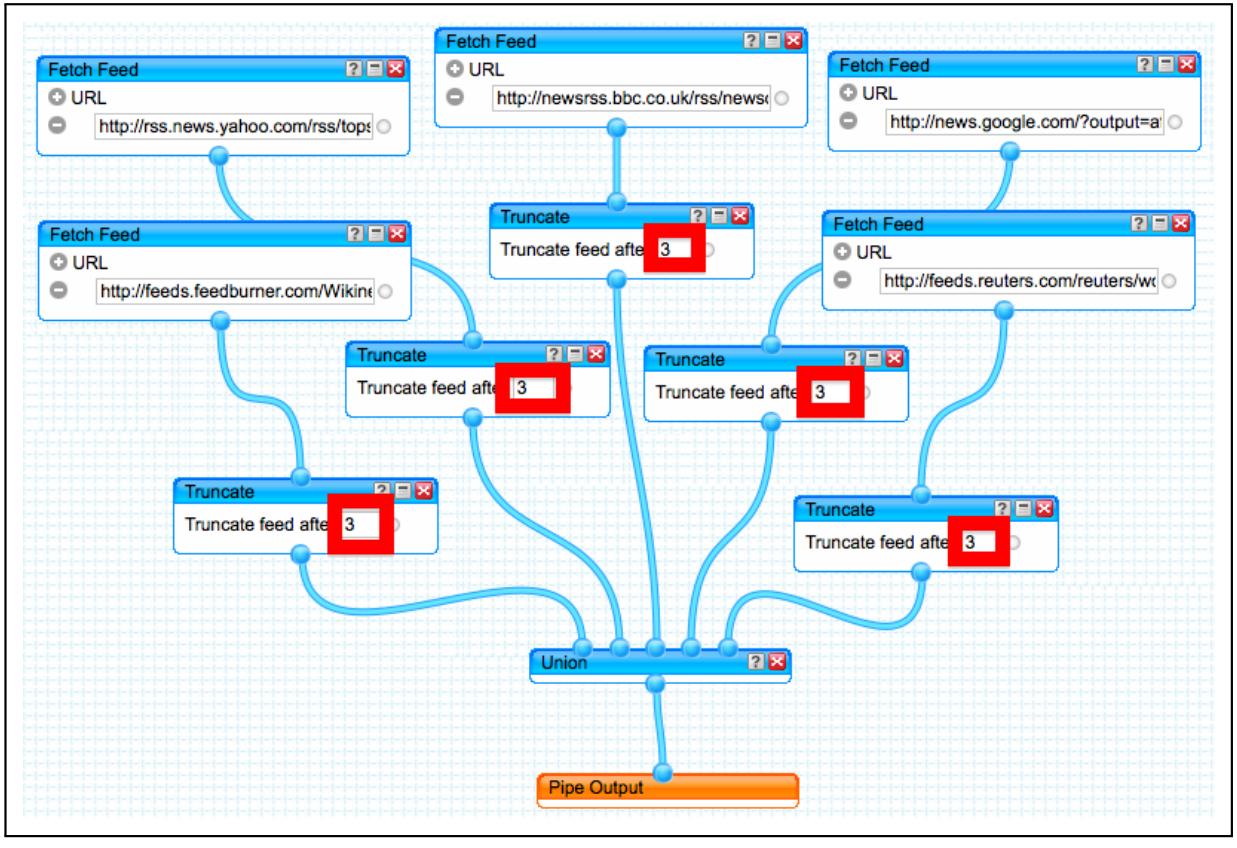
Hard to maintain; missed opportunity for abstraction



Redundancy and Abstraction

Refactor: Pull Up Module

Extracts duplicate strings into a newly created module and provides string values via wires to the previous owners of the strings



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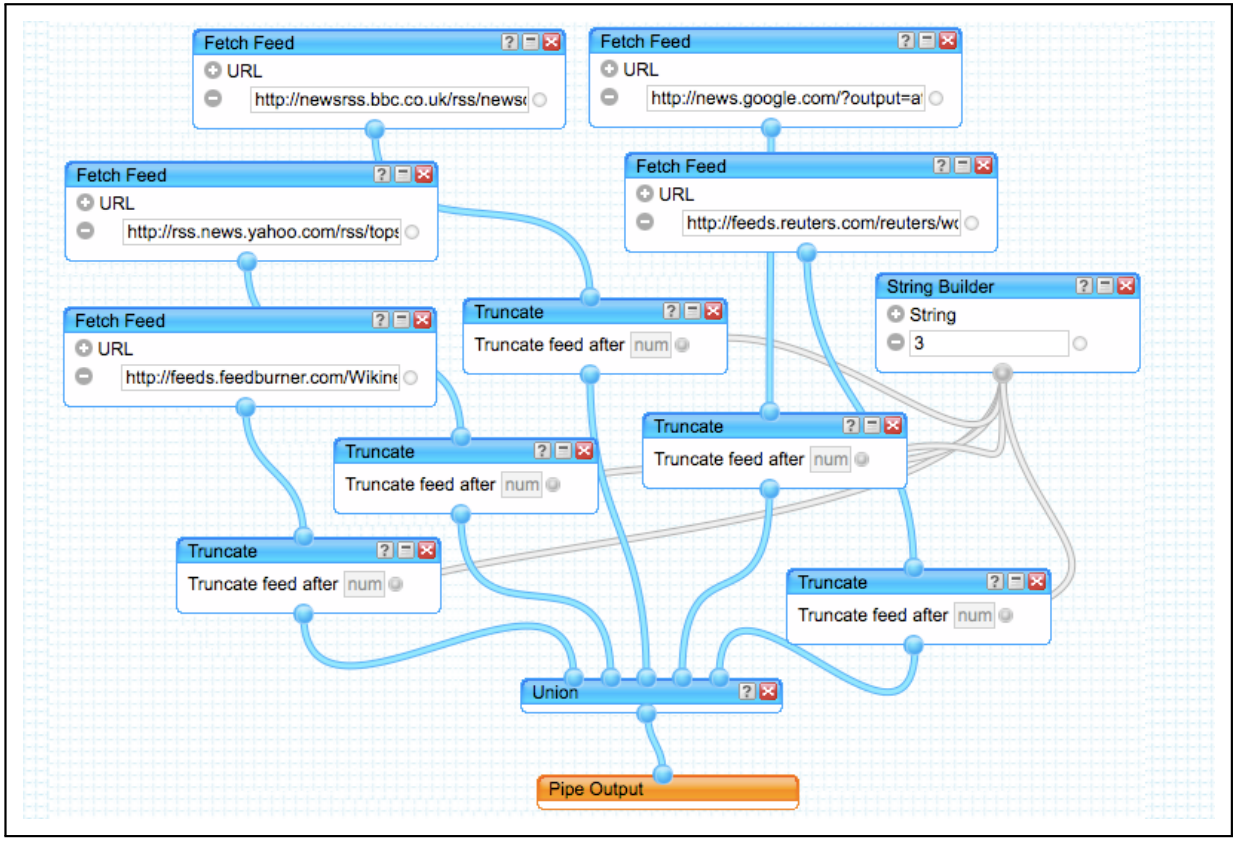

Redundancy and Abstraction

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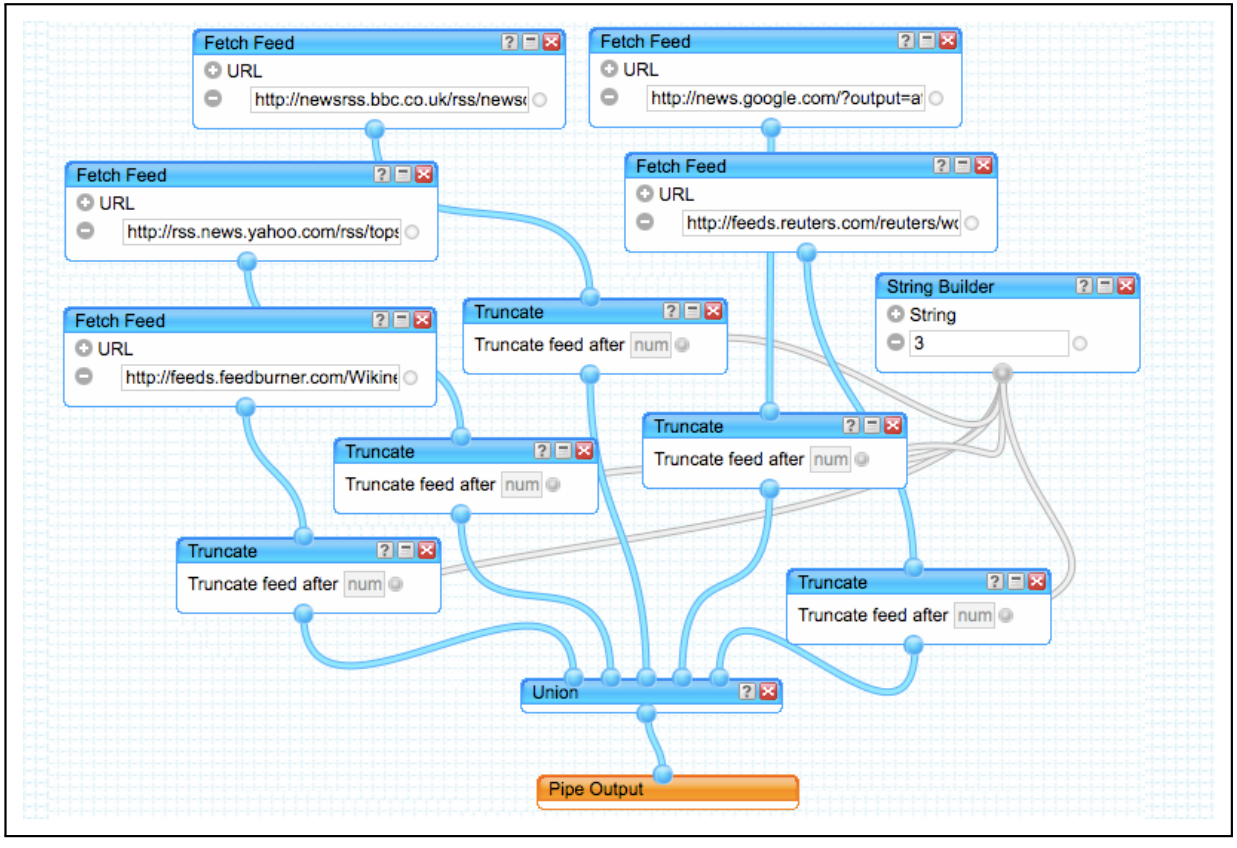
Inspiration

Pull Up Method refactoring



Smell Types

- Laziness – ineffectual or unnecessary components
- Redundancy – duplicate components
- **Environmental – external changes cause impact**
- Population-Based – deviants from community norms

Properties of Internet Resources:*

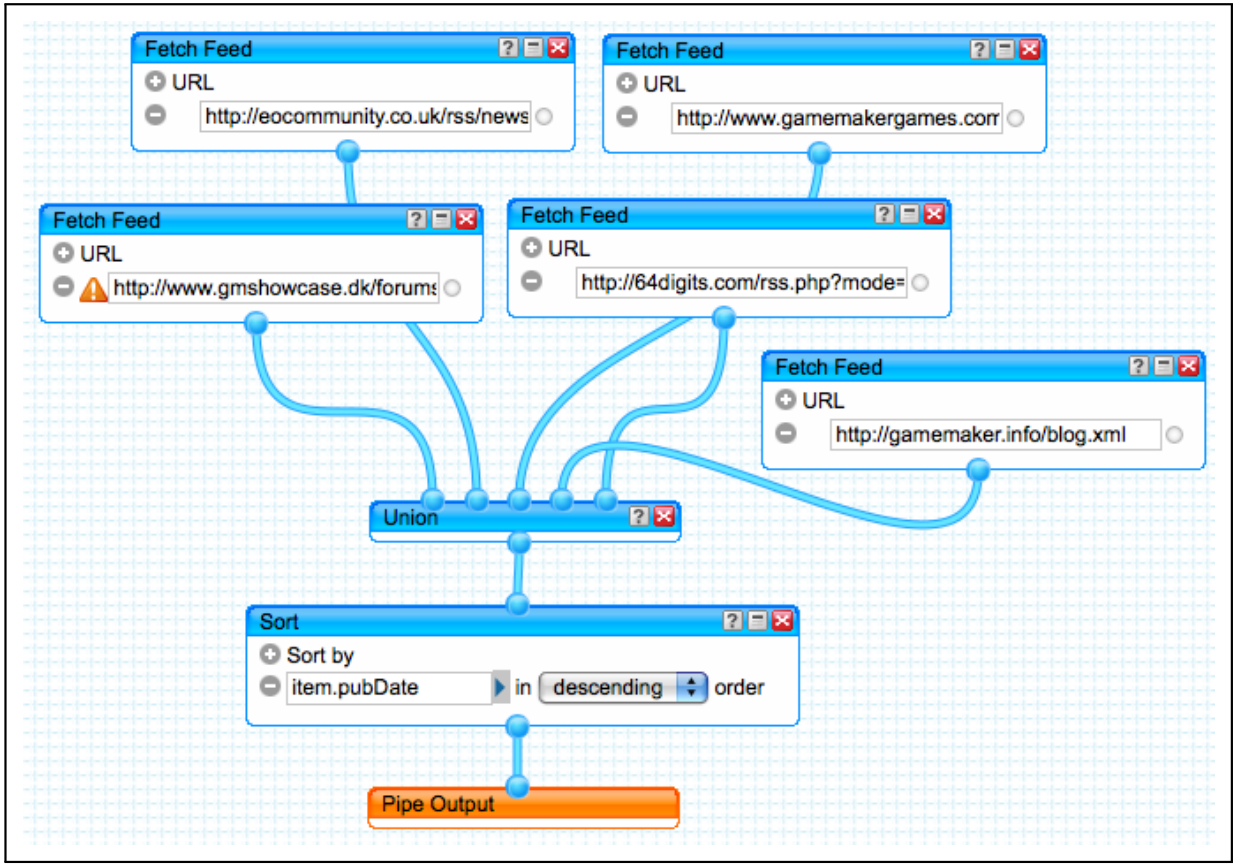
- Independently created and managed
- May change structure or format without notice

* Credit to Mary Shaw

Environmental and Deprecation

Smell: Invalid Source

An external data source is invalid if *n* consecutive attempts to retrieve data from it report errors



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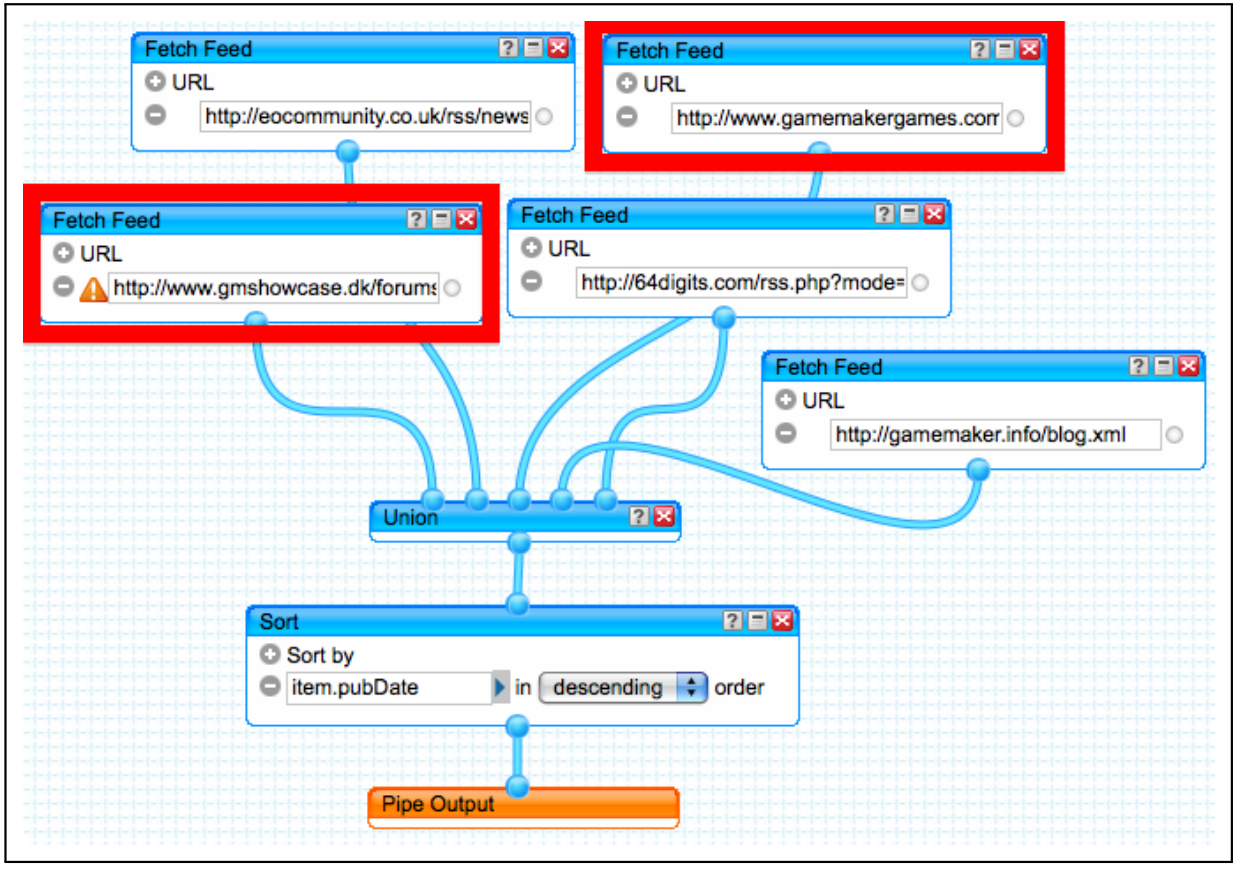

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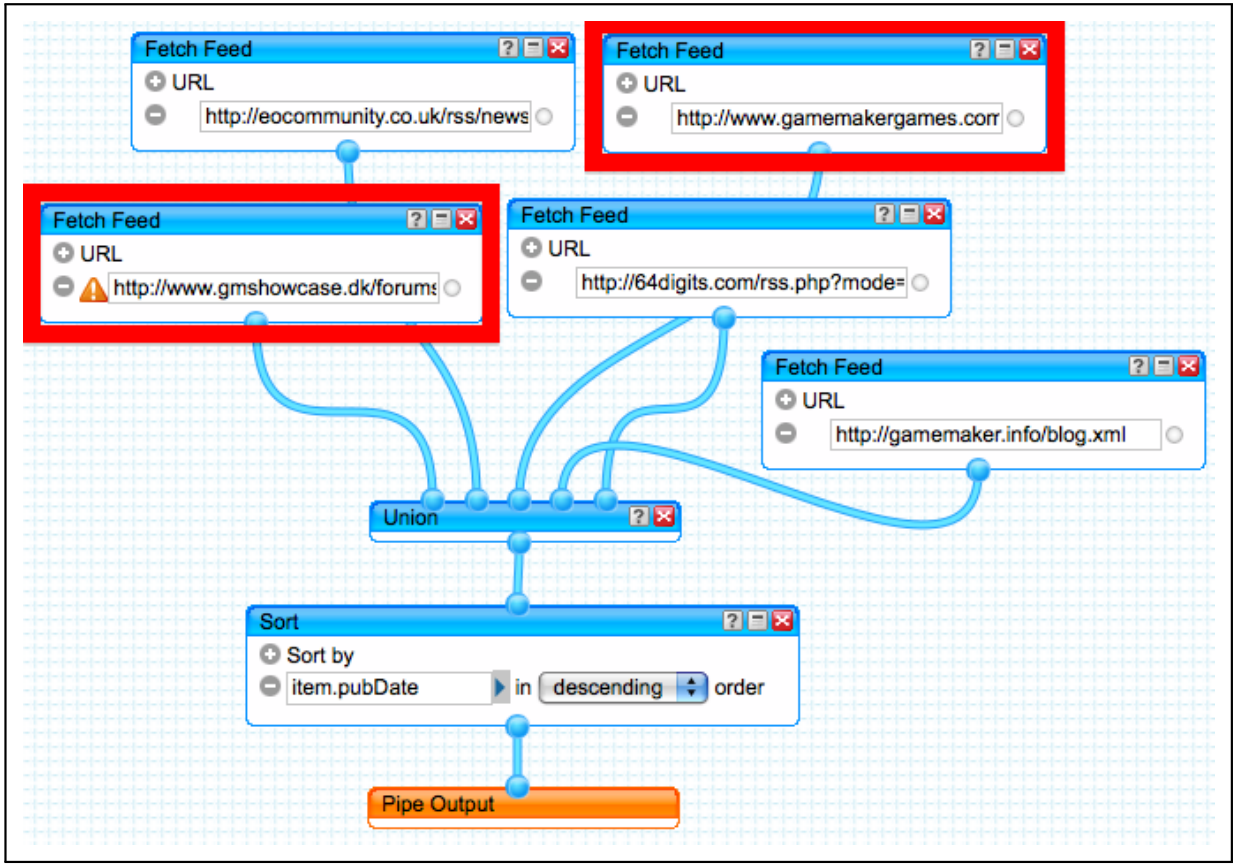
Bloats the code; introduces nondeterminism



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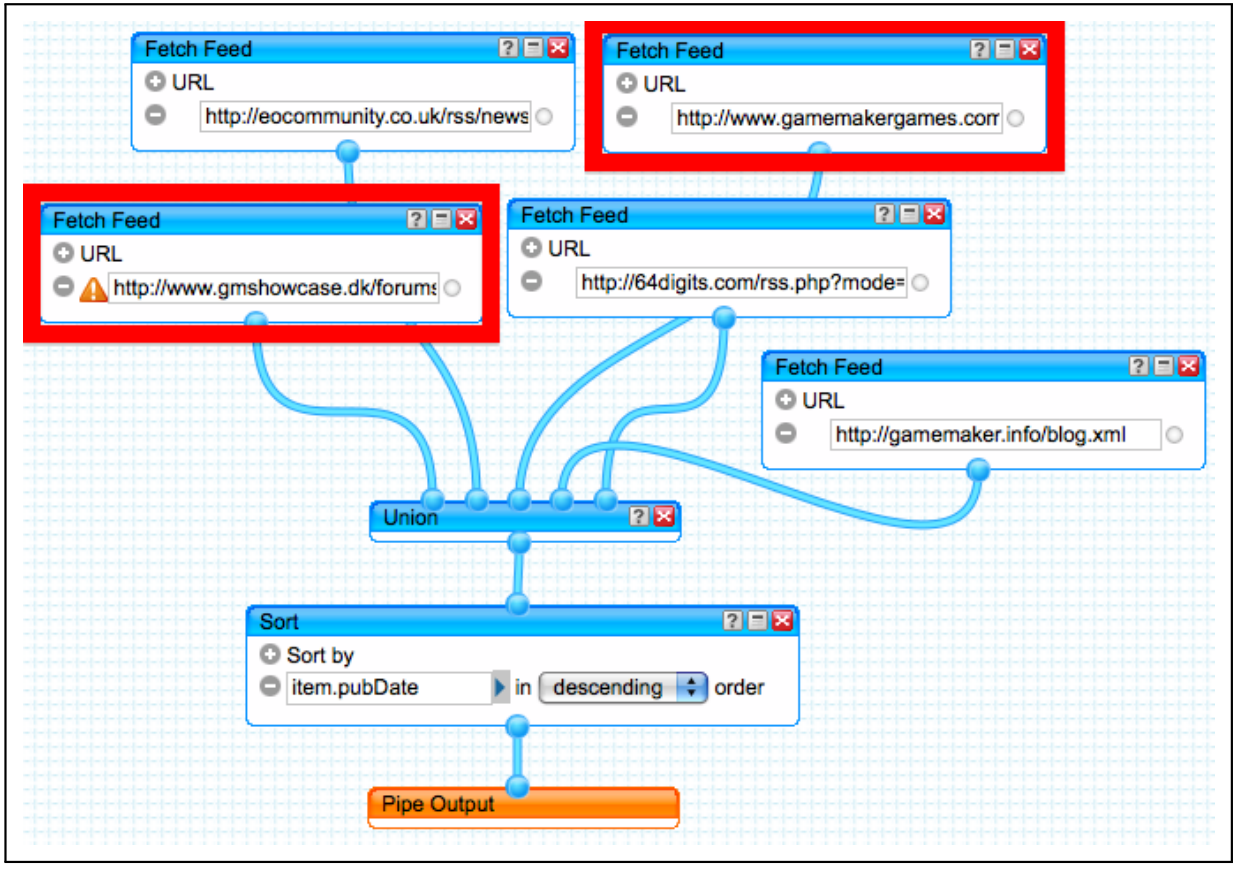
Insight

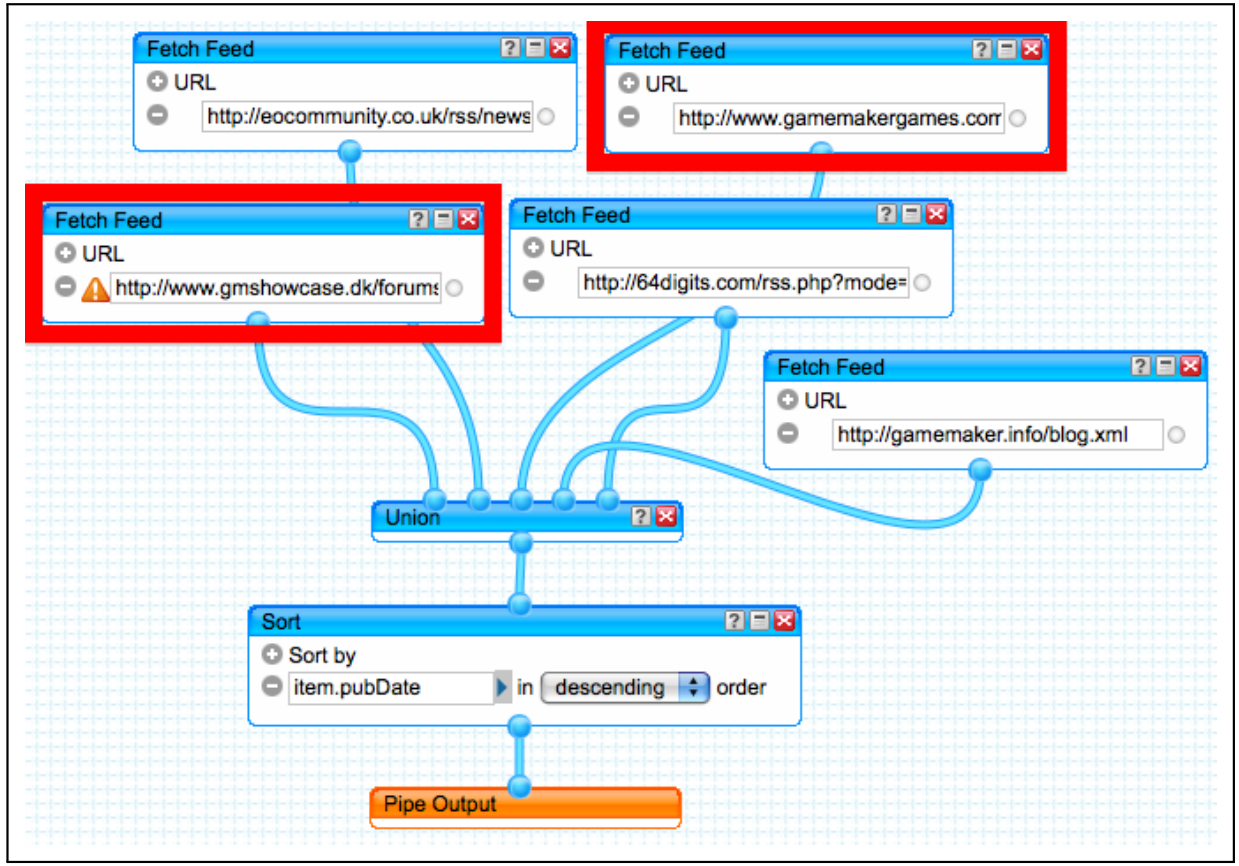
Internet resources are subject to change without notice



Environmental and Deprecation

Refactor: Remove Deprecated Sources

Remove all references to invalid external data sources



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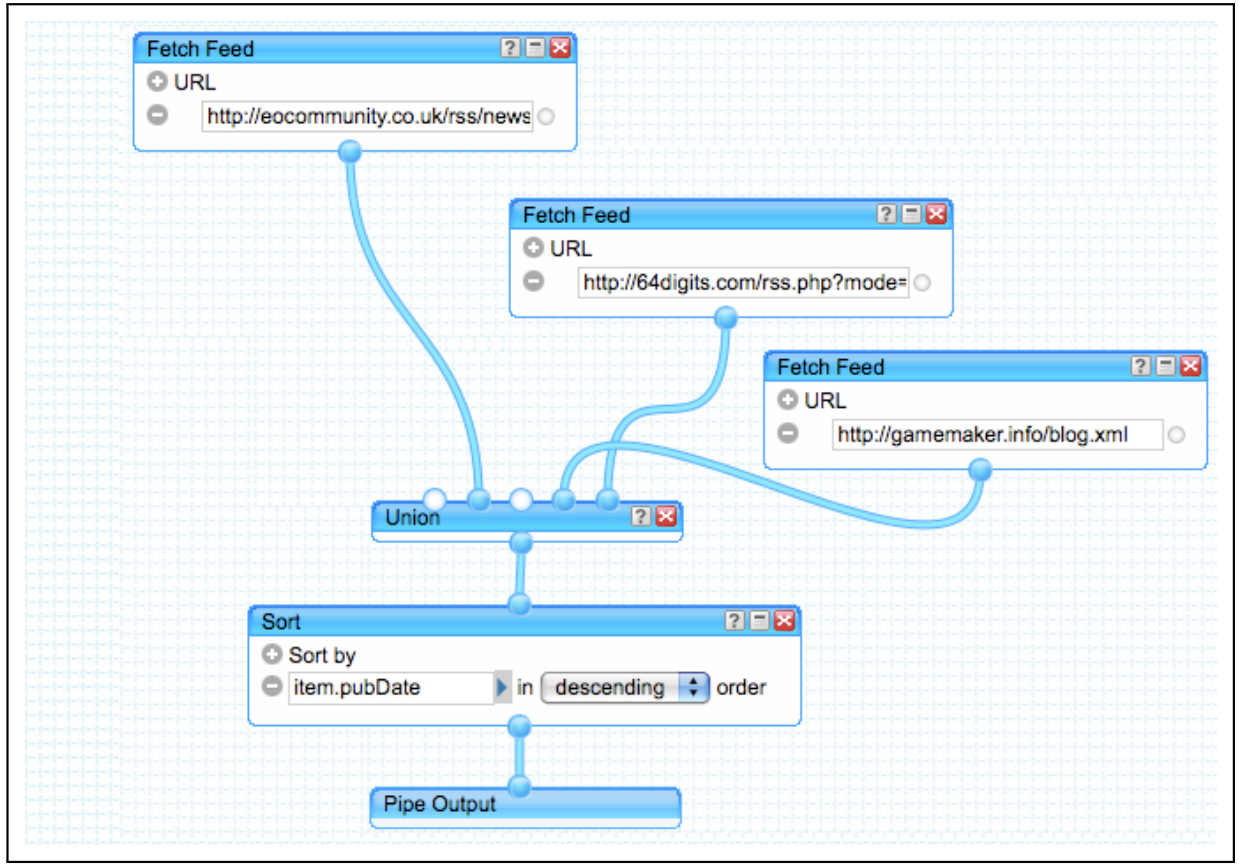
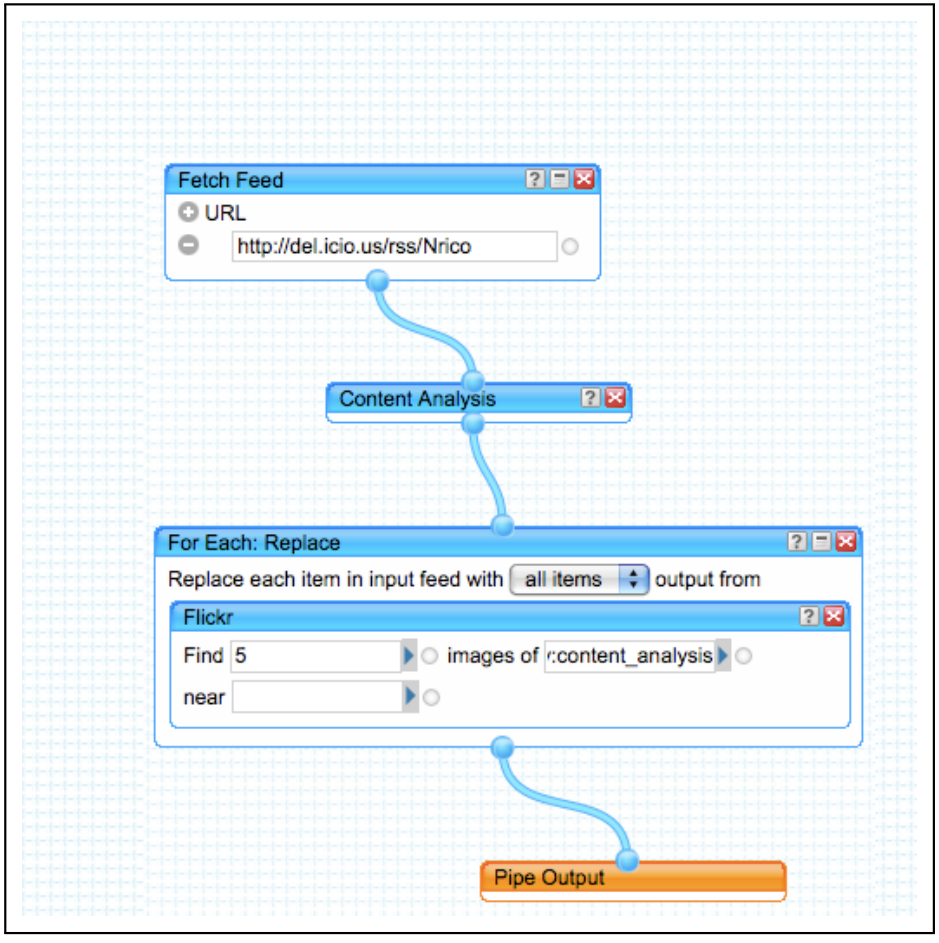


Environmental and Deprecation

Smell: Deprecated Module

A module that is no longer supported by the environment



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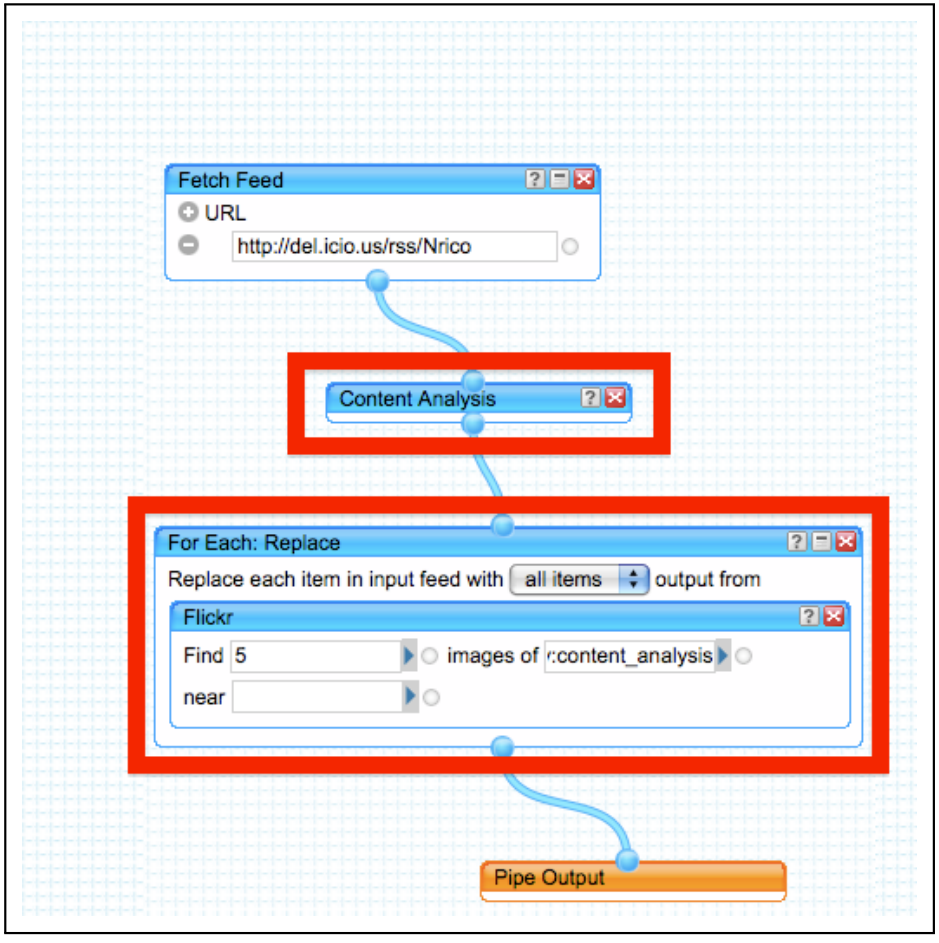

Environmental and Deprecation

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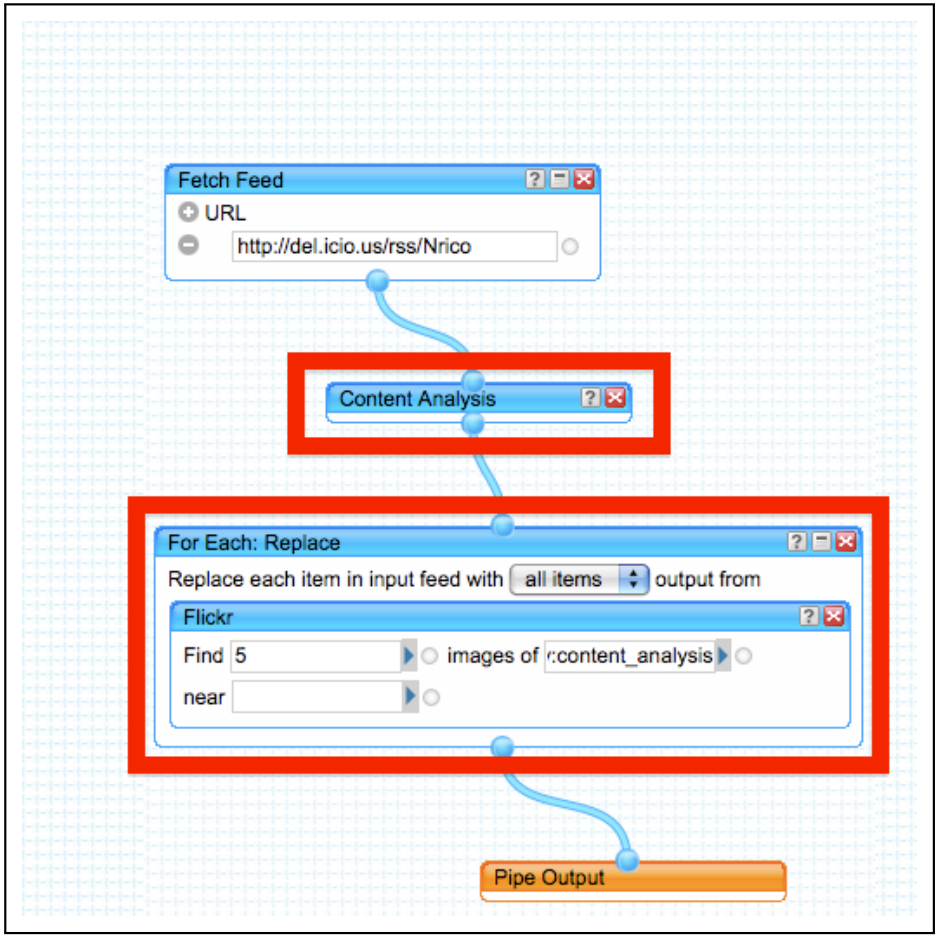
Why is this Smelly?

Module may cause unexpected or faulty behavior



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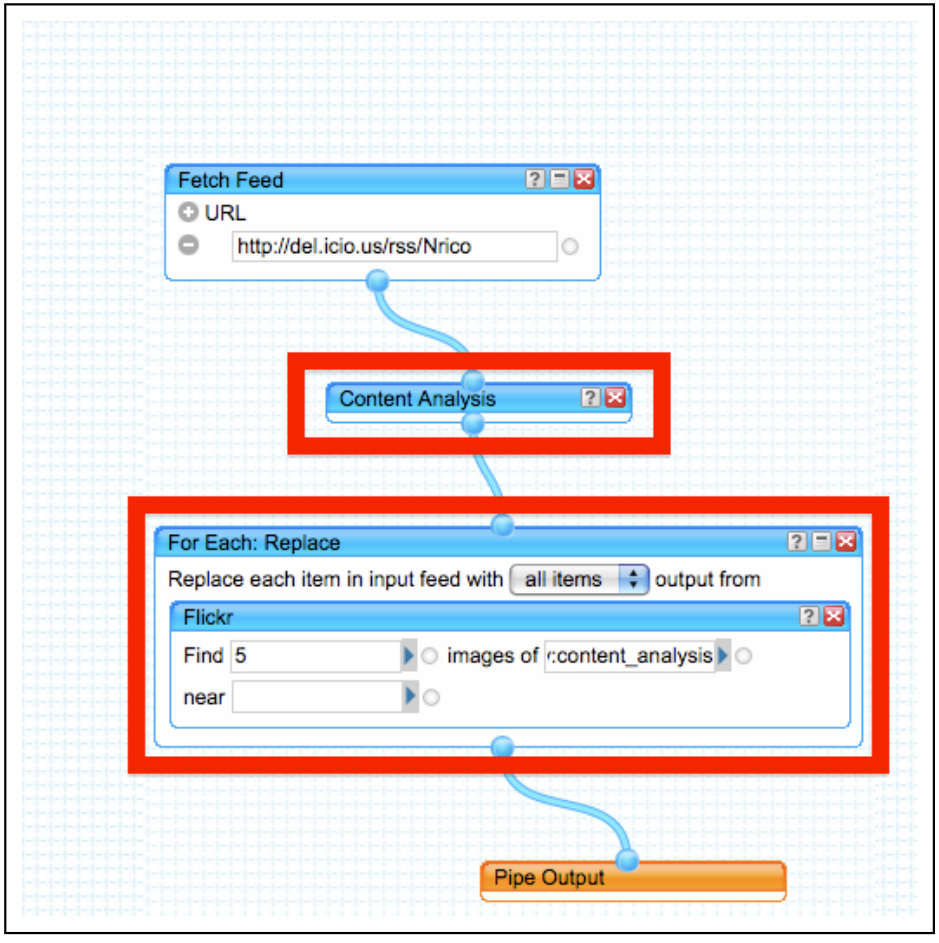
Insight

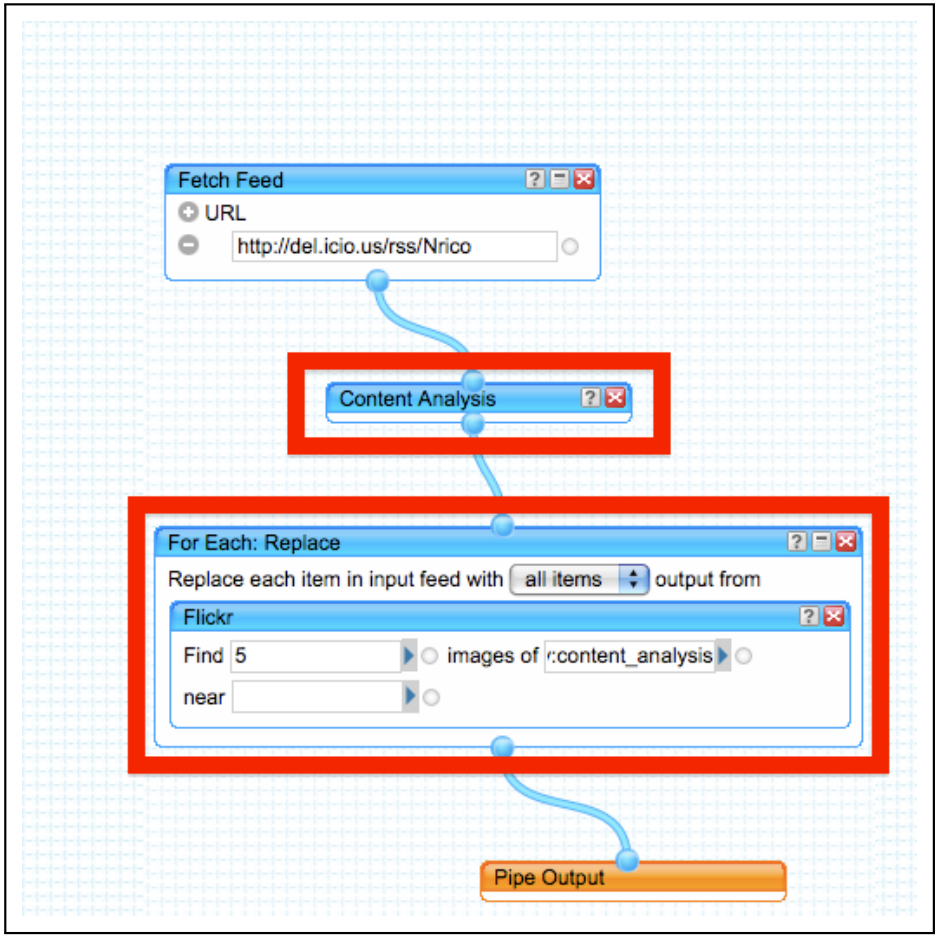
Language resources are independently created and managed



Environmental and Deprecation

Refactor: Replace Deprecated Module

Replace all deprecated modules with their semantic equivalents



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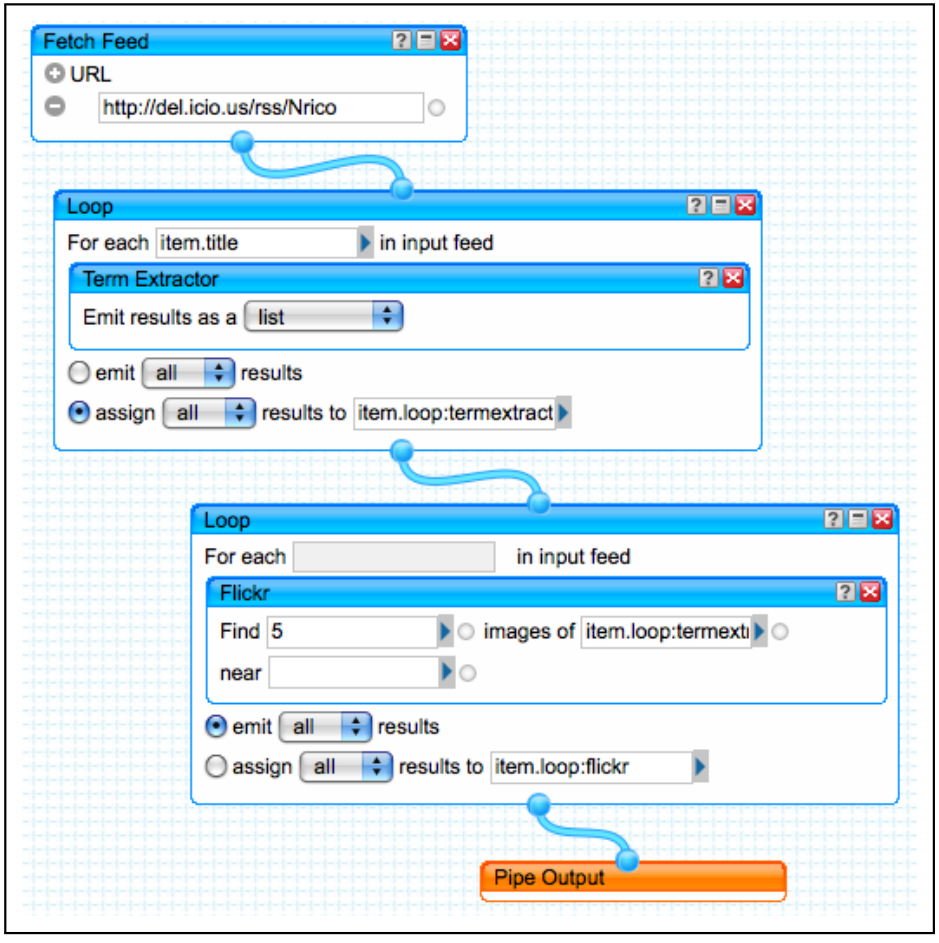

Environmental and Deprecation

Refactor: Replace Deprecated Module

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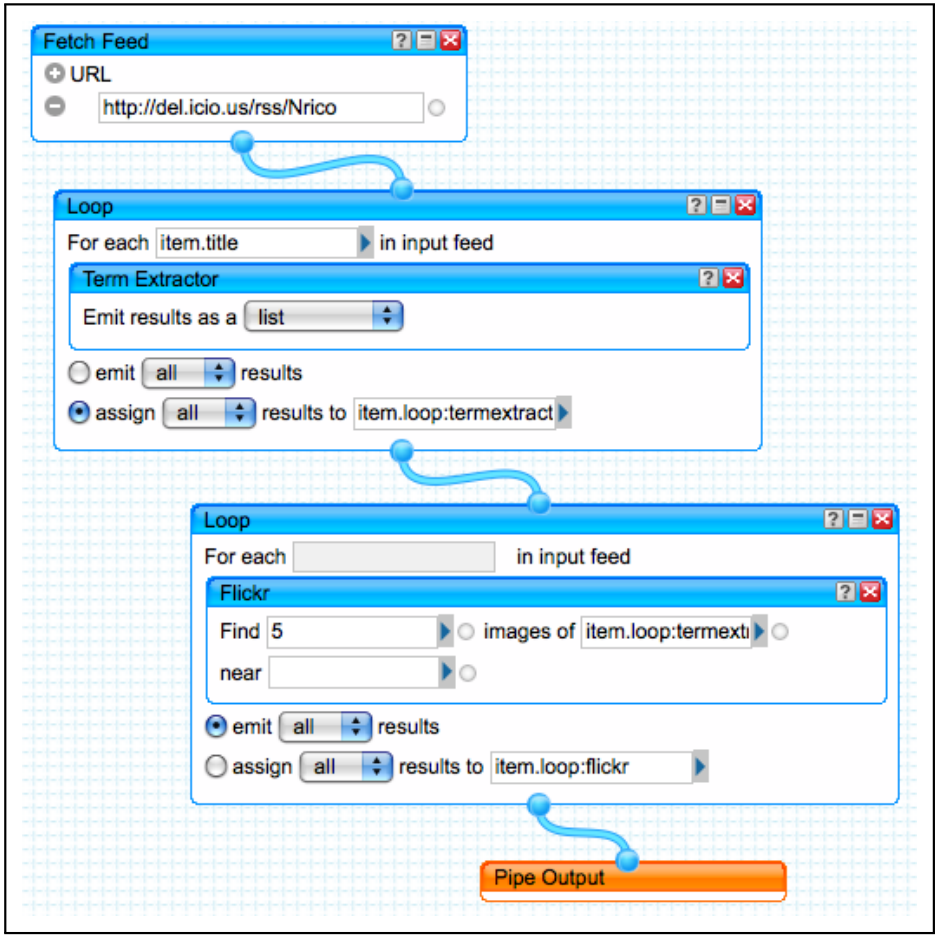
Inspiration

Previous work that uses refactoring to update references to deprecated Java libraries*



I. Balaban, F. Tip, and R. Fuhrer. Refactoring support for class library migration. In OOPSLA, 2005.

Smell Types

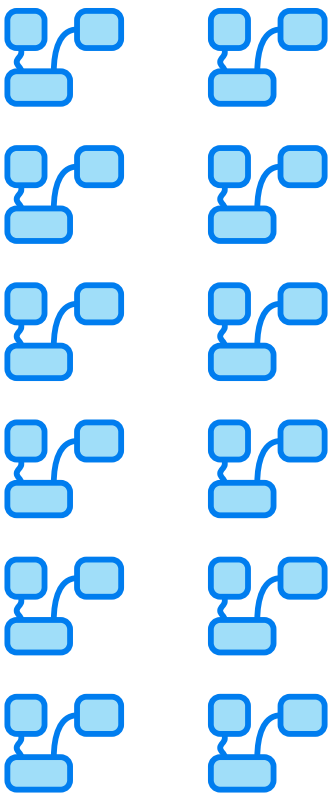
- Laziness – ineffectual or unnecessary components
- Redundancy – duplicate components
- Environmental – external changes cause impact
- **Population-Based – deviants from community norms**

Leveraging a Community of Resources:

- Popular resources can represent accepted “standards”
- Common patterns may indicate a need for additional community resources

Population-Based Refactorings

Pipes
Population



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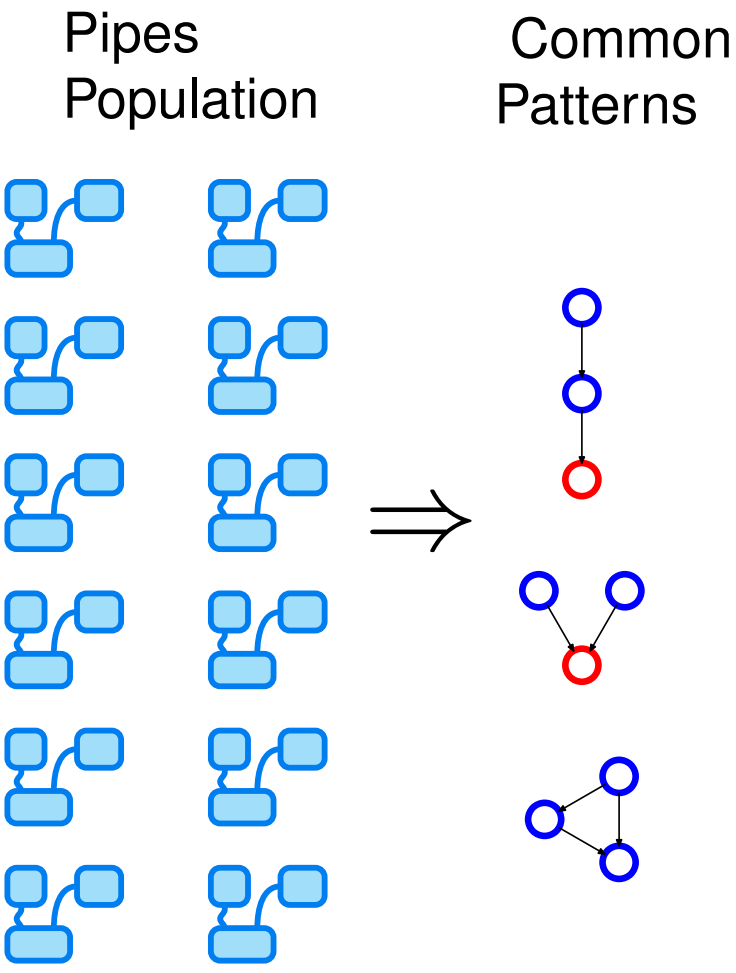

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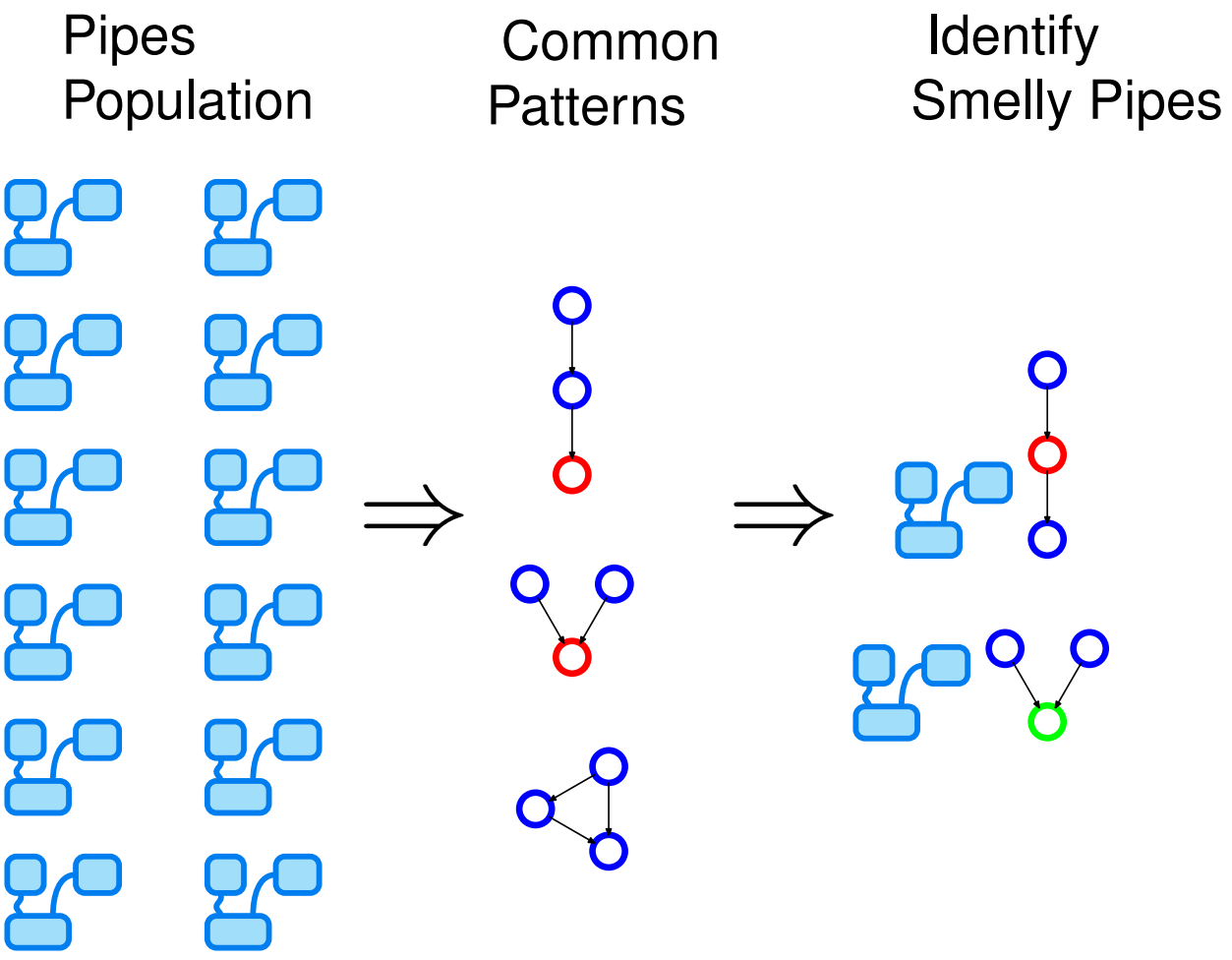


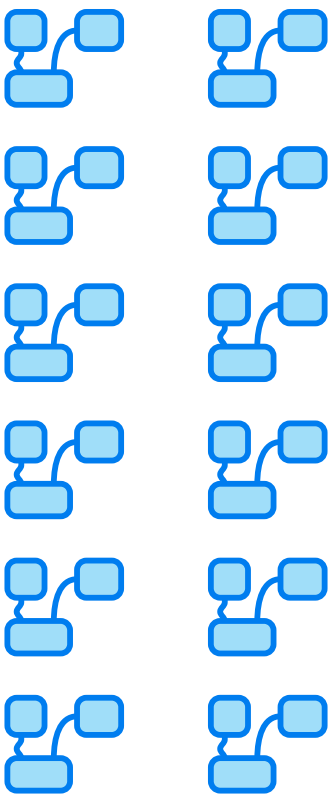
Population-Based Refactorings

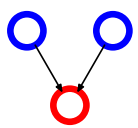
Pipes Population

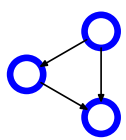
Common Patterns

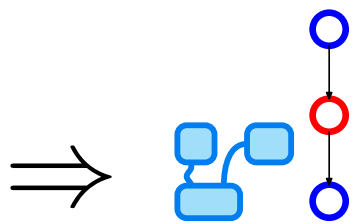
Identify Smelly Pipes

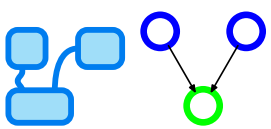
Refactor to Standardize









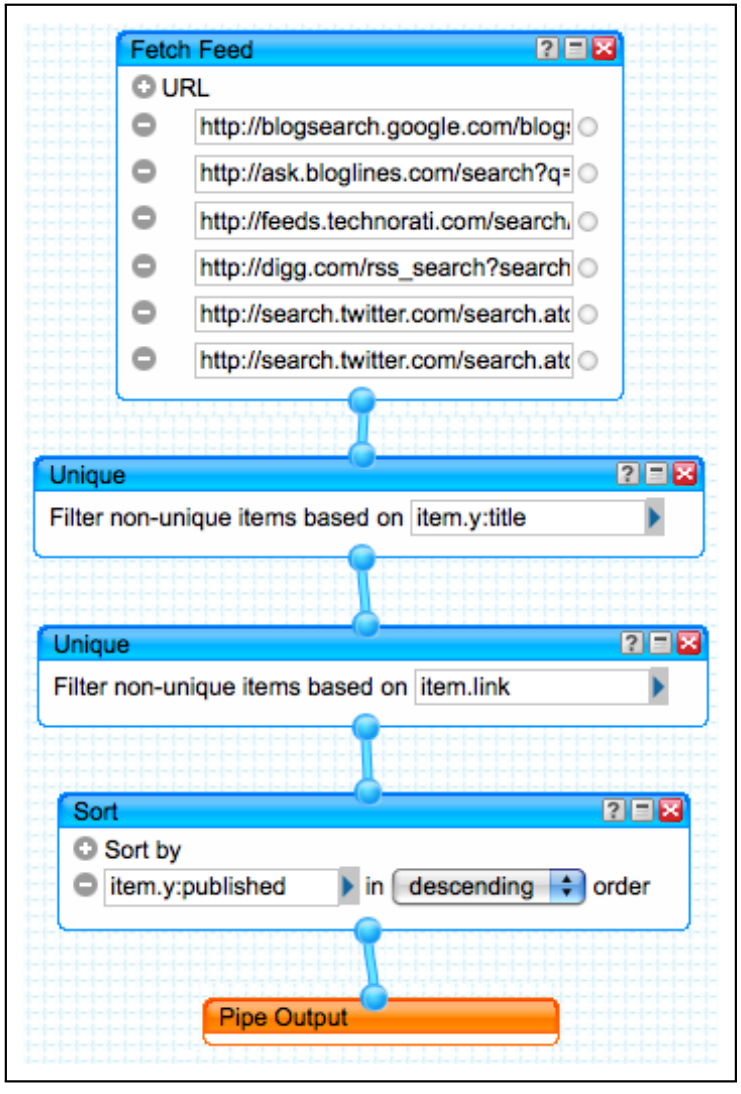


- Normalize Order of Operators
- Extract Global Subpipe
- . . .

Population-Based

Smell: Global Isomorphic Path

Paths that are isomorphic among pipes in the population



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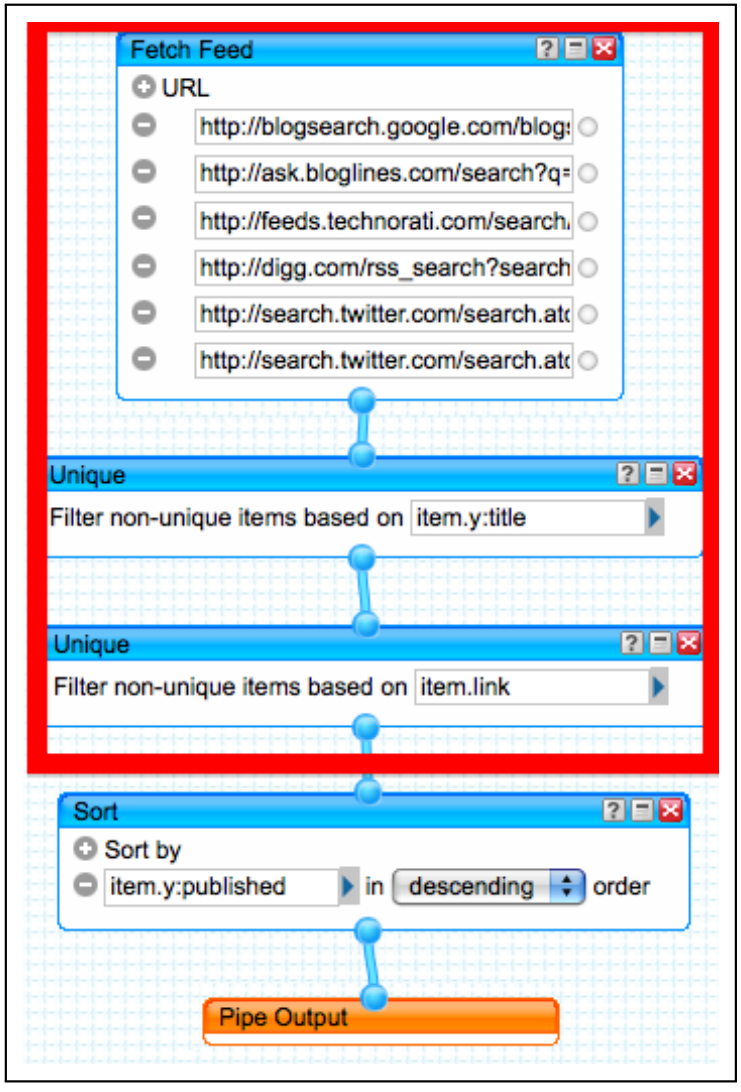


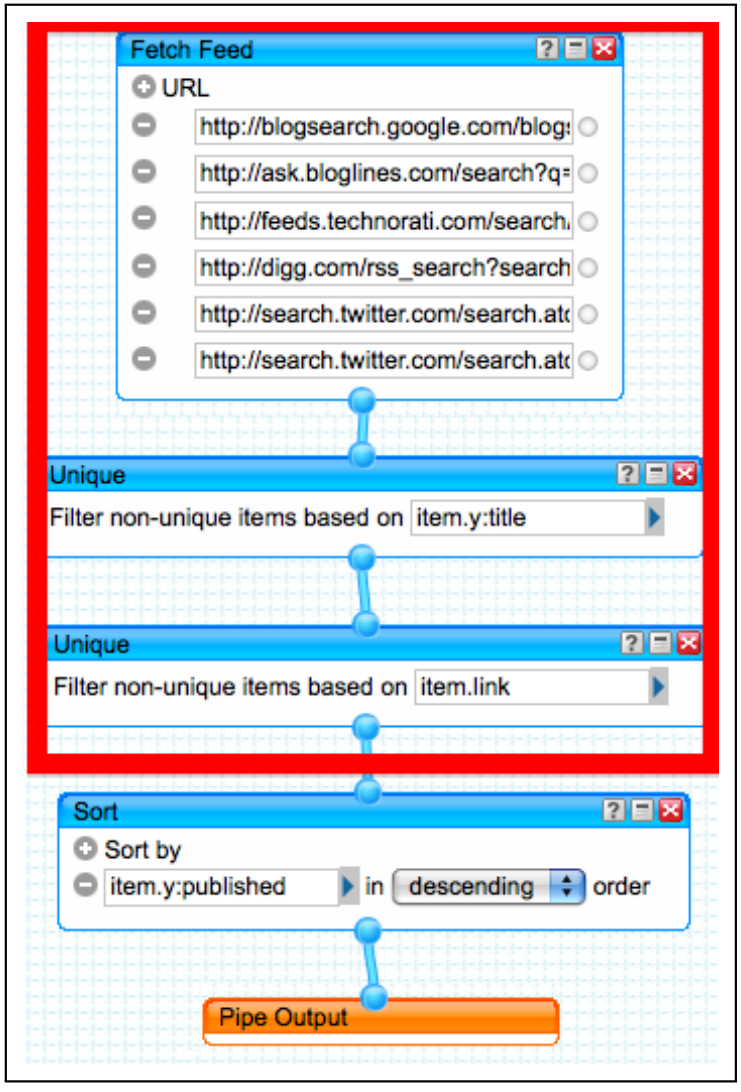
Population-Based

Smell: Global Isomorphic Path

Paths that are isomorphic among pipes in the population

Why is this Smelly?

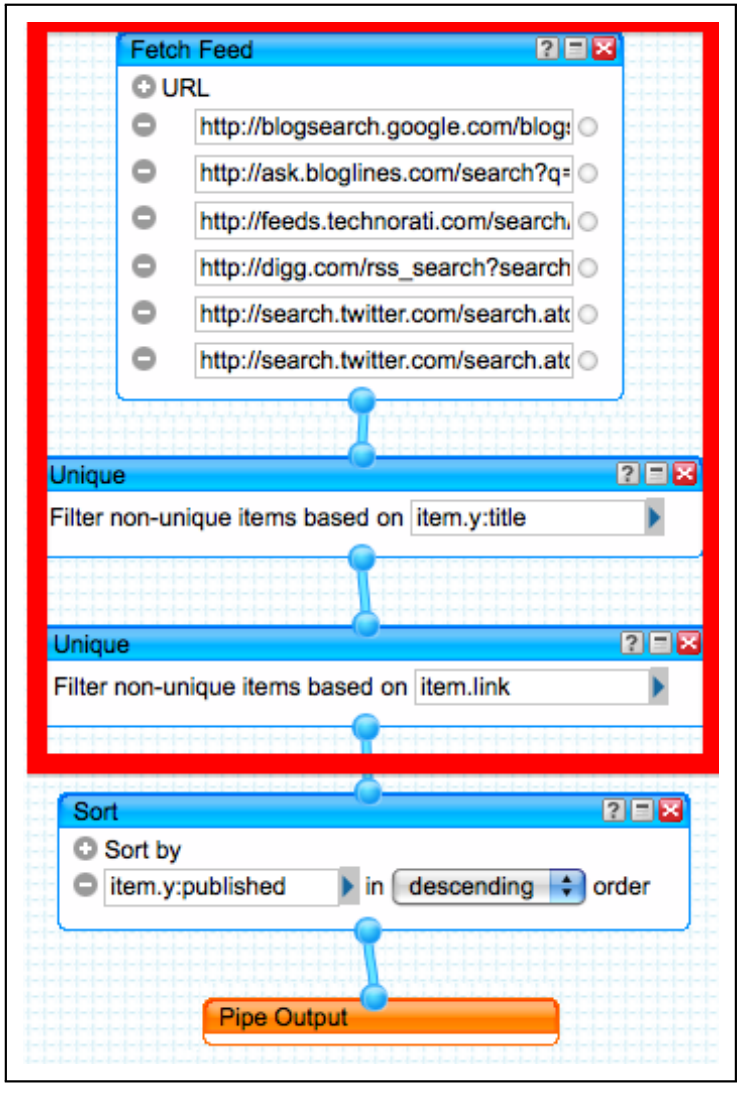
Missed opportunity for abstraction; may inhibit reuse



Population-Based

Refactor: Extract Global Subpipe

Replaces the isomorphic path with a subpipe from the population



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Refactor: Extract Global Subpipe

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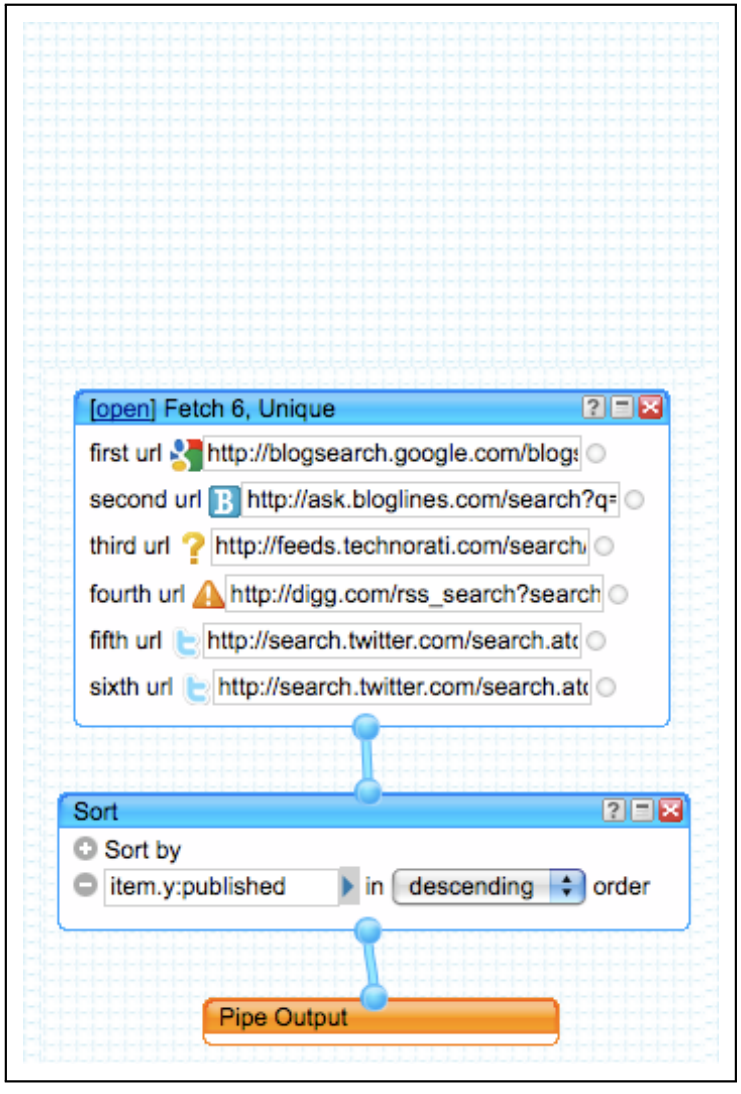


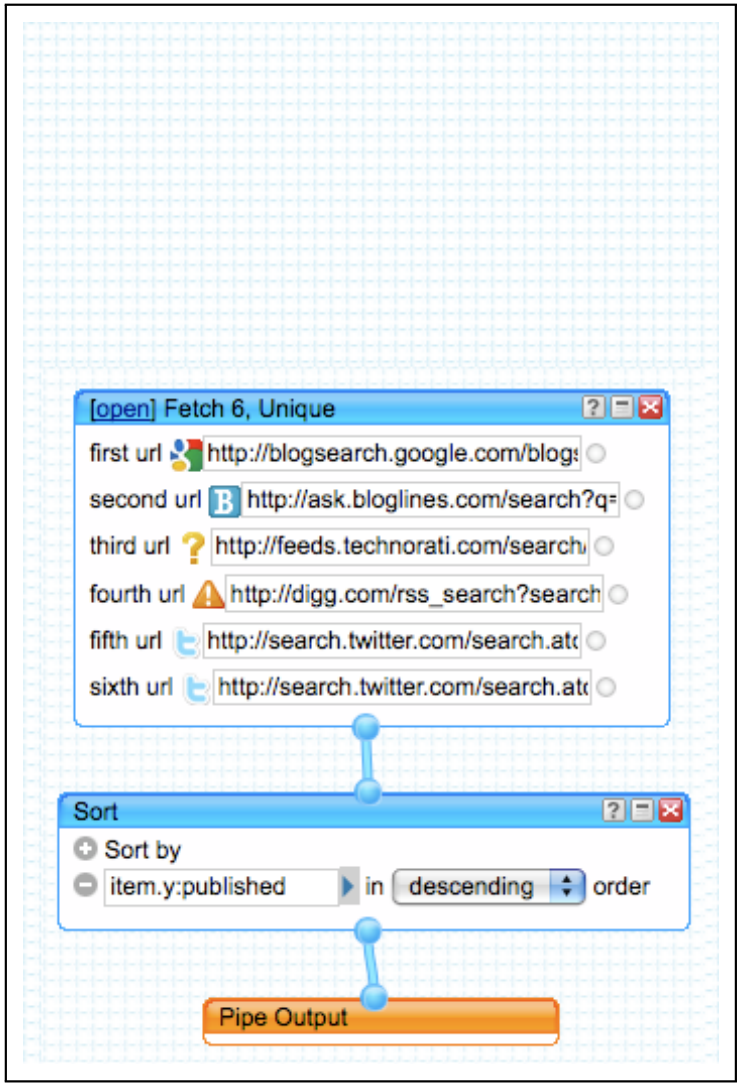
Population-Based

Refactor: Extract Global Subpipe

Replaces the isomorphic path with a subpipe from the population

Inspiration

There is much overlap and clutter across artifacts in end user repositories



Taking Stock: Smells

Smell Type	**Smell**	**Inspiration**
Laziness	Noisy Module Unnecessary Module Unnecessary Abstraction	*Lazy Class*
Redundancy	Duplicate Strings Duplicate Modules Isomorphic Paths	*Duplicate Code* —
Environmental	Deprecated Module Invalid Source	*Java API* —
Population-Based	Non-Conforming Ordering Global Isomorphic Paths	*Coding standards* —

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Taking Stock: Refactoring

Refactoring Type	Refactoring	Inspiration
Reductions	Clean Up Module	*Remove Parameter*
	Remove Non-Contributing	*Lazy Class*
	Push Down Abstraction	*Inline Method*
Consolidations	Merge Redundant Modules	*Inline Class*
	Collapse Duplicate Paths	—
Abstractions	Pull Up Module	*Pull Up Method*
	Extract Local Subpipe	
Deprecations	Replace Deprecated Mod.	*Java API*
	Remove Invalid Sources	—
Population-Based	Normalize Operations	—
	Extract Global Subpipe	—

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Refactoring 8,051 Pipes Programs

		Max % Removed	
	Frequency	**Individually**	**Collectively**
Noisy Module	28%	18%	43%
Unnecessary Module	13%	100%	100%
Unnecessary Abstraction	12%	100%	100%
Duplicate Strings	32%	100%	100%
Duplicate Module	23%	72%	90%
Isomorphic Paths	7%	100%	100%
Deprecated Module	18%	100%	100%
Invalid Source	14%	99%	99%
Non-Conforming Op Order	19%	100%	100%
Global Isomorphic Paths	6%	100%	100%
All Smells	**81%**	**–**	**80%**

Do Smells Matter?

Empirical Study

- 14 'end-user' participants
- Crowdsourced using Mechanical Turk
- All participants demonstrated basic competence in Yahoo! Pipes
- Assumed random assignment of tasks

Empirical Study

Research Question I

Are pipes with smells **less preferable** than pipes without smells?

Empirical Study

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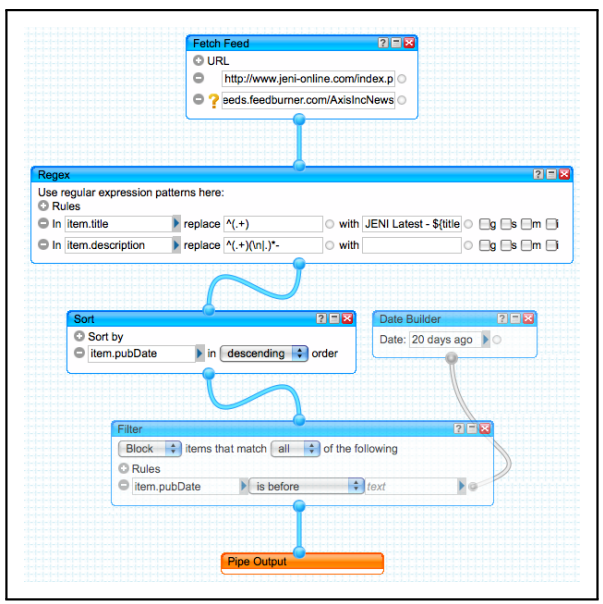

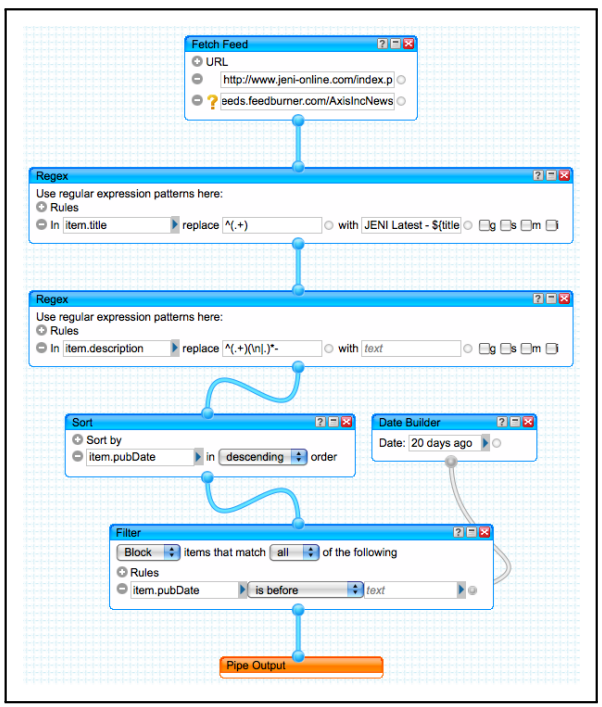

Question: Select the pipe that is easiest *to understand*

Empirical Study

Research Question I

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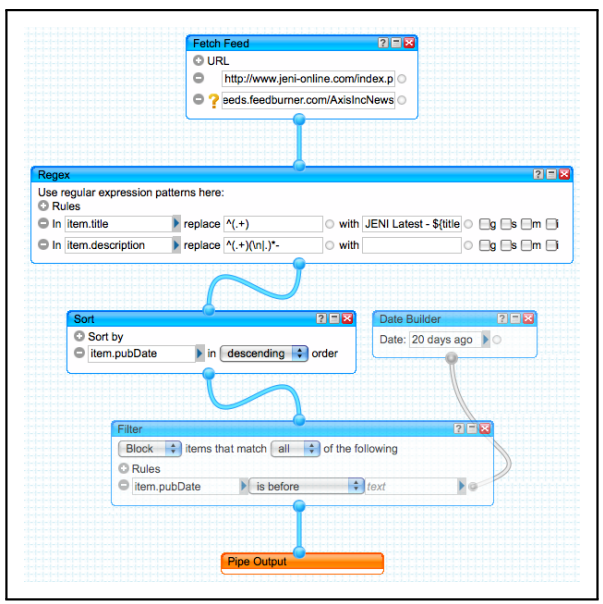

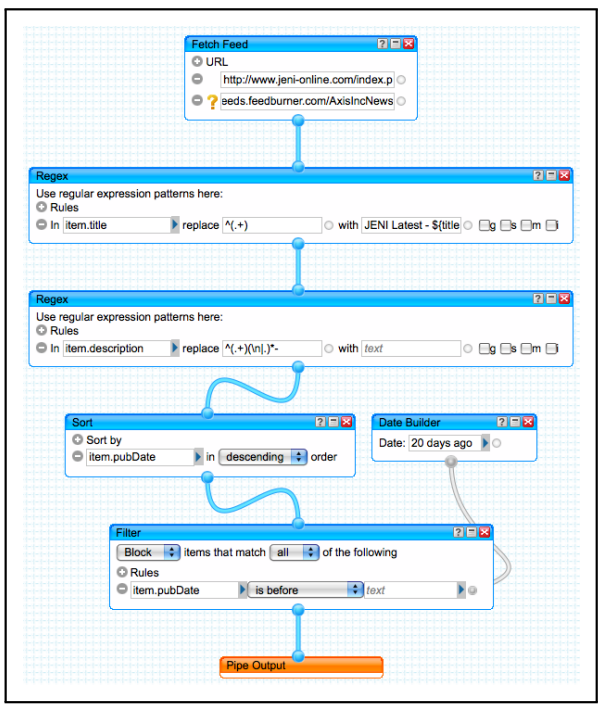

Is the refactored pipe preferred?

Yes:	**63%**
No:	24%
Unsure:	13%

Question: Select the pipe that is easiest *to understand*

RQ I: Results Summary

Smell Type + Refactoring	Question	Non-Smelly
Redundancy + Consolidation	Understanding	90%
Redundancy + Abstraction	Maintainability	90%
Redundancy + Consolidation	Understanding	50%
Laziness + Reduction	Maintainability	73%

RQ I: Results Summary

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Redundancy + Consolidation	Understanding	90%
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Redundancy + Consolidation	Understanding	50%
Laziness + Reduction	Maintainability	73%
Environ. + Deprecated Src.	Maintainability	38%
Environ. + Deprecated Mod.	Understanding	33%

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Environ. + Deprecated Mod.	Understanding	33%
Population (Global Path)	Understanding	33%
Population (Operator Ordering)	Others to Understand	88%

Empirical Study

Research Question II

Are smelly pipes **less understandable** than pipes without smells?

Empirical Study

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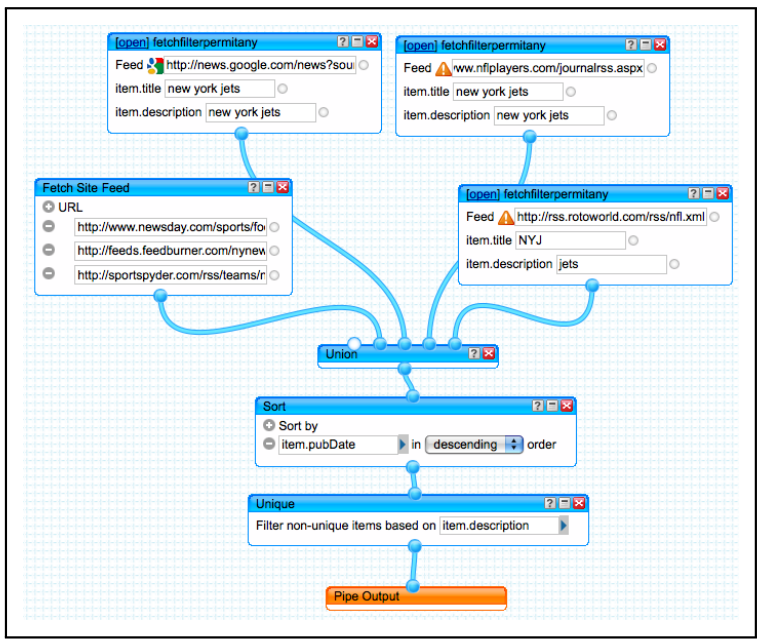

Select the pipe's output:

1. No Output
2. All of the content of the websites specied in the URL Builders.
3. The content of eight websites, filtered based on the presence of a user-defined value in the title of each item.
4. The content of four websites, filtered based on the presence of a user-defined value in the title of each item.

Empirical Study

Research Question II

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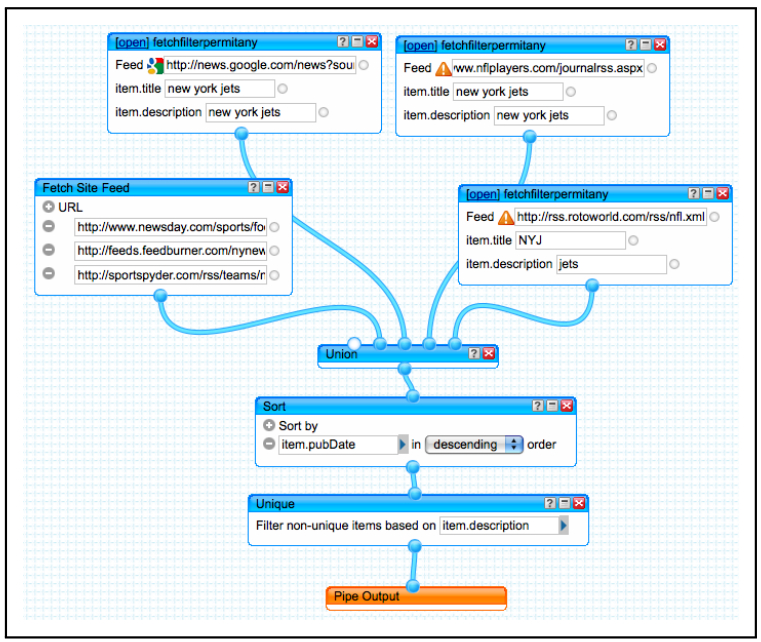

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Correctly answered tasks:

Non-Smelly	**80%**
Smelly	67%

Motivations to Refactor

Professional Programmers

- Reduce Complexity
- Increase Understandability
- Create cleaner code
- Improve software design
- Permit more effective testing
- Better maintainability
- Update deprecated library calls
- Parallelization
- Increase code reuse
- . . .

End User Programmers*

* Taken from responses in user study

- Reduce complexity
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Taking Stock

What we learned:

- Pipe-like mashups are littered with smells
- Refactorings are effective at removing smells
- End users prefer pipes without smells

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What we don't know:

- Will end-user programmers adopt a refactoring tool?
- How can refactoring be extended to other domains?
- Can other end-user domains create opportunities for new refactorings?

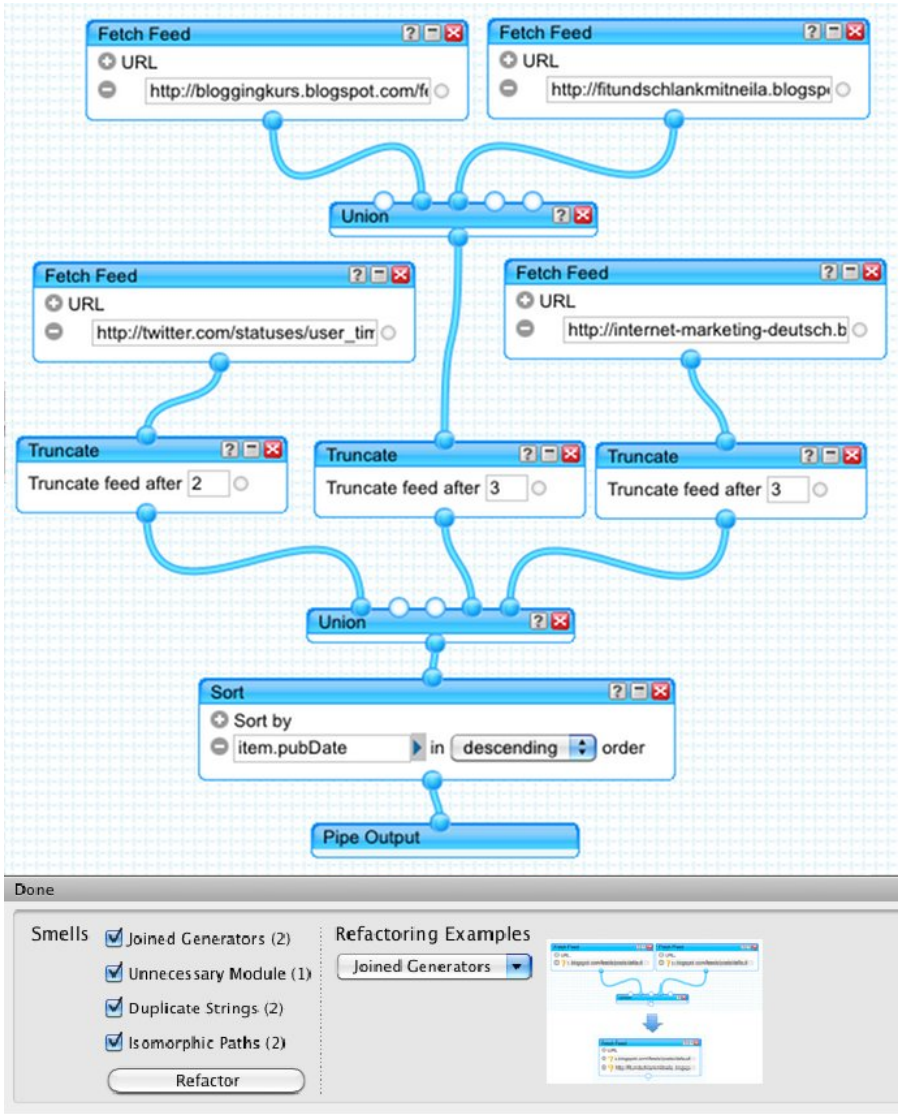
In this talk

- End-user software engineering
- Refactoring for web mashups
- Mashup languages create opportunities to extend refactorings
- Speculate how refactoring adapts to other end user domains

End User Refactoring Engine for Yahoo! Pipes

Idea:

- Integrated into the browser (no extra tool)
- Shows preview of the result for each refactoring (no surprises)
- Offers to perform refactorings for the end user (no extra effort)



Web Macros

Environments: CoScripter, . . .

Programs: log a user into a system, insert information from spreadsheet to form, . . .

Refactoring in Web Macros

Refactor for Privacy and Flexibility:

1. User records a macro with username and password
2. User wants to share the macro, but maintain privacy
3. Refactor to reference username and password in personal database

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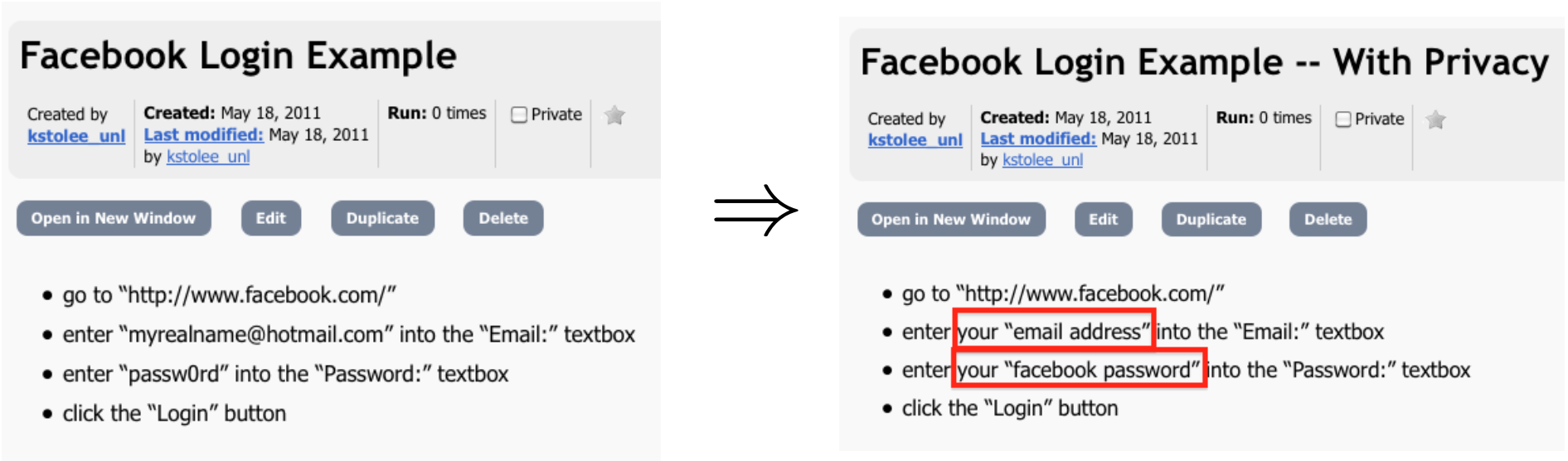

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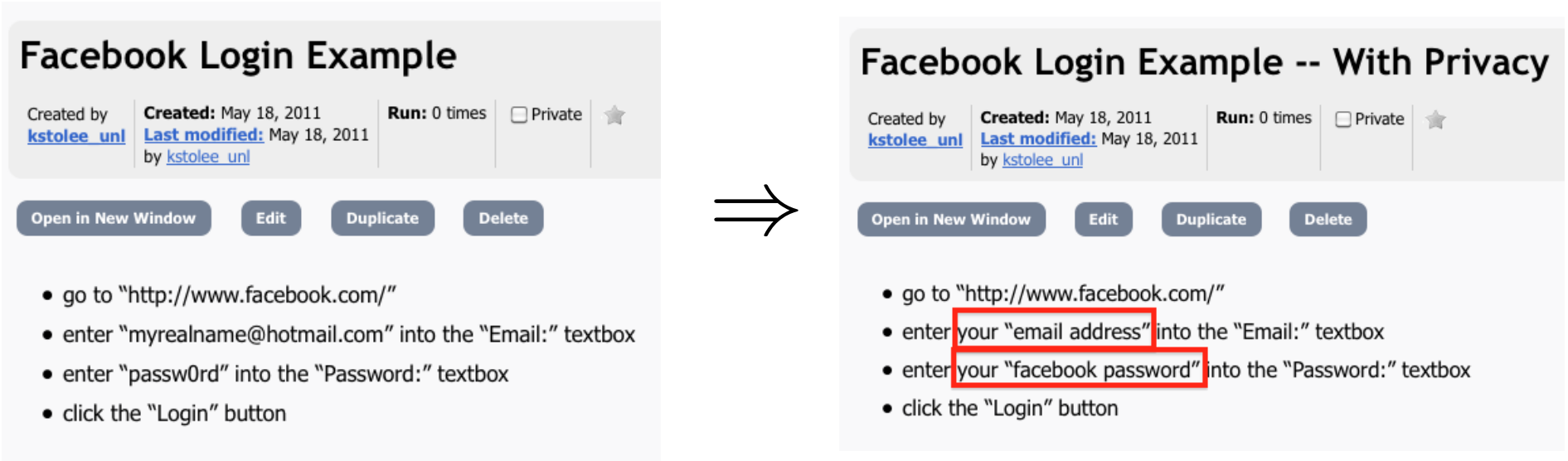
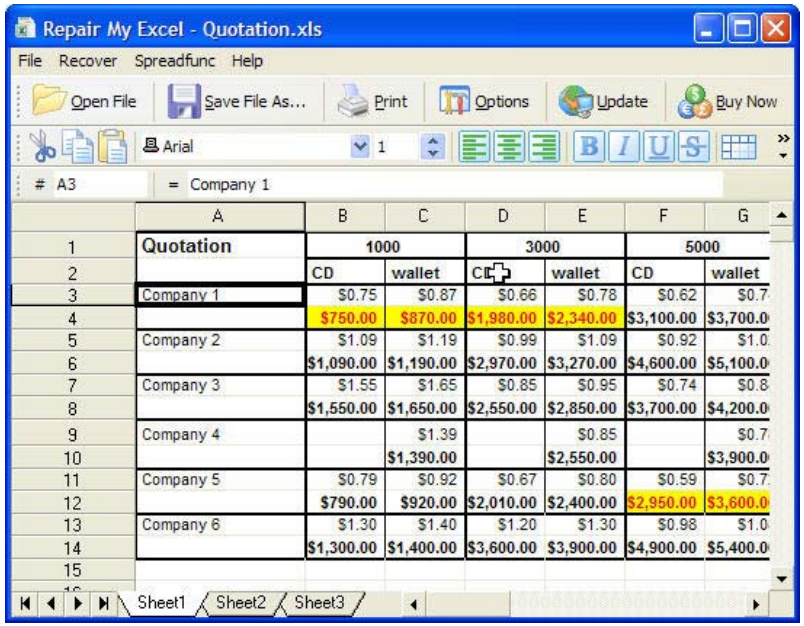


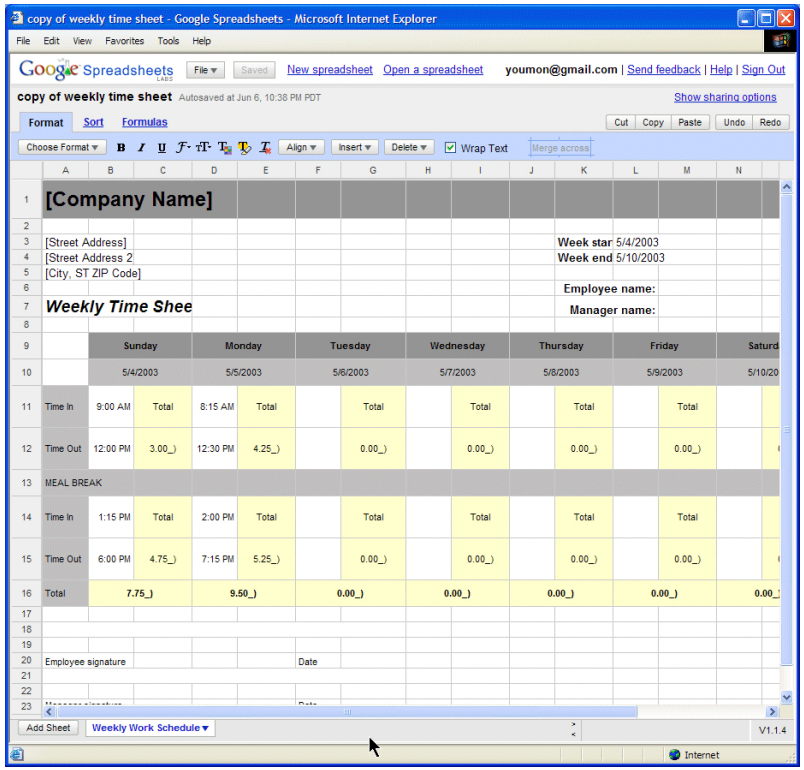
Other opportunities: performance, parallelization, invalid sources, cleanliness

Spreadsheets

Environments: Excel, Google Spreadsheet, . . .

Programs: Accounting worksheet, event planning, financial forecasting, . . .





Refactoring in Excel

Refactor for Standardization to Community:

1. User creates accounting spreadsheet like this:

A	B	C	D	E	F
Reference	**Date**	**Description**	**Balance**	**Credit**	**Debit**
Target	5/17/2011	Clothing, Shoes	$1,279.89	$ 65.43	
Shell	5/17/2011	gas	$1,236.34	$ 43.55	
Express	5/17/2011	refund for shirt	$1,269.54		$ 33.20

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2. Analysis of community spreadsheets shows most others like:

Date	Description	Reference	Debit	Credit	Balance
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Date	Description	Reference	Debit	Credit	Balance
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Other opportunities: maintenance, text to drop-down, remove temporary variables

Educational Languages

Environments: Scratch, Alice, Kodu, . . .
Programs: Animations, simulations, interactive games, . . .

Refactoring in Kodu

Refactor for Simplicity:

1. User creates many rules with replicated conditions
2. Multiple actions can be bound to a single condition
3. Concatenate multiple actions with a single condition

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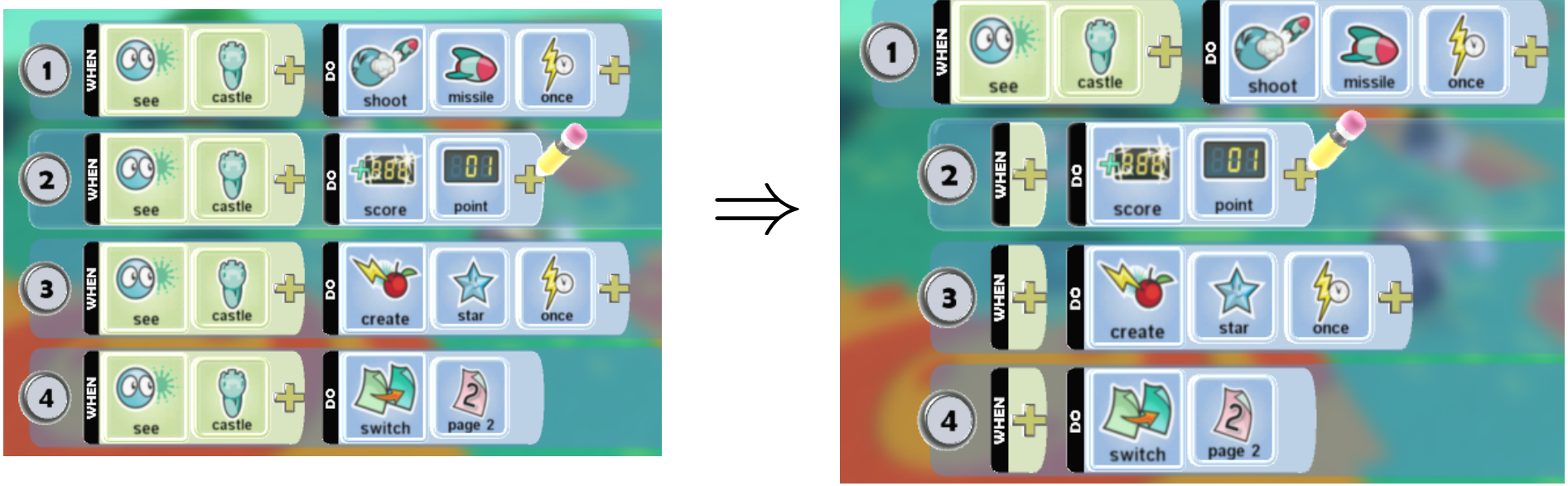

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Other opportunities: remove dead code

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