Refactoring Pipe-like Web Mashups for End-User Programmers

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Introduction

End User Programmers

People who engage in programming activities to support their hobbies and work.

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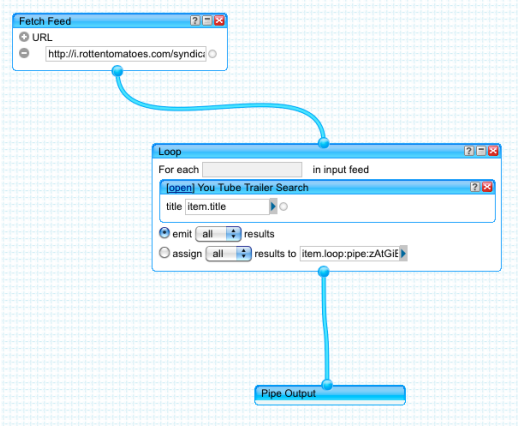
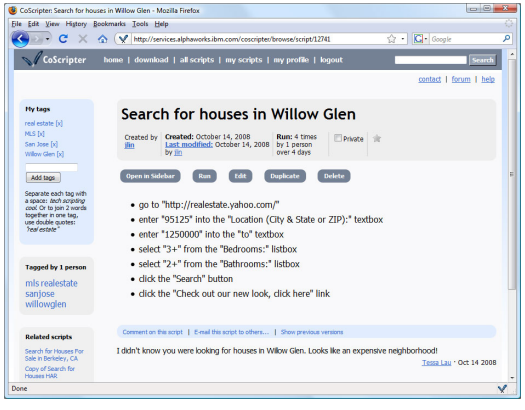
	Professionals	**End Users**
Number in U.S. (2005)	3 million	55 million
Typical Education	C.S. Degree	Other Degree
Role of Programming	It's their job	It supports their job

Many Domains and Applications

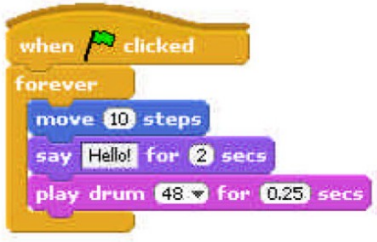
Web Mashups:

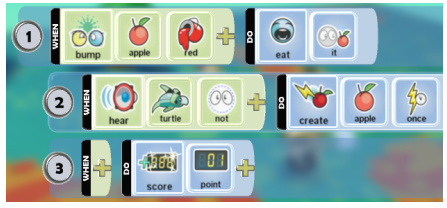


Web Macros:

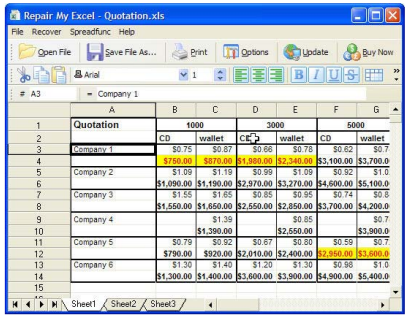


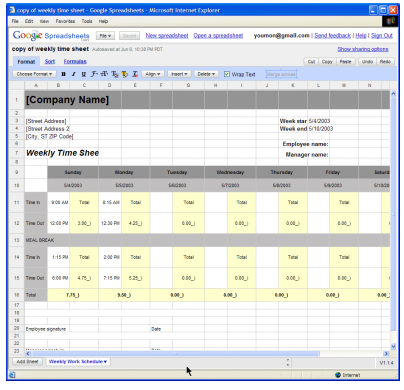
Educational Games:



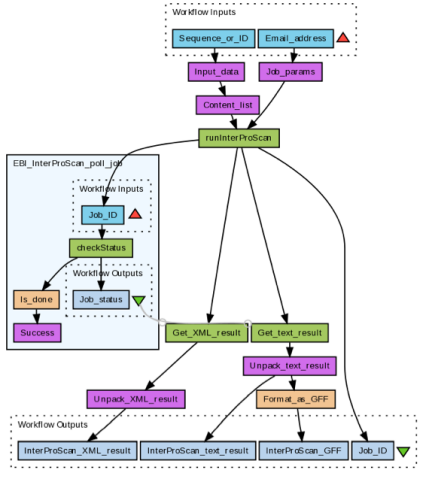


Spreadsheets:





Scientific Workflow:



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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

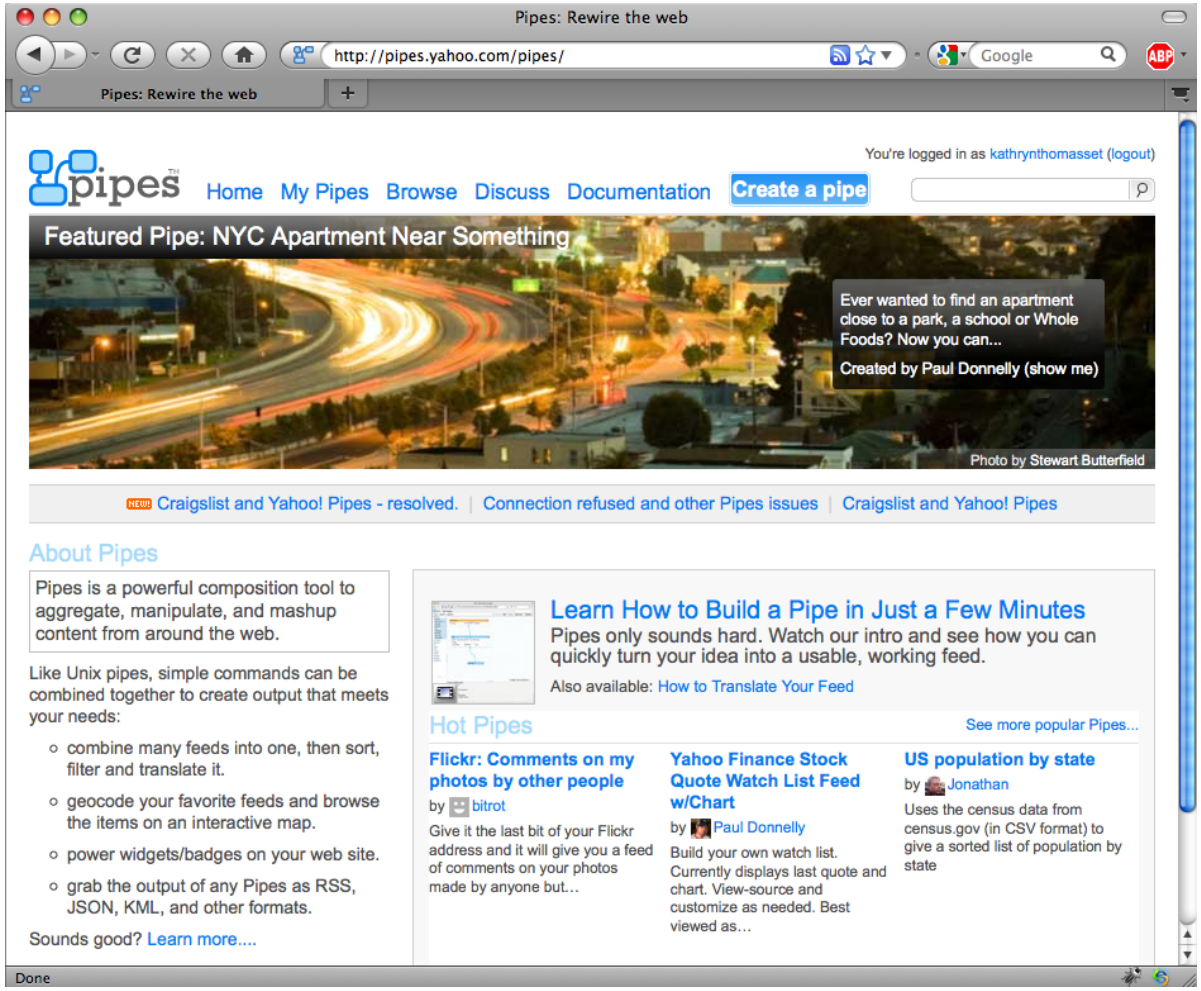
  Zang, N. and Rosson, M.B. Playing with information: How end users think about and integrate dynamic data. VL/HCC 2009
- Maintenance in mashups is common: nearly 24% of Yahoo! Pipes mashups were modified after they were made public

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

About Yahoo! Pipes

It's Popular

- Over 90,000 authors have created mashups
- Active community with message boards, tutorials, and literature
- Large public repository of sample code (nearly 100k pipes)



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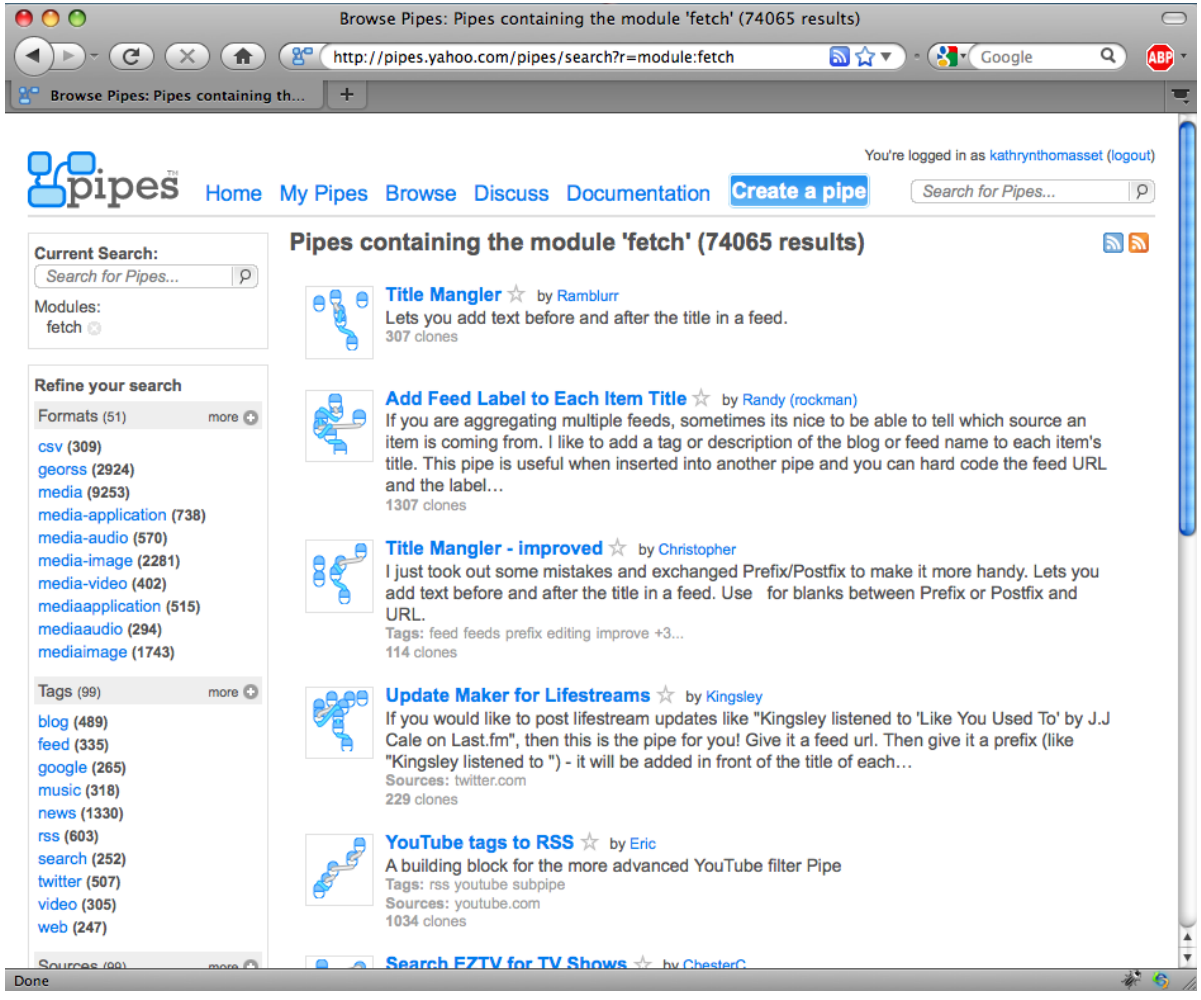

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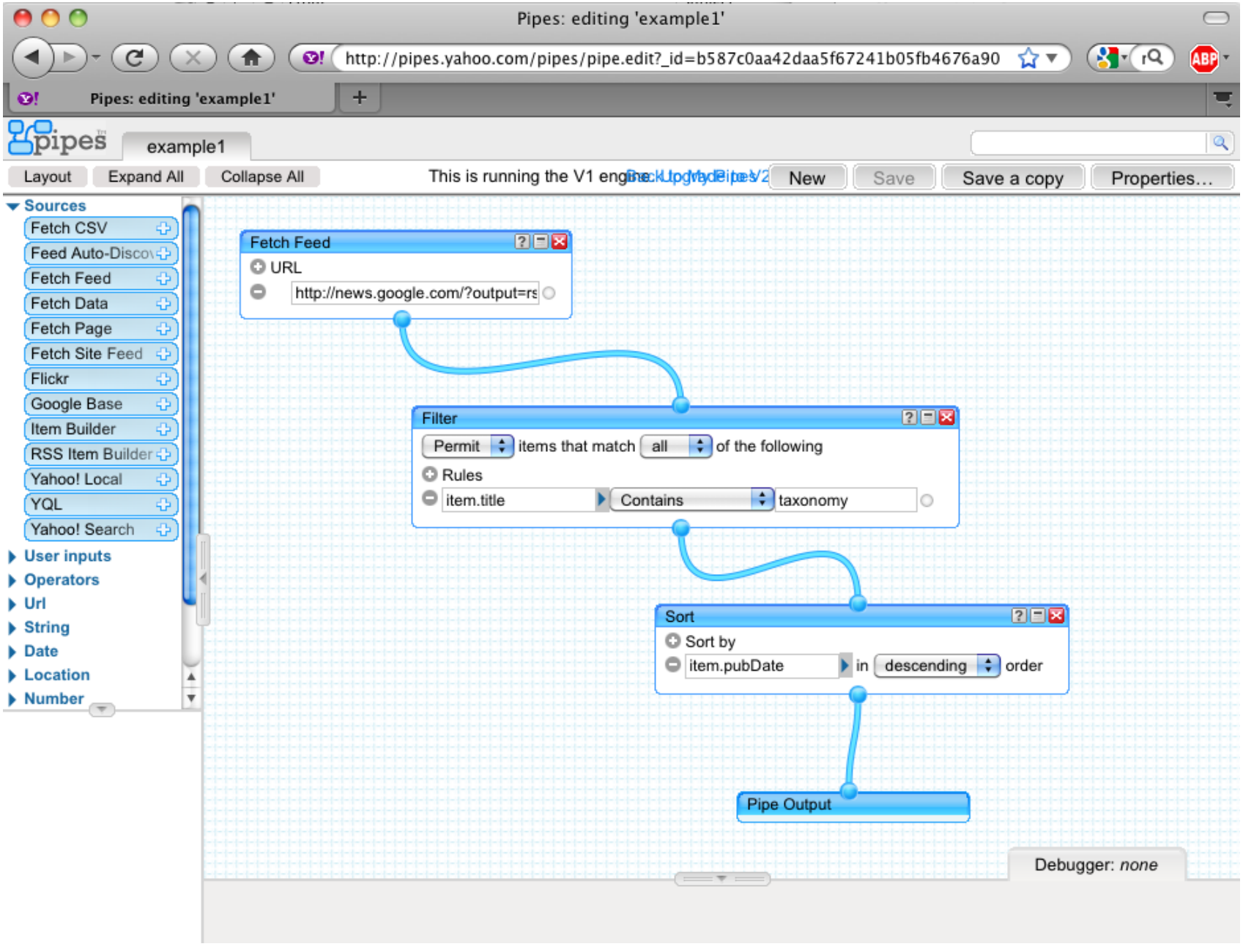

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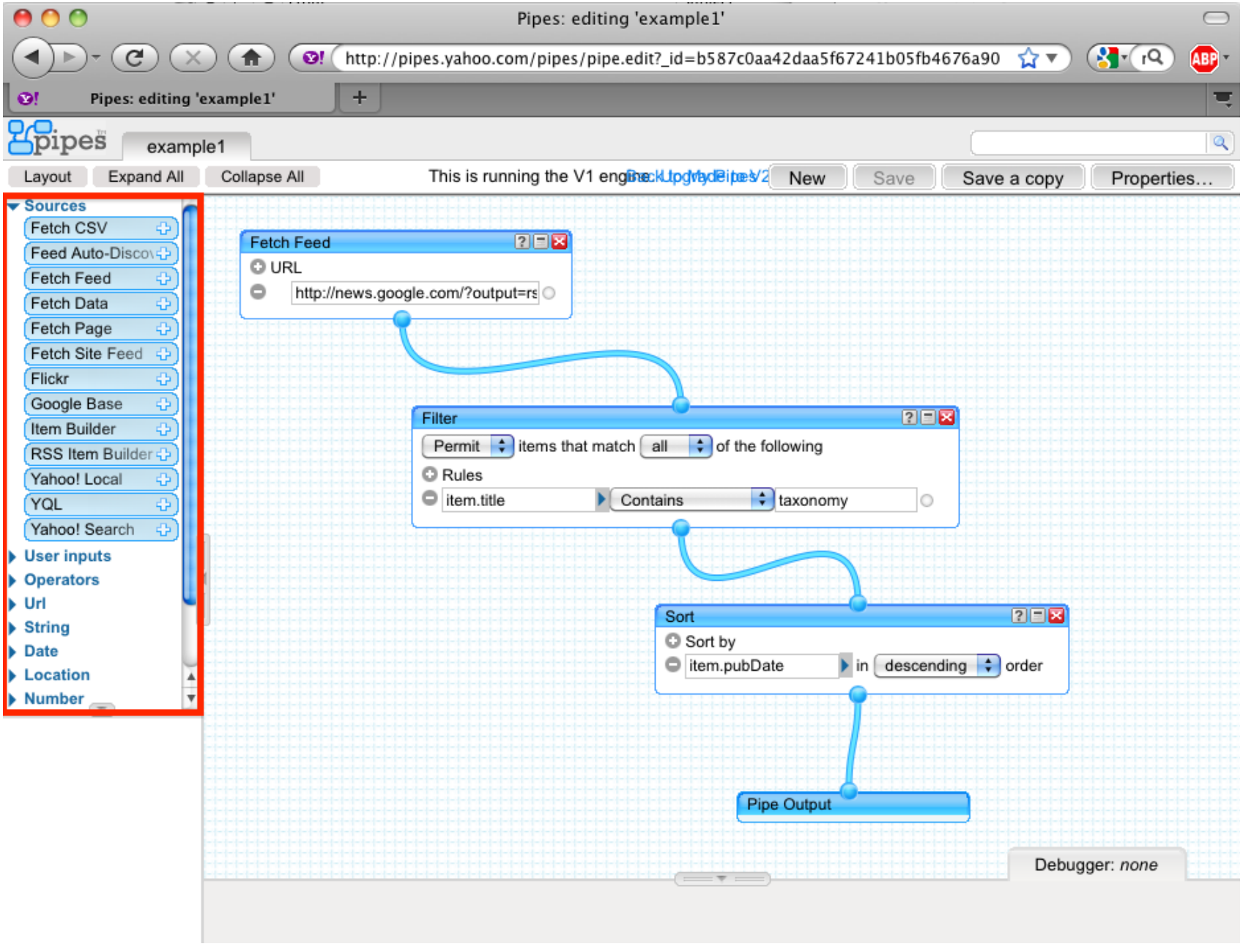

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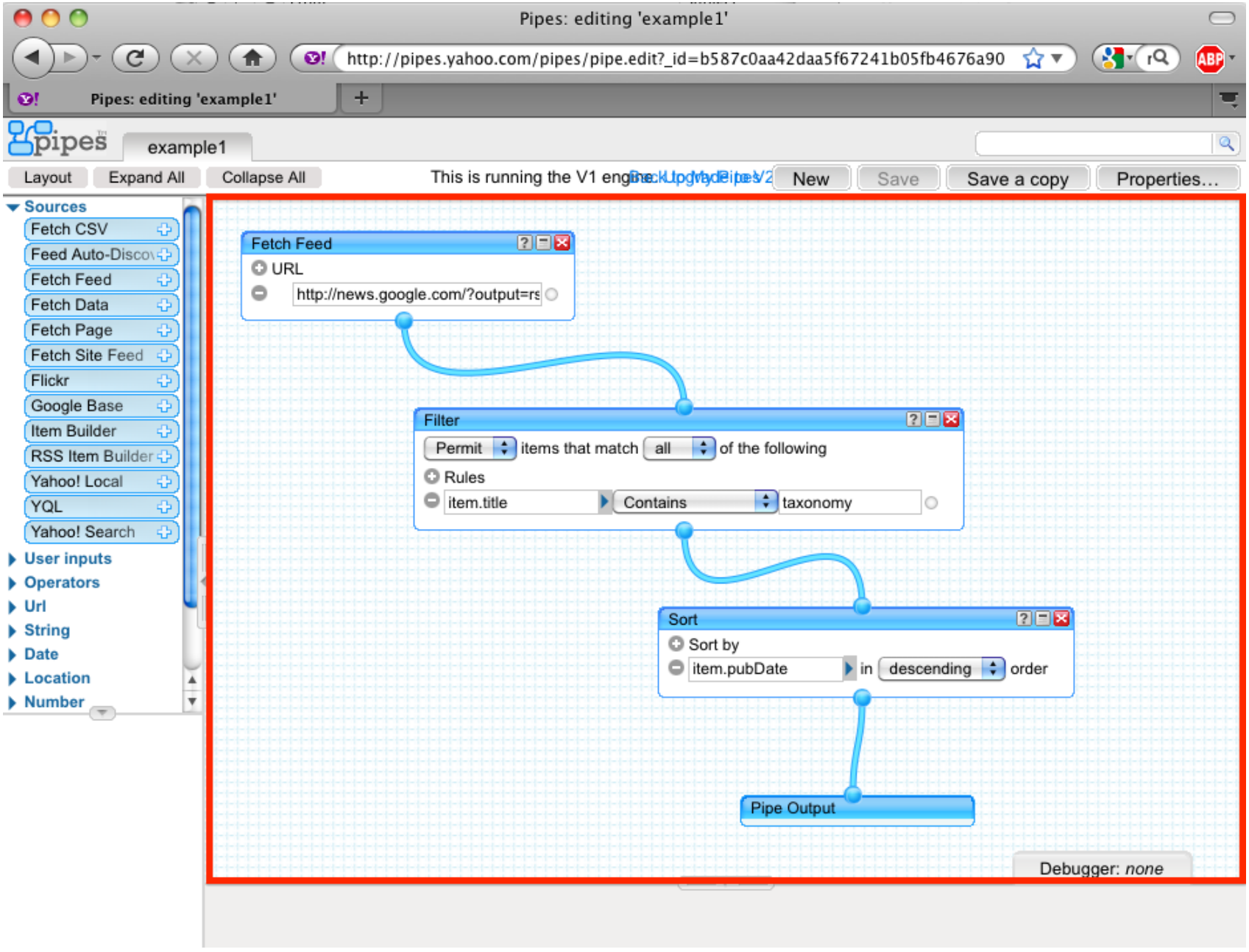

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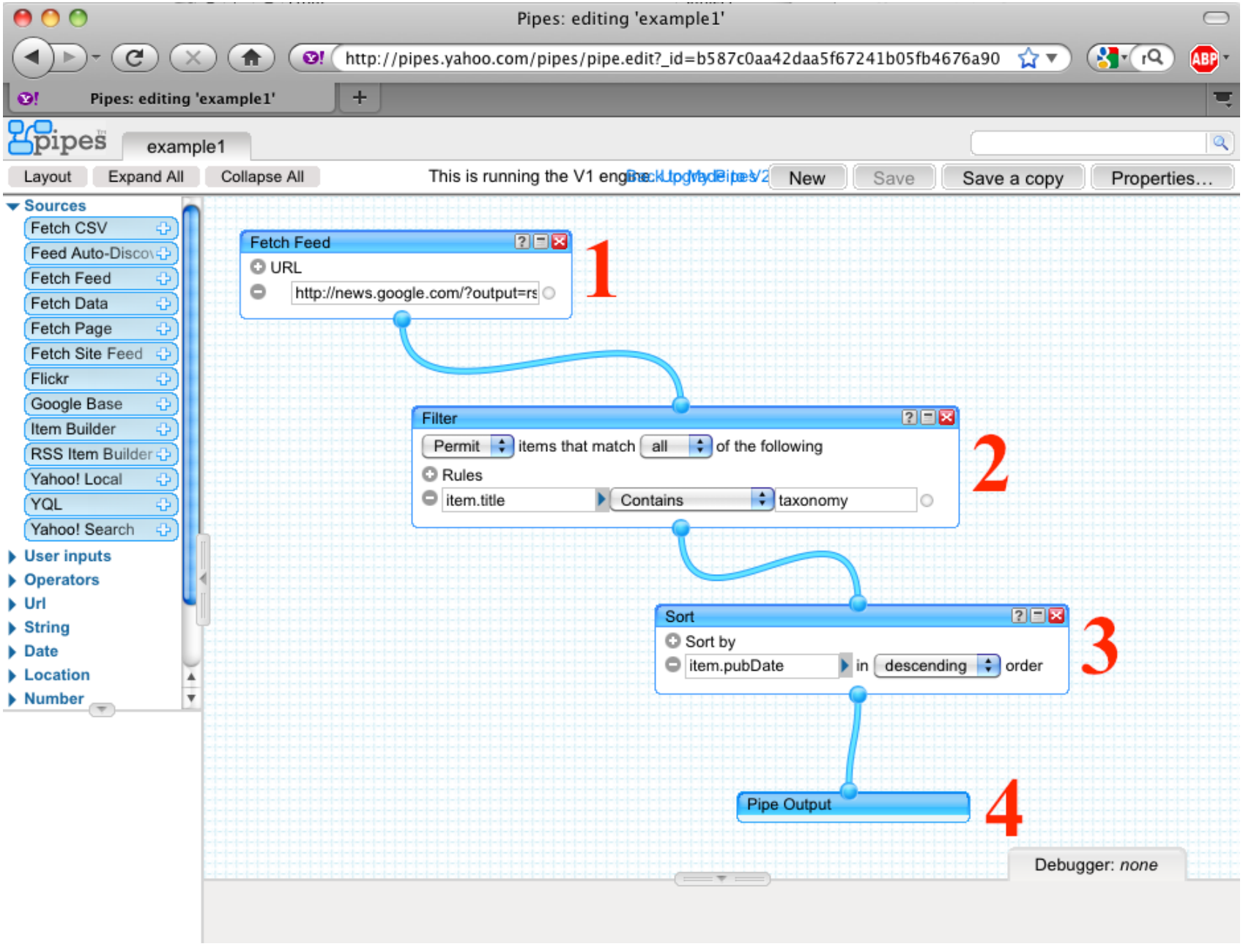
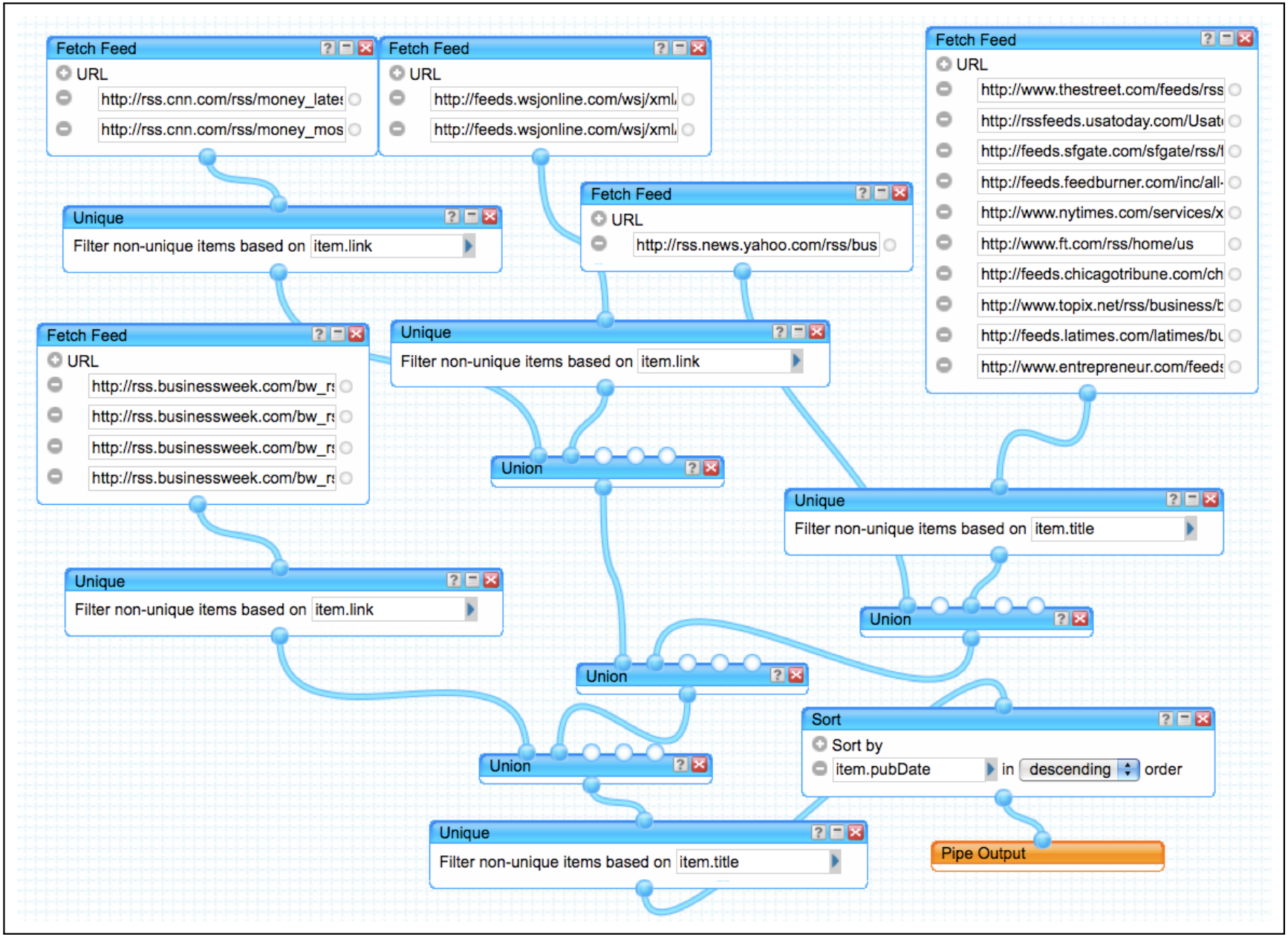


Motivating Example



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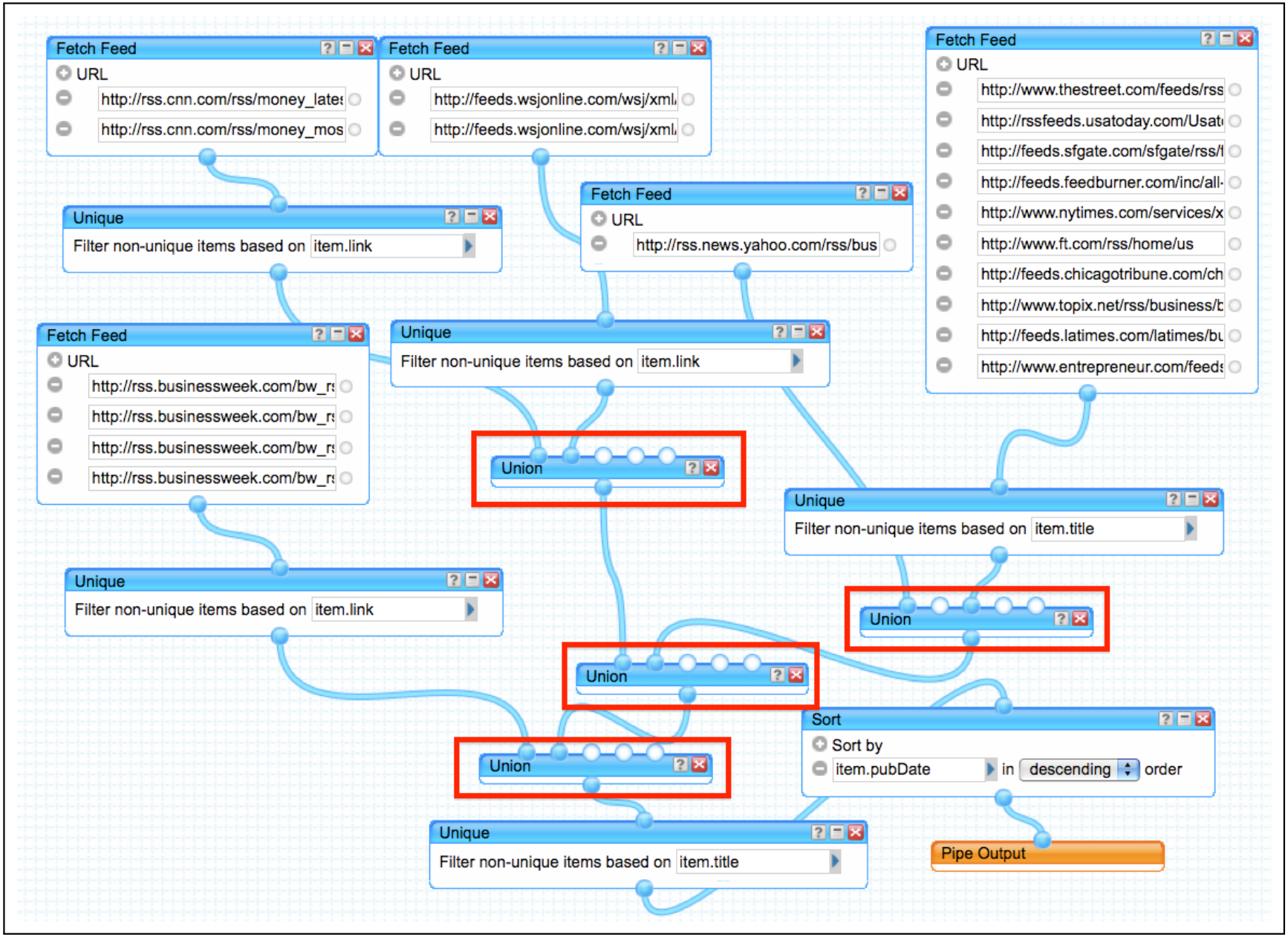

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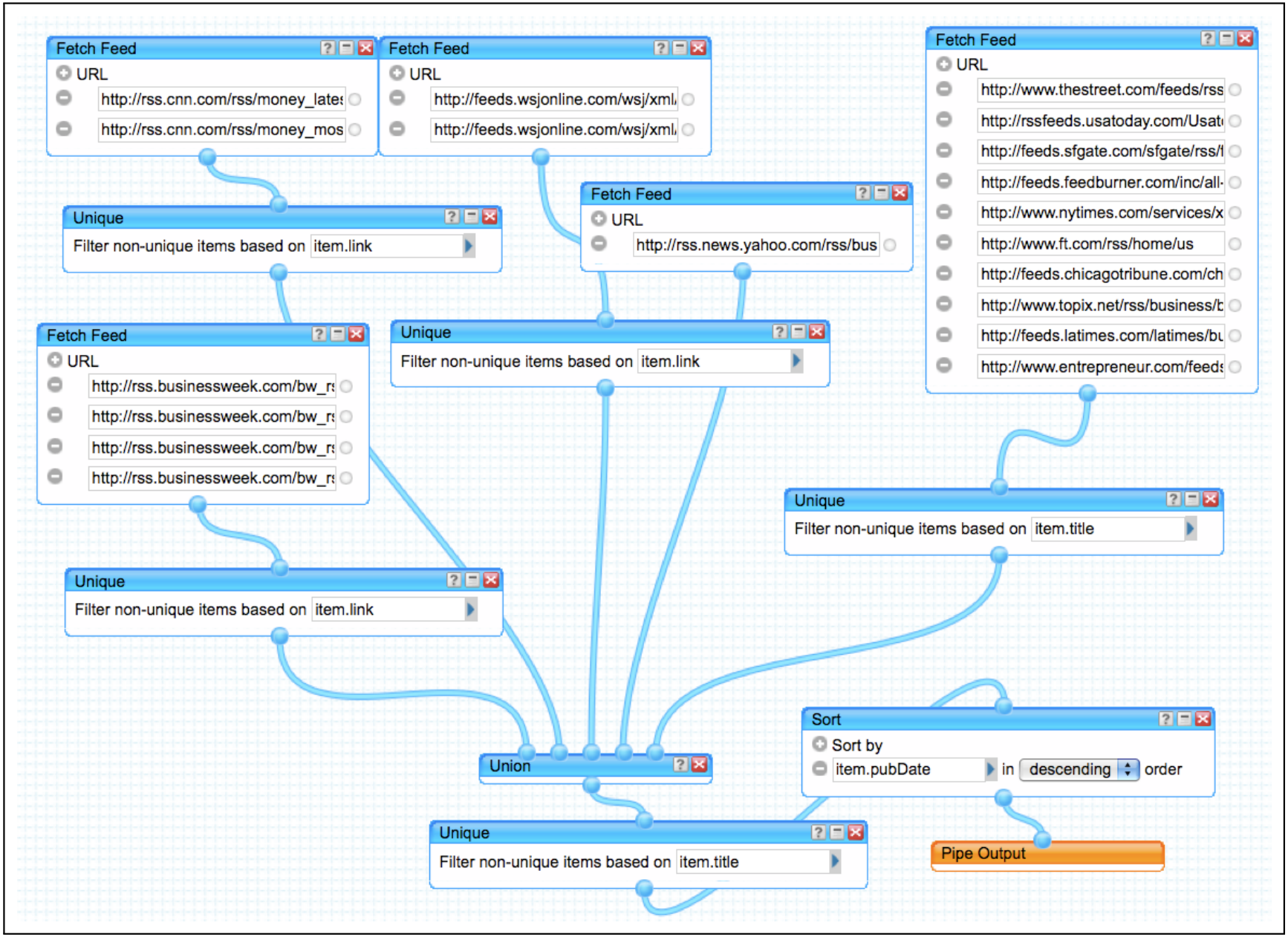

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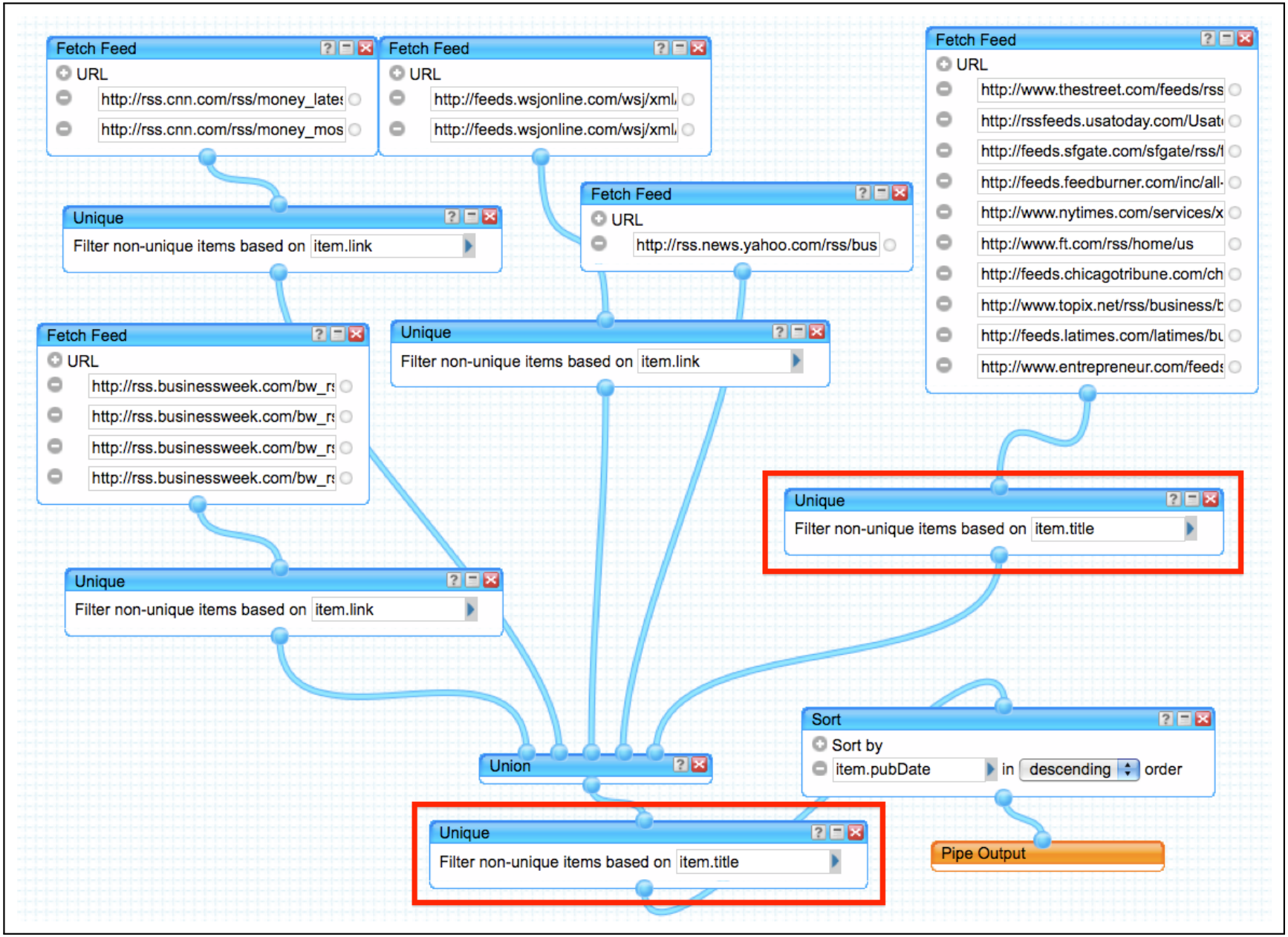

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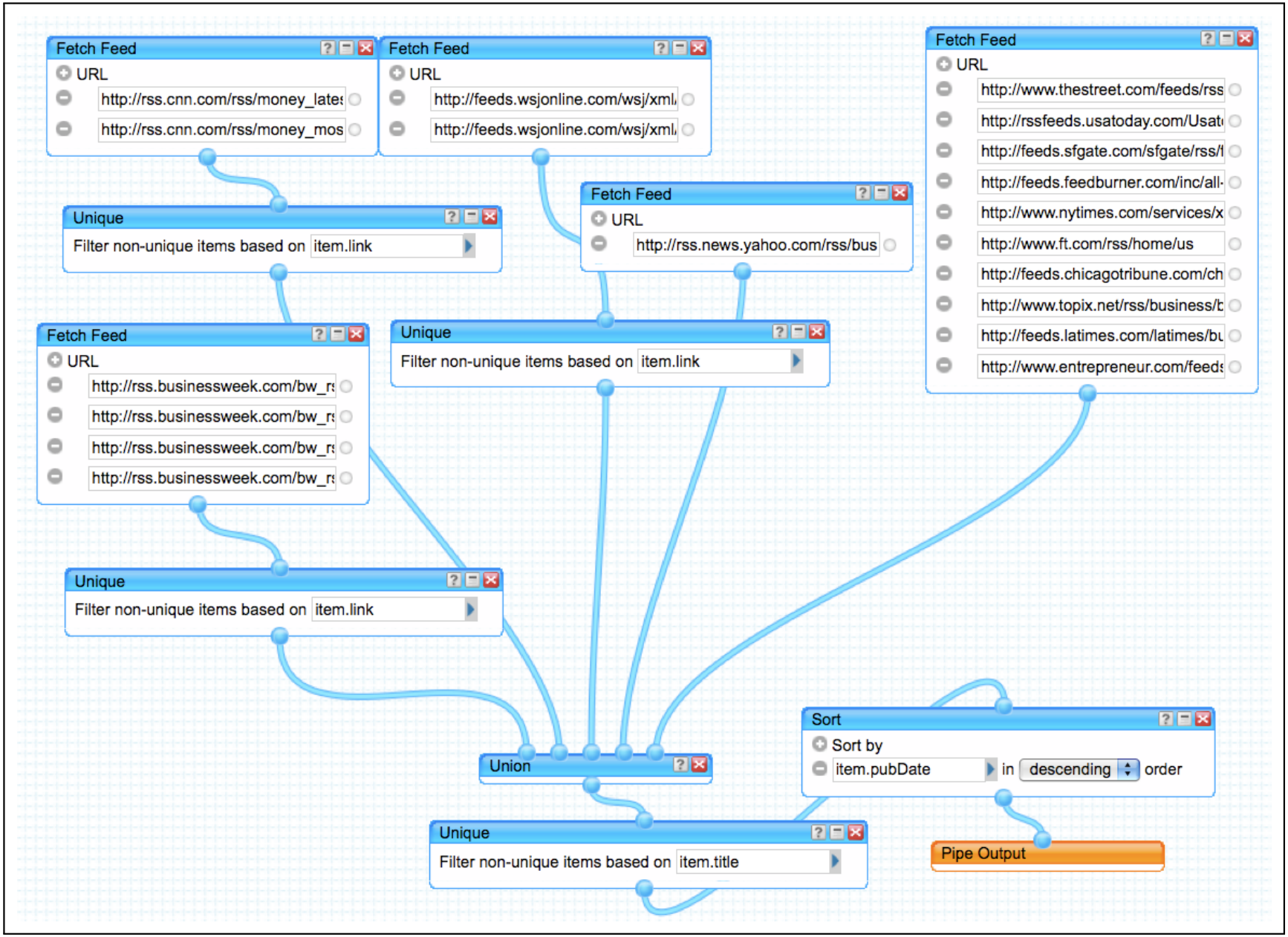

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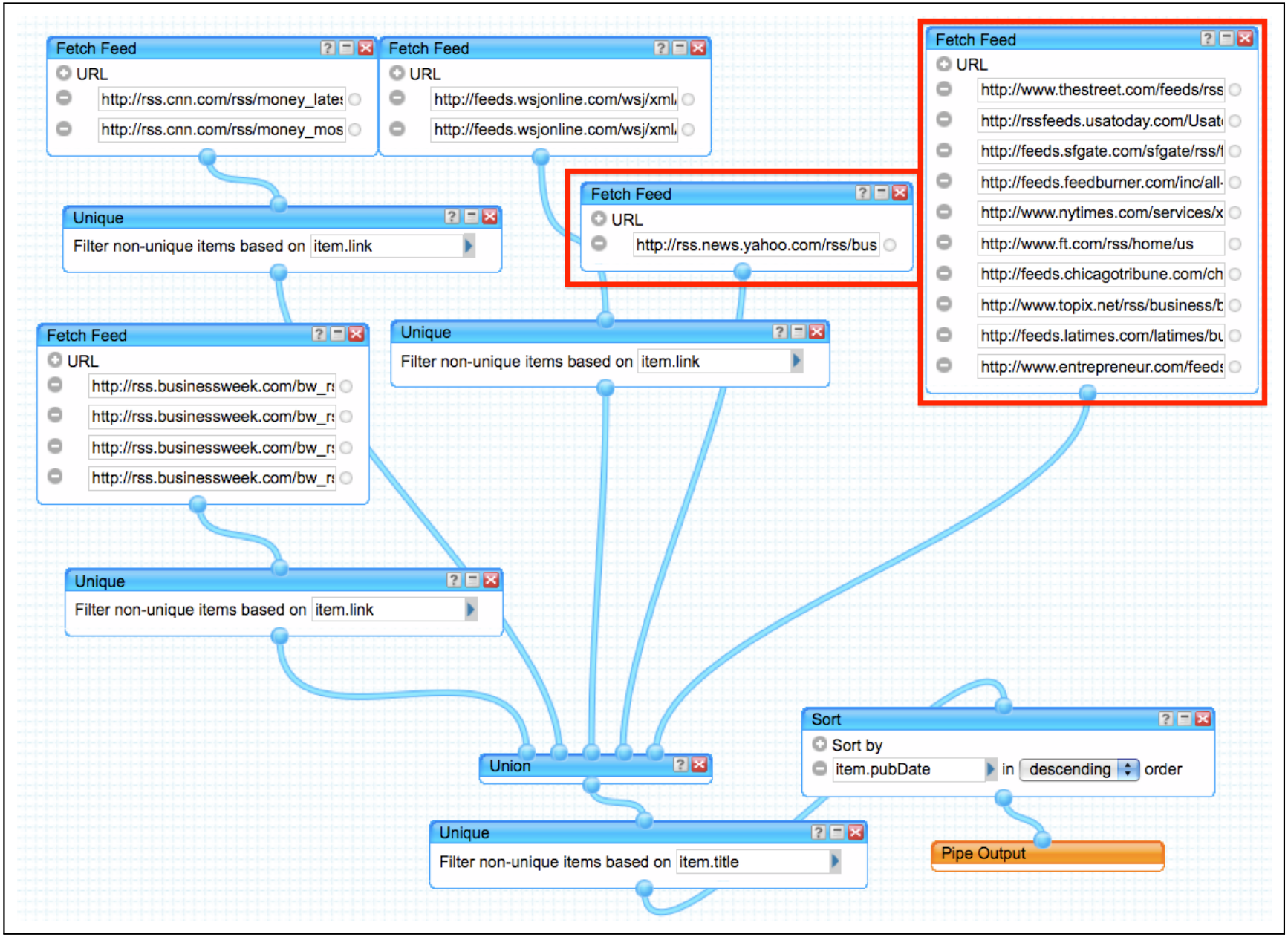

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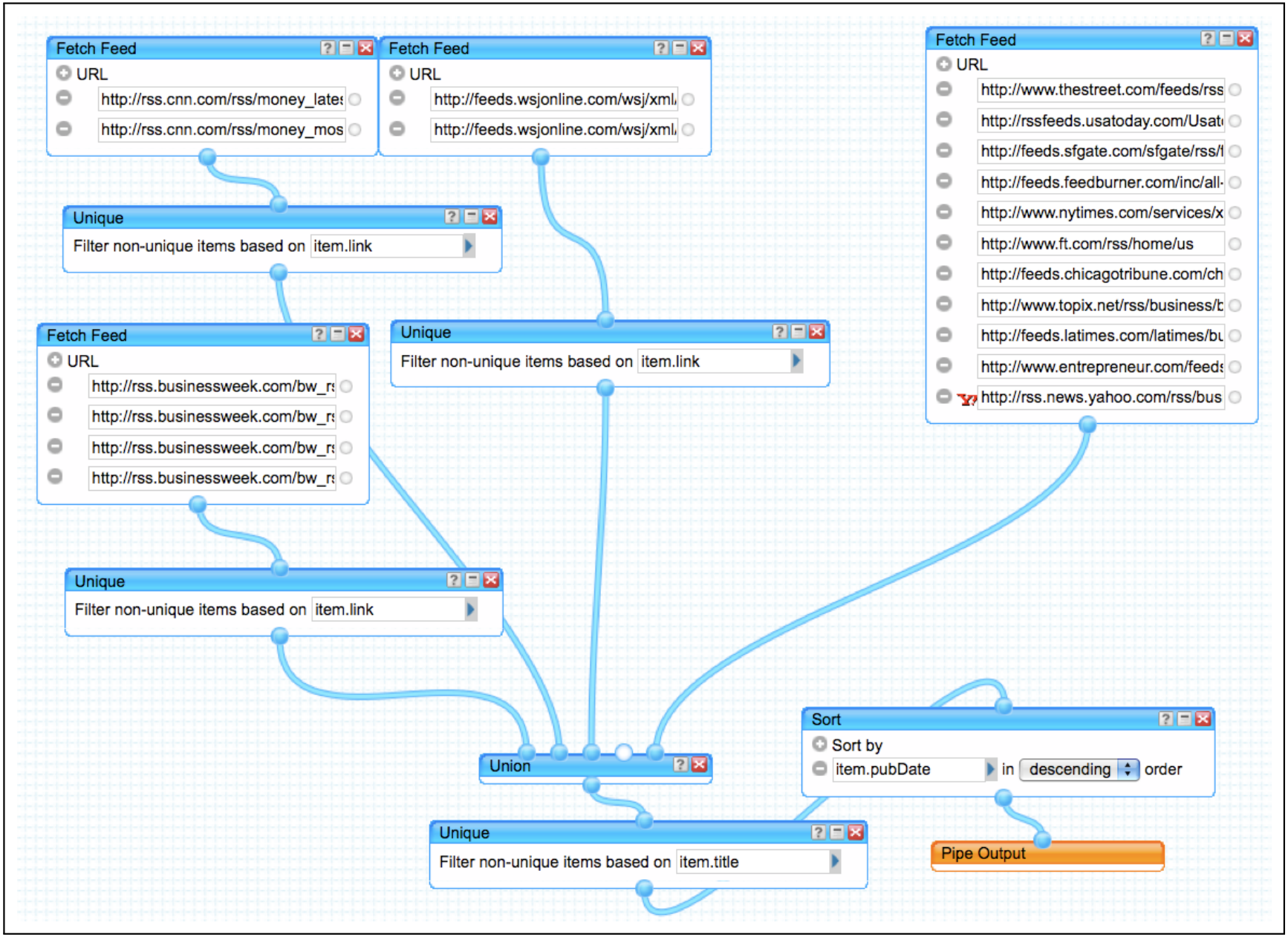

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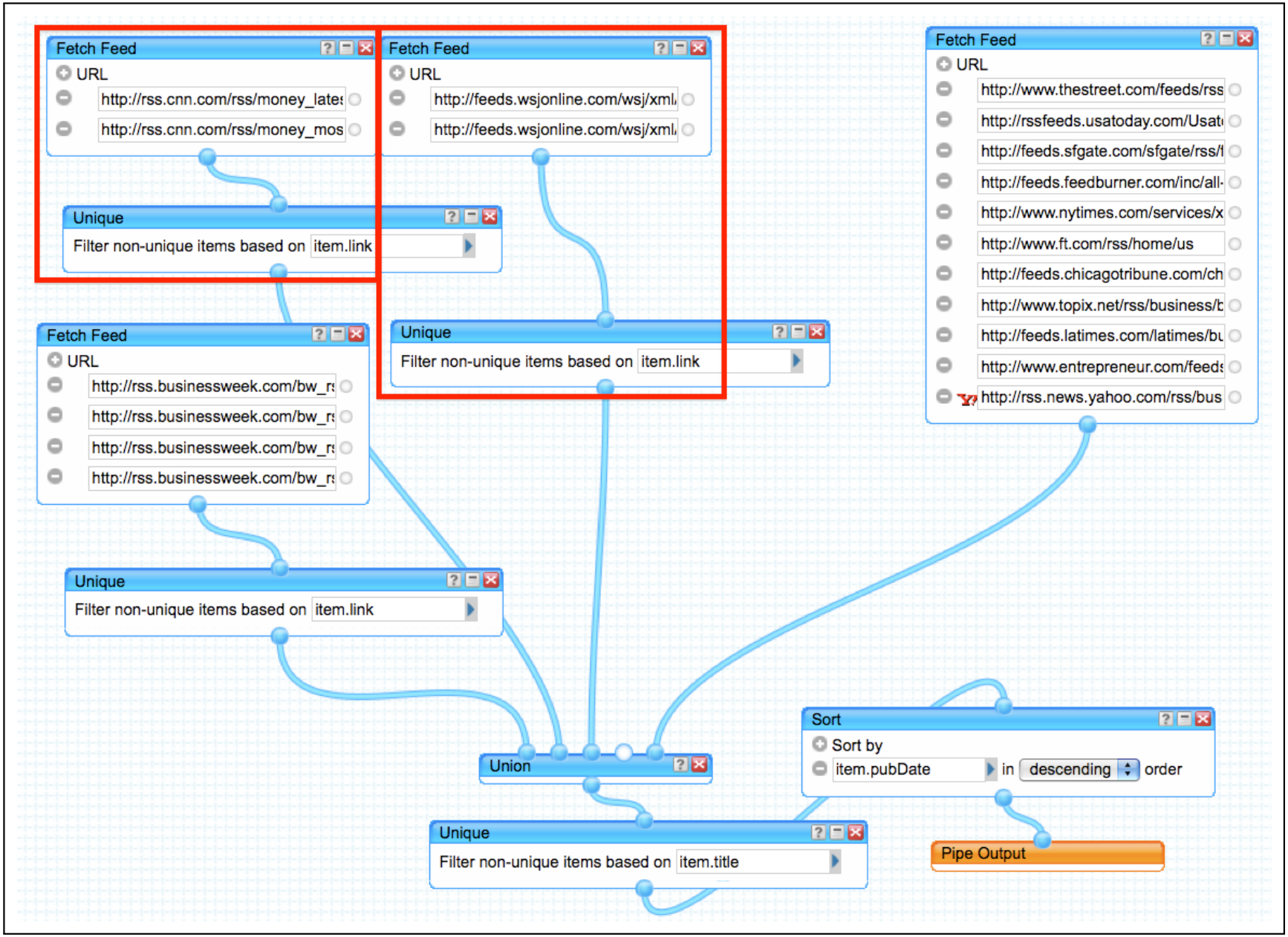

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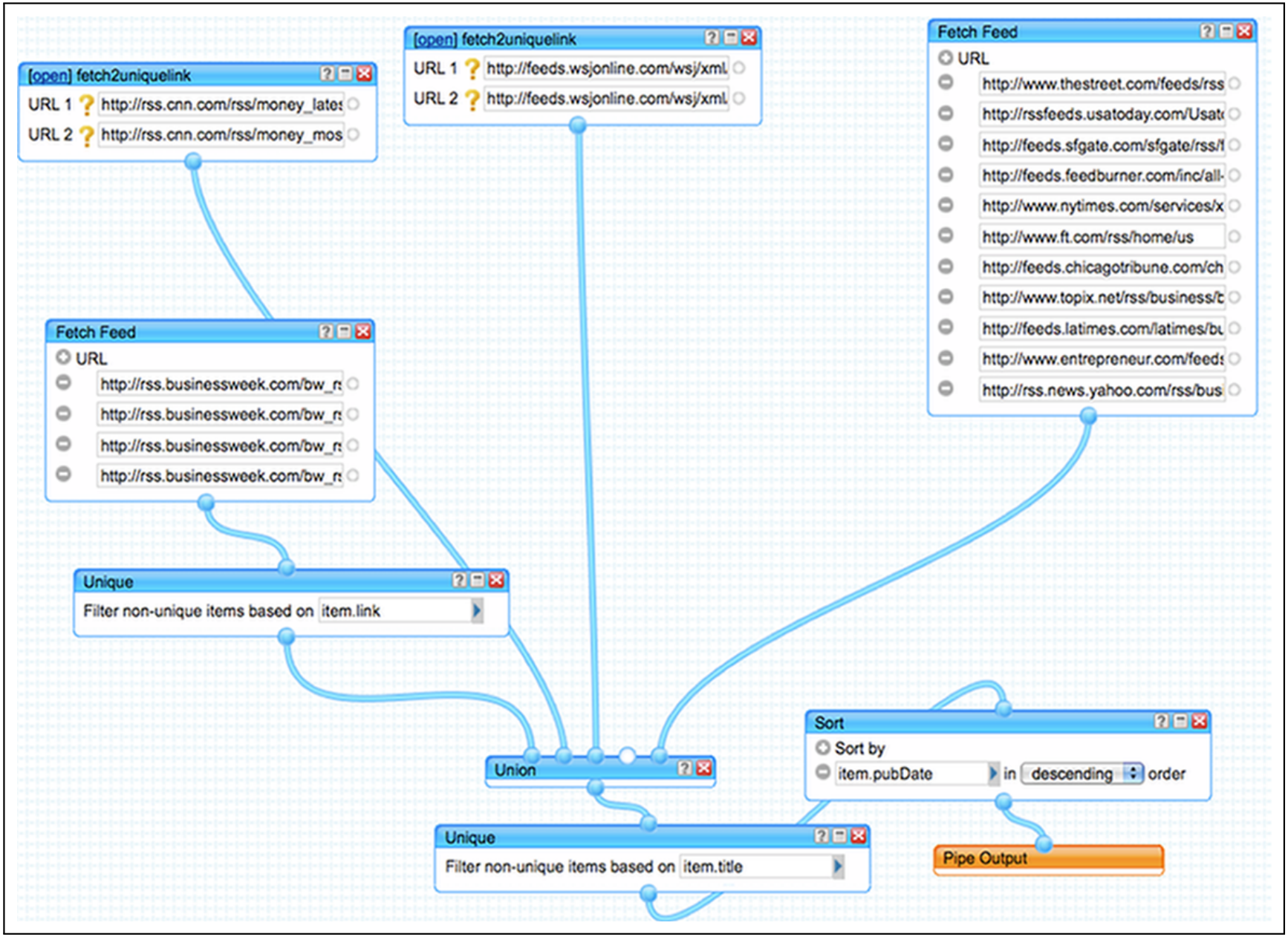

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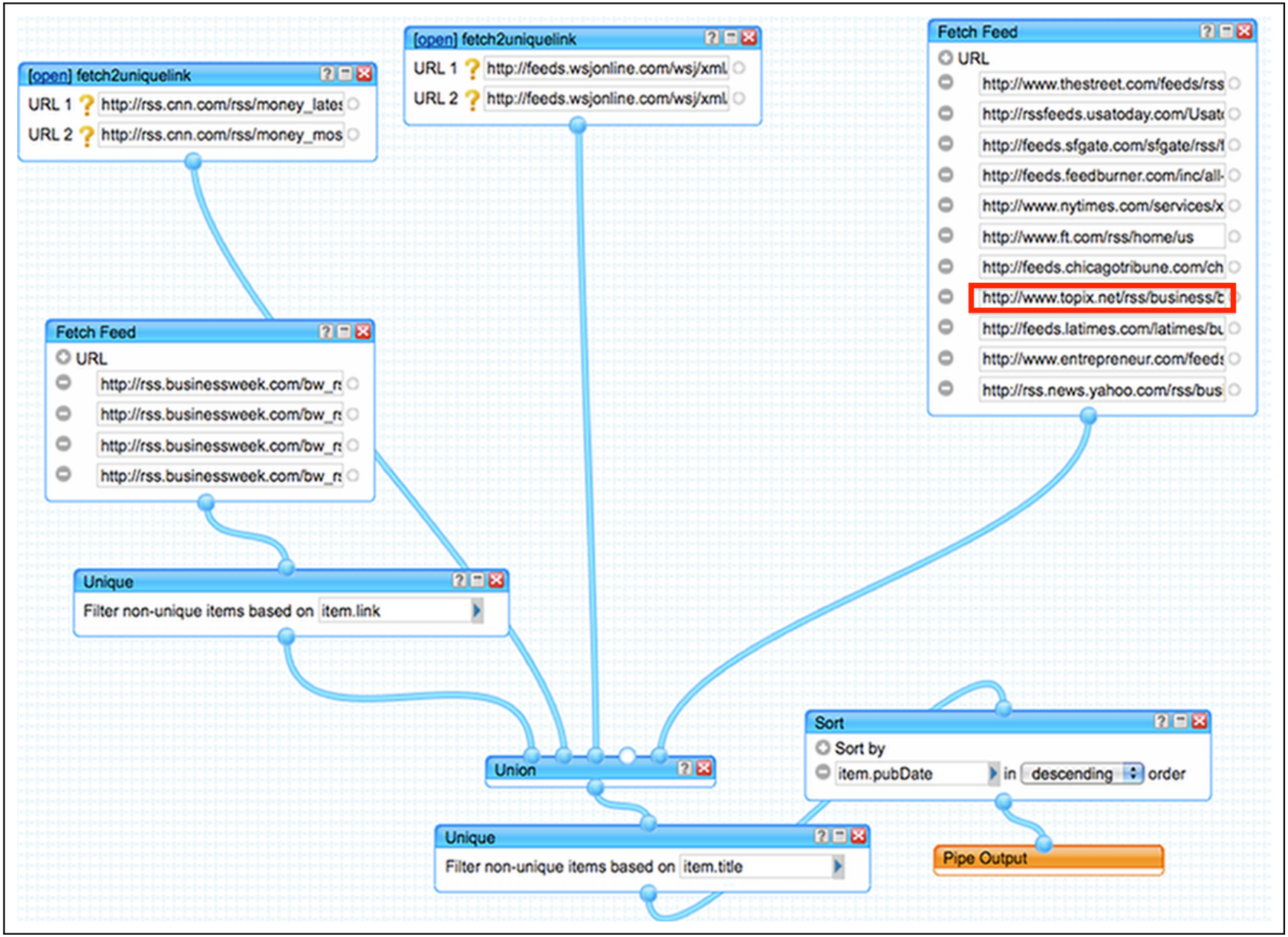

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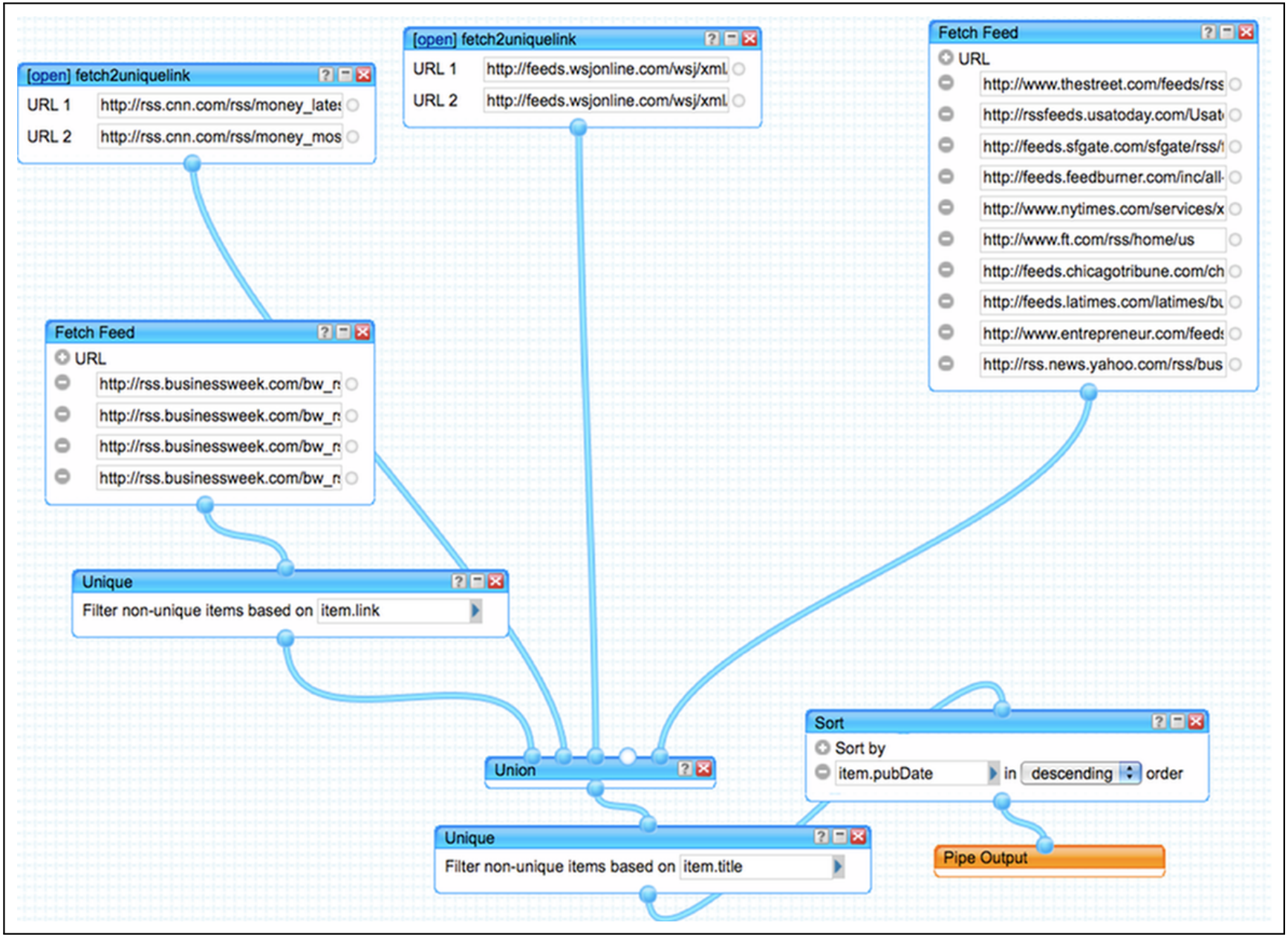
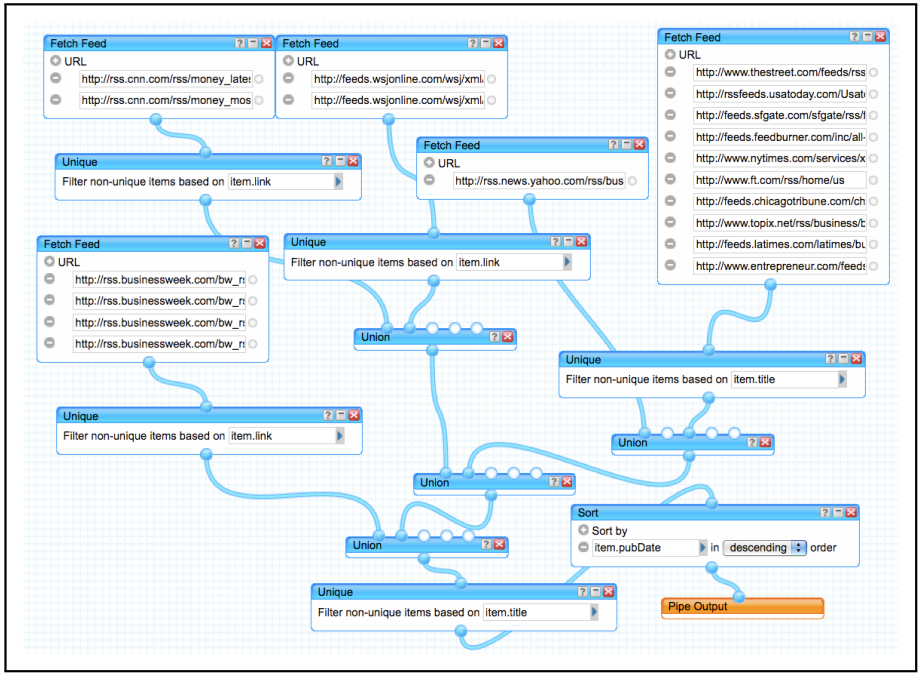


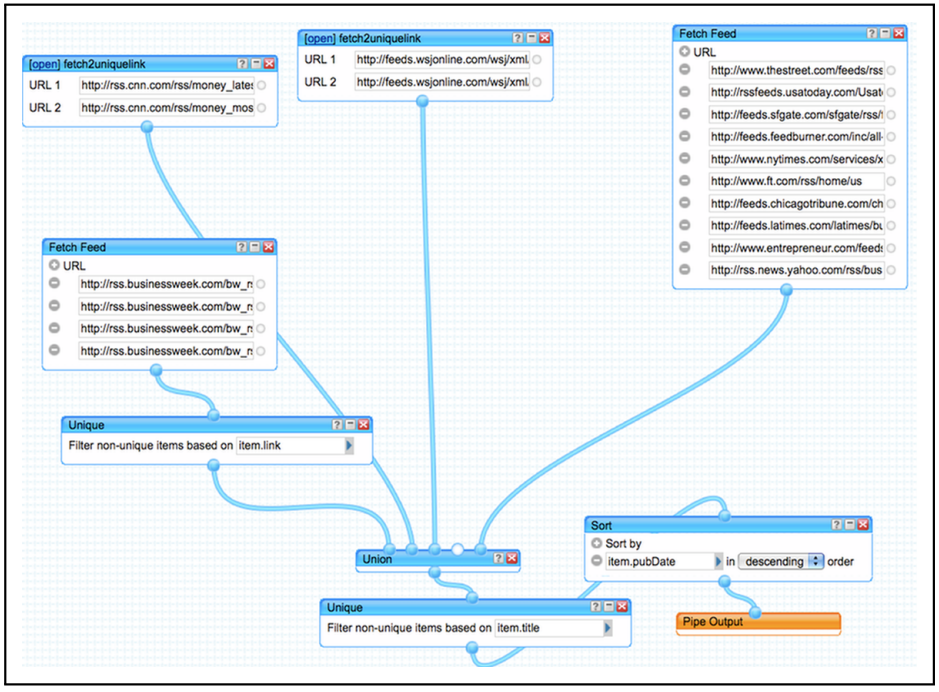
Motivating Example: Before and After

Before



- Redundant structures
- Broken data sources

After



- Less complex
- All valid sources

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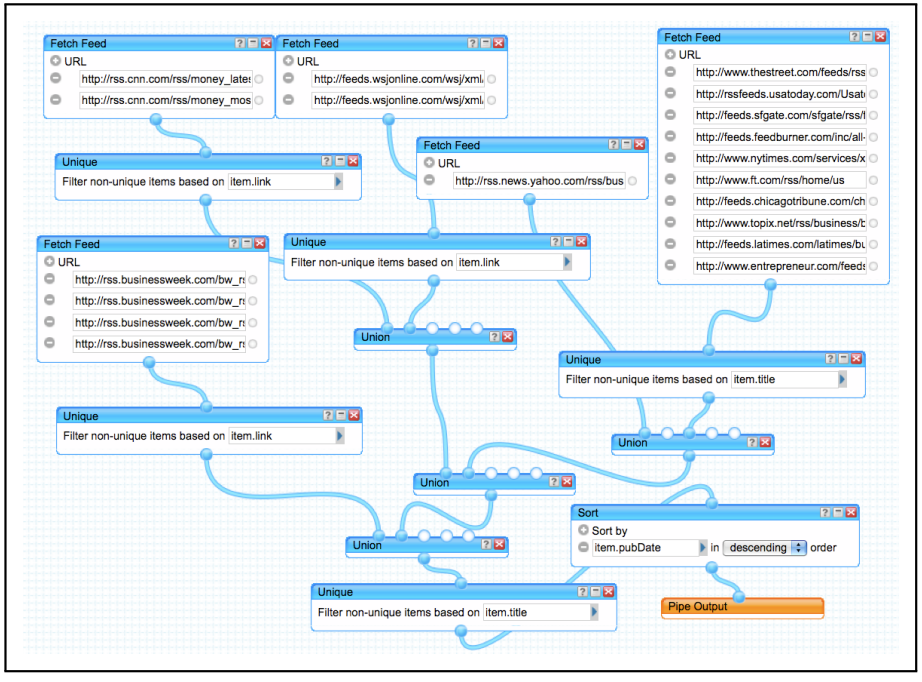

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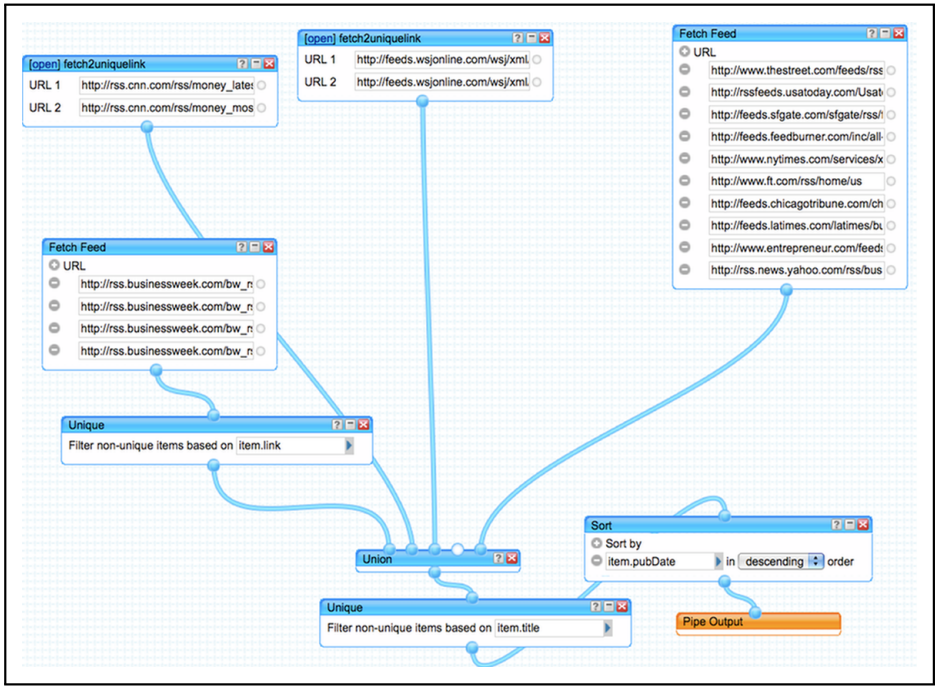

- Less complex
- All valid sources

Issue: Deficiencies are propagated through reuse

- Out of 8,000+ pipes, 66% had been reused
- 810 pipes (10%) had been reused *and* reference invalid sources

Definitions

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Code Smell

Program characteristics that identify deficiencies in code

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Refactoring

A semantic preserving transformation on a program

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We seek to better support end user programmers by applying the software engineering concepts of code smells and refactorings to web mashups.

Smells in Mashups

Smell Type	**Smells**
Laziness	Noisy Module Unnecessary Module Unnecessary Abstraction
Redundancy	Duplicate Strings Duplicate Modules Isomorphic Paths
Environmental	Deprecated Module Invalid Source
Population-Based	Non-Conforming Ordering Global Isomorphic Paths

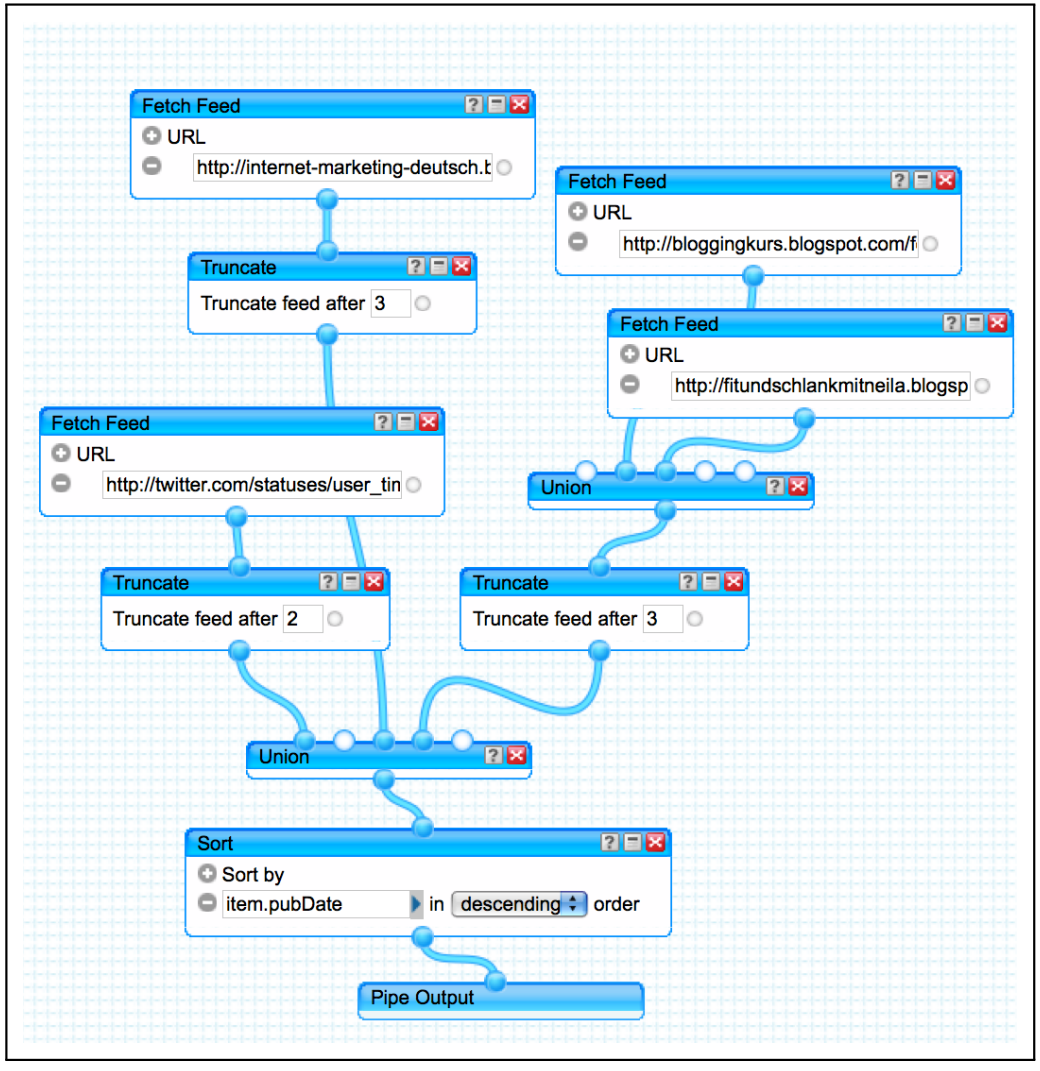
Redundancy: Duplicate Modules

Joined Generators

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

Why is this Smelly?

Module redundancies add unnecessary complexity



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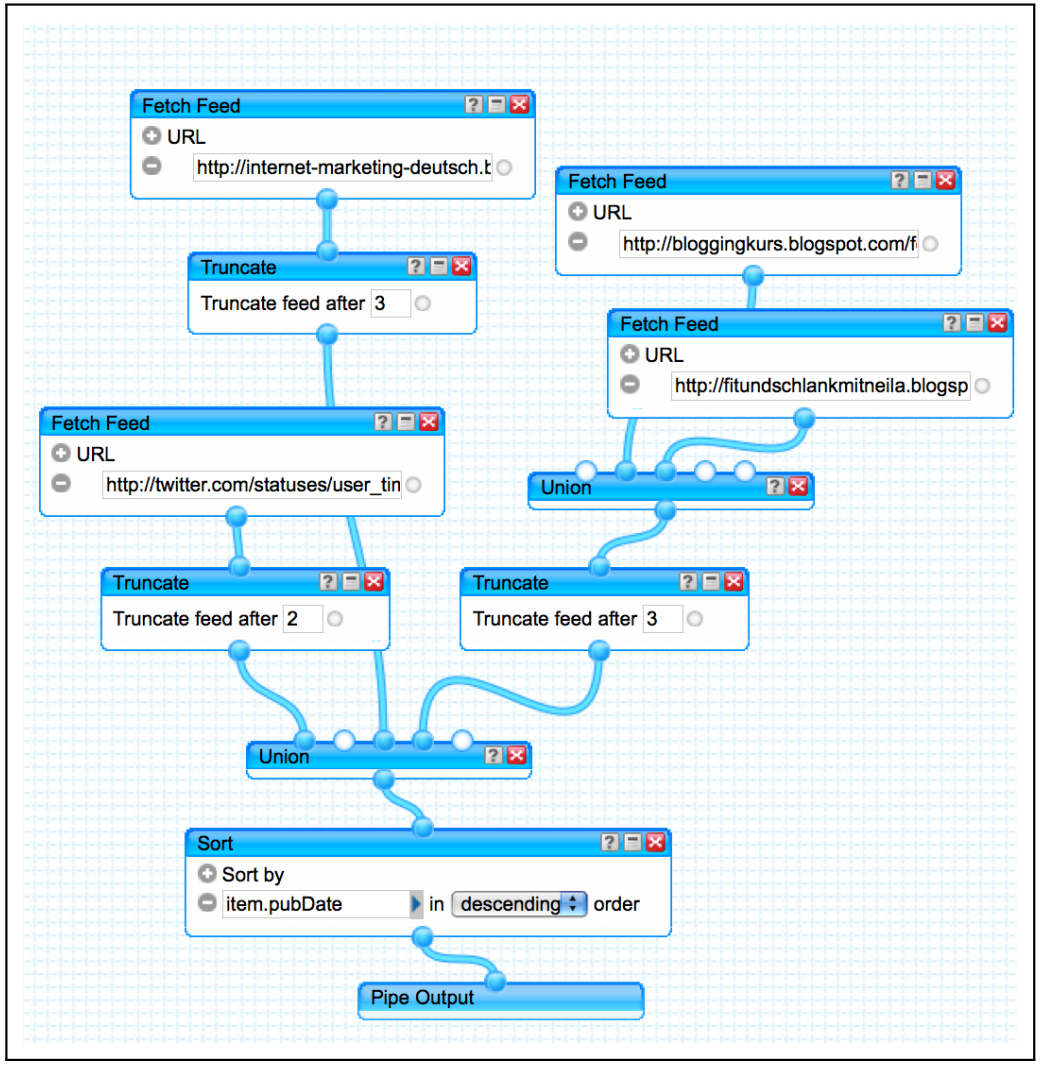
$$\exists m, n \in \mathcal{M} \mid m \neq n \wedge$$
$$m.name = n.name \wedge$$
$$gen(m) \wedge gen(n) \wedge$$
$$connected\_to\_union(m, n)$$



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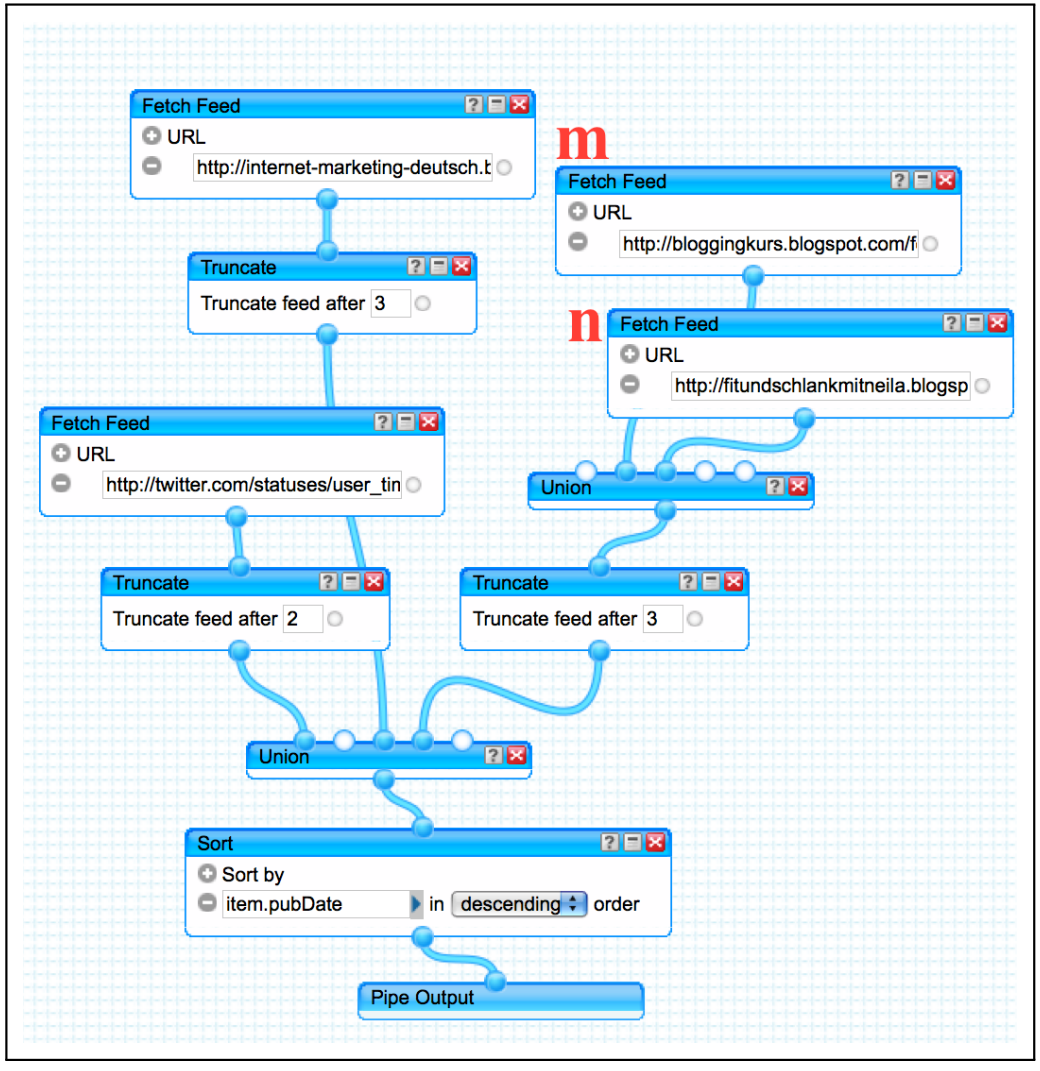

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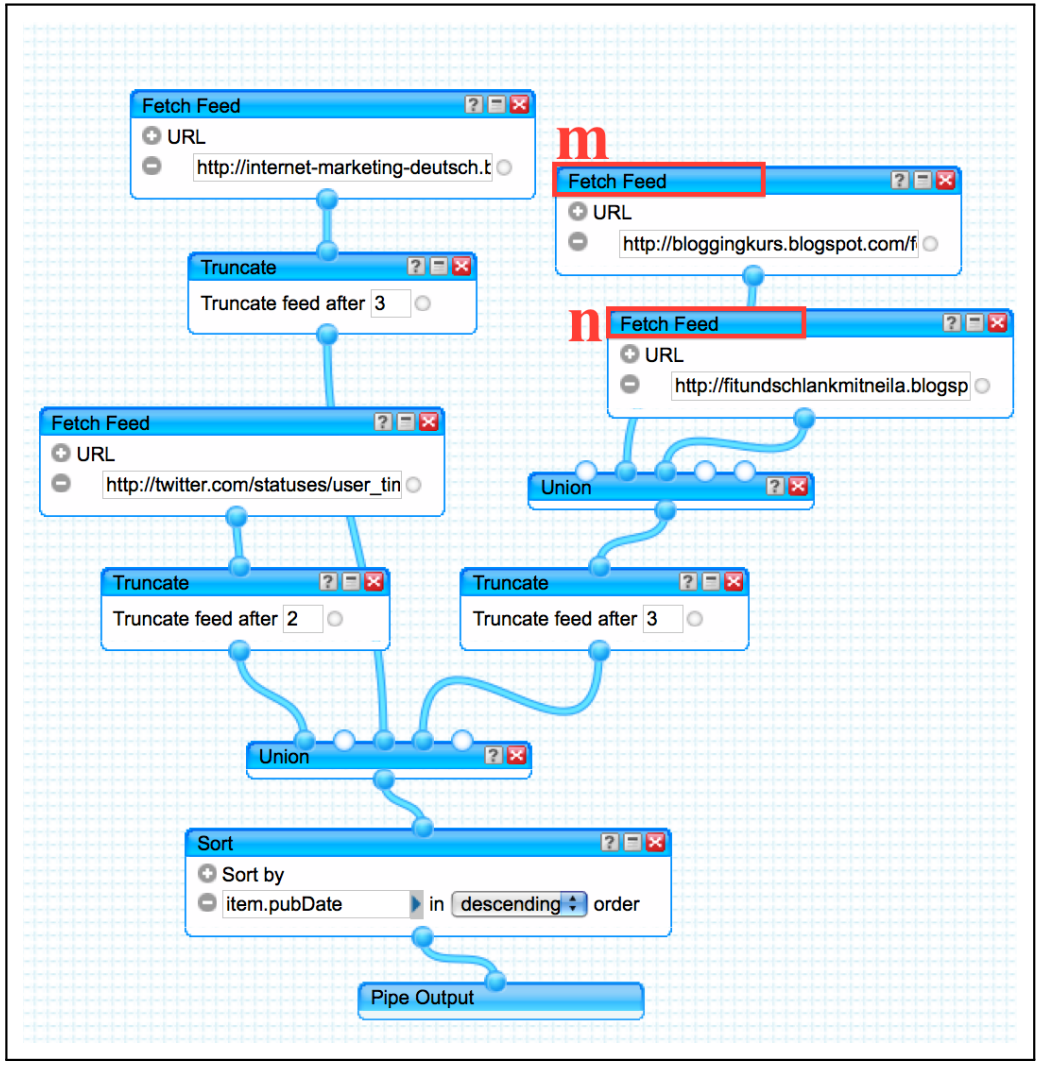

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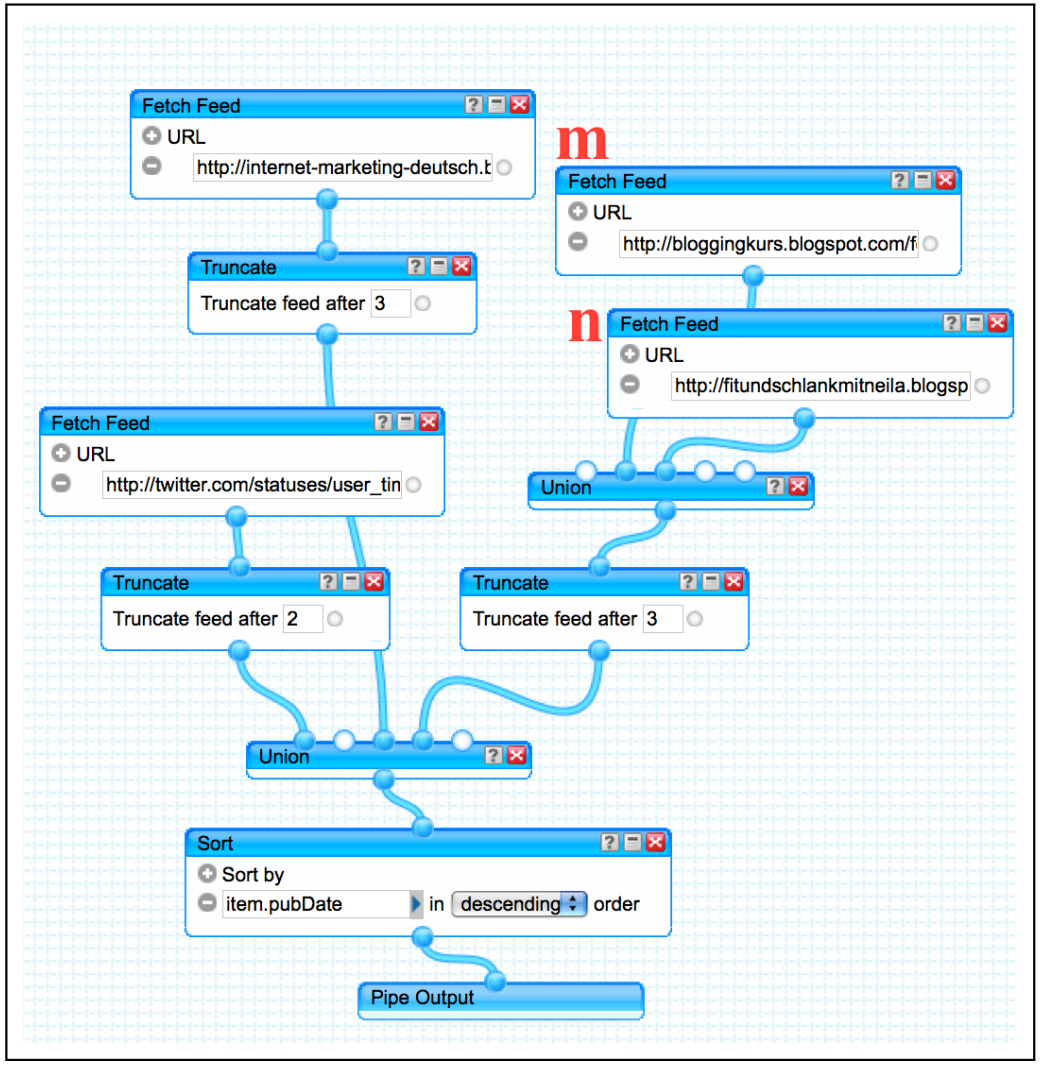

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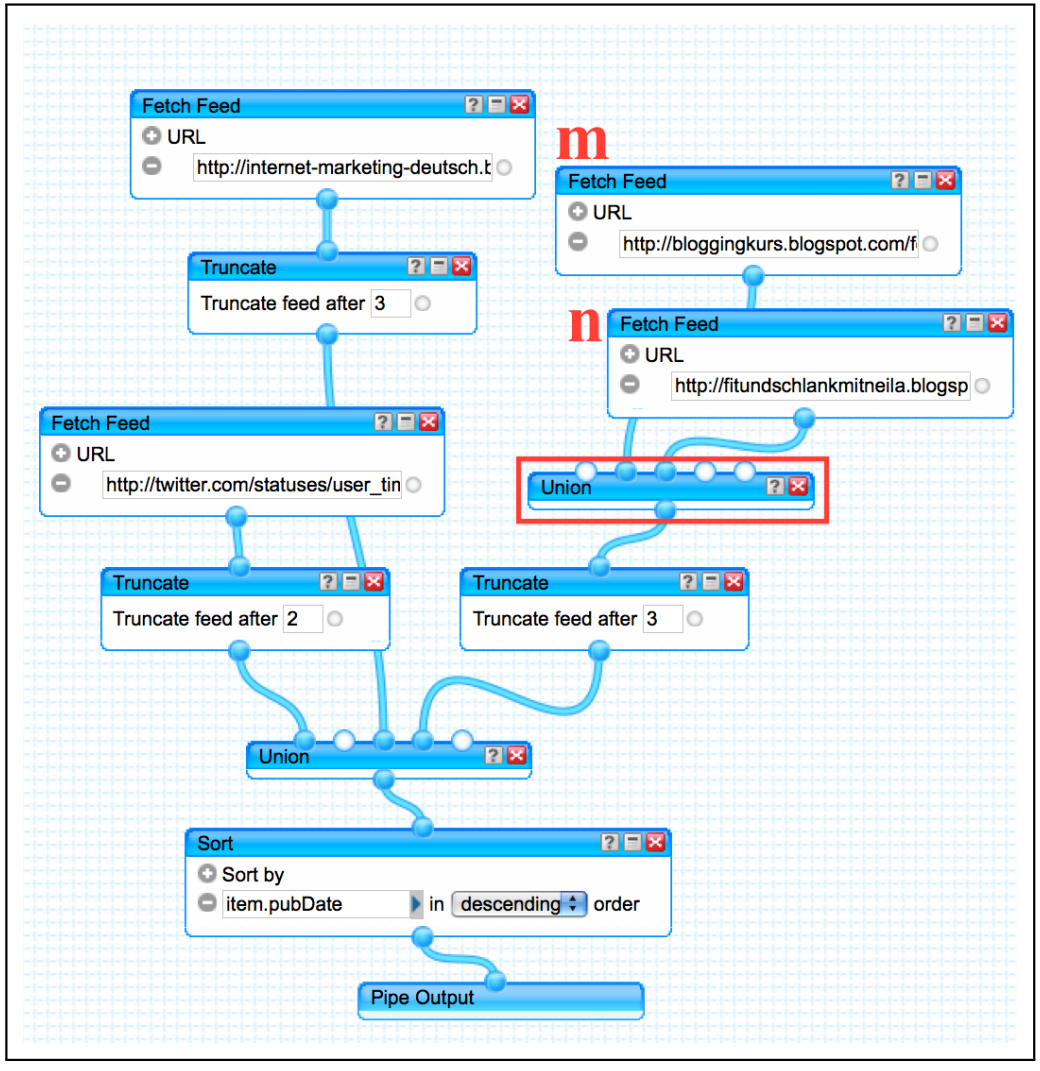

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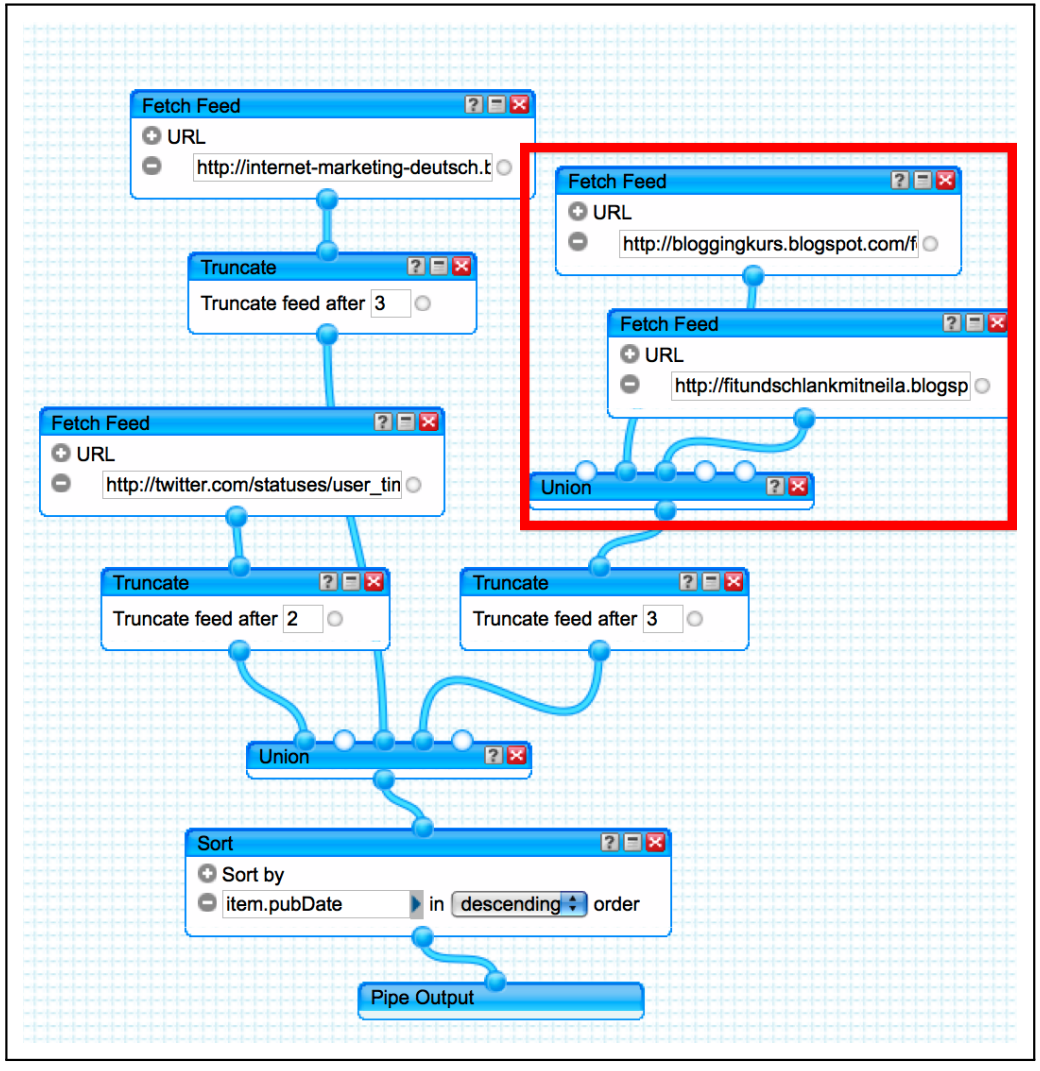

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A constant string that is used in at least *n* wireable fields in at least two modules.

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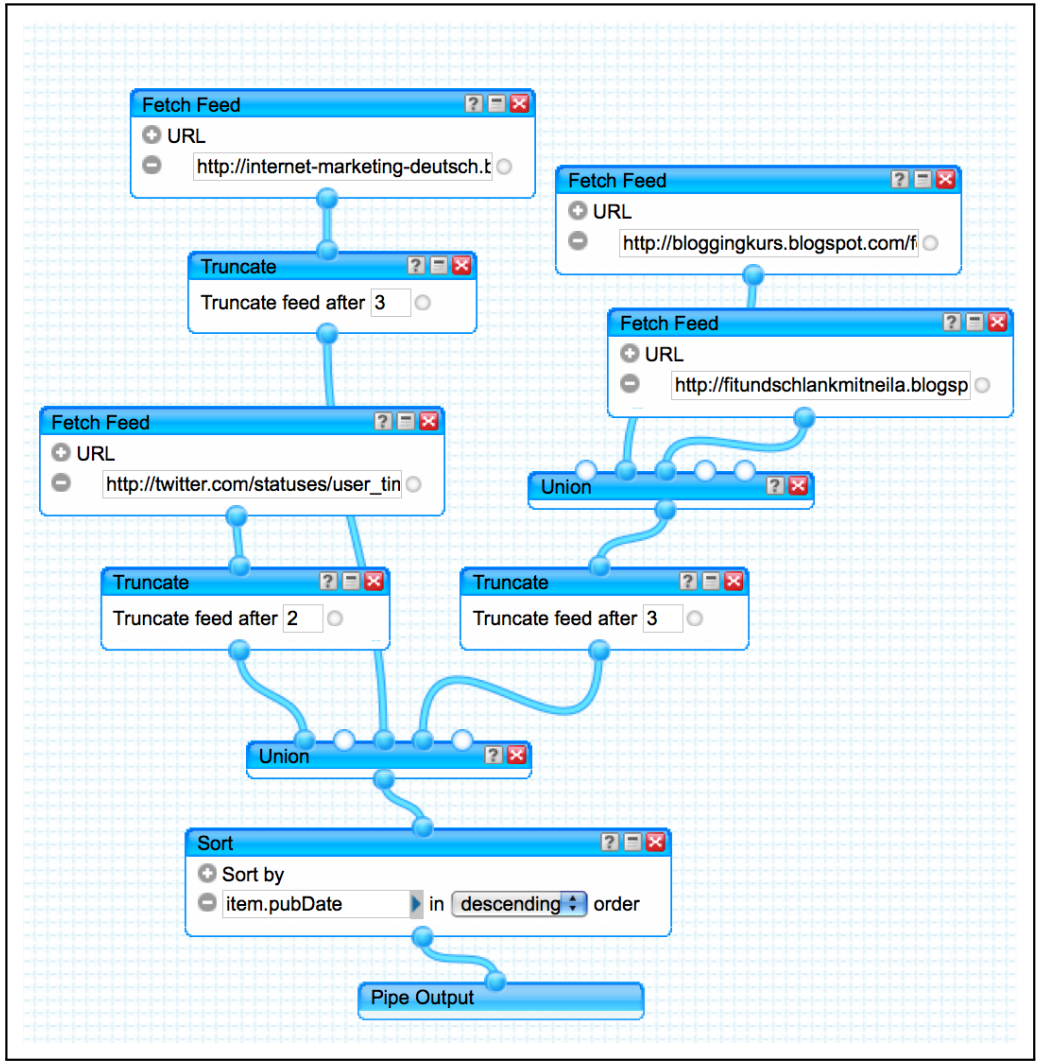
Missed opportunity for abstraction



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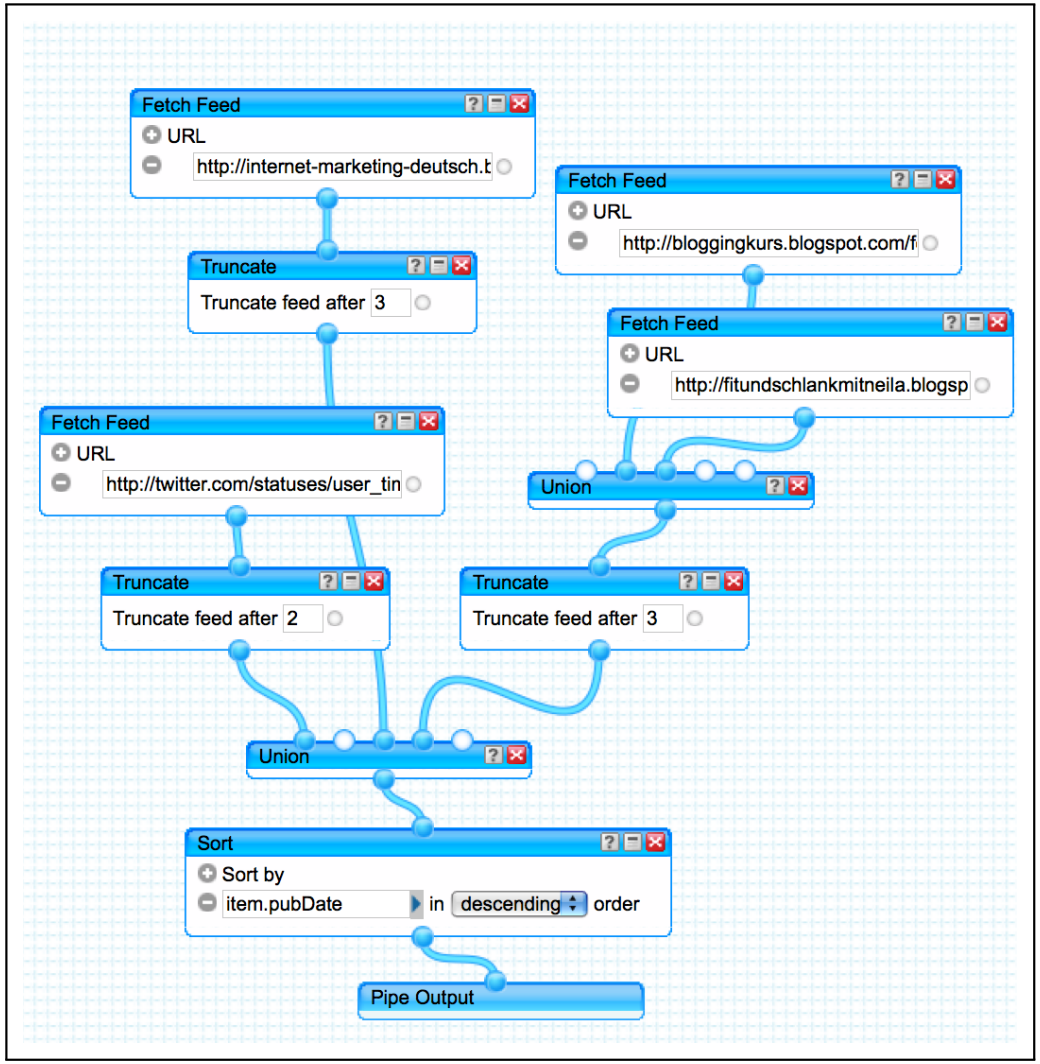

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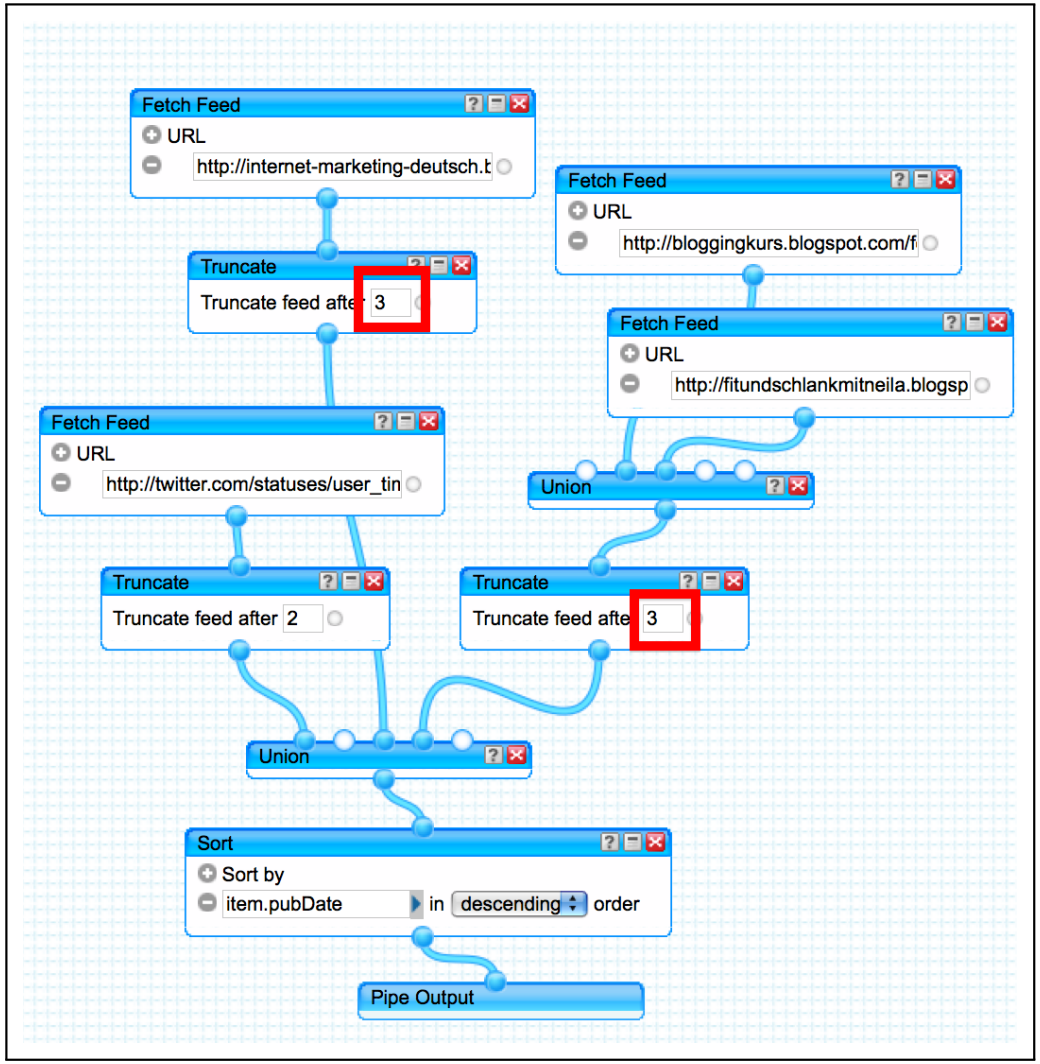

Population-Based: Global Isomorphic Paths

Global Isomorphic Path

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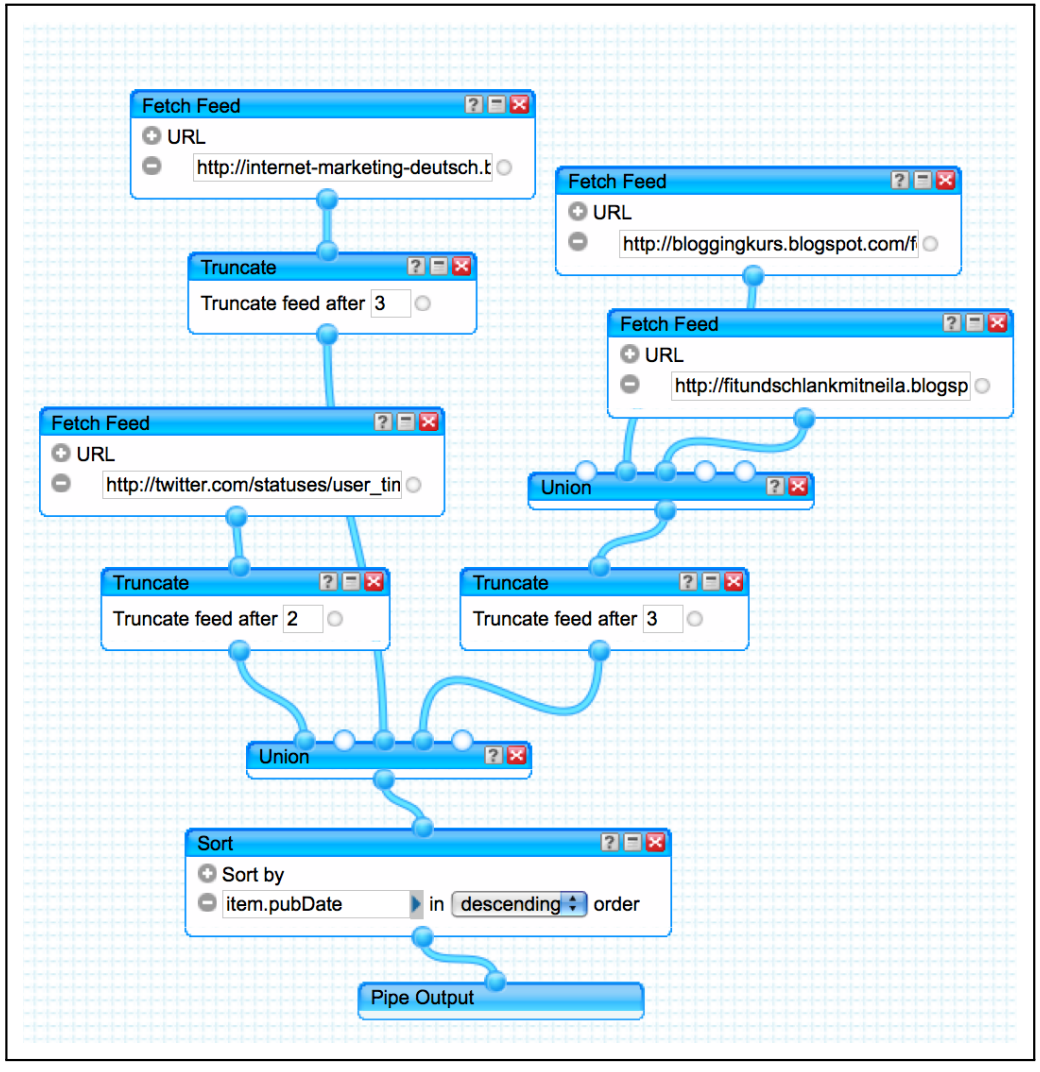
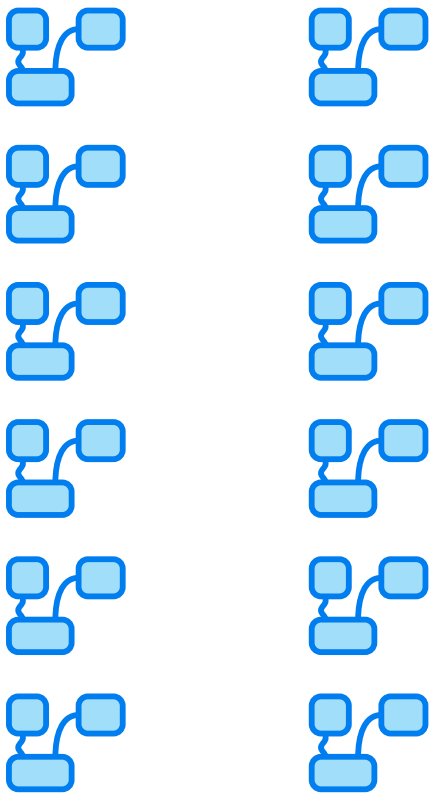


Population-Based Refactorings

Pipes Population



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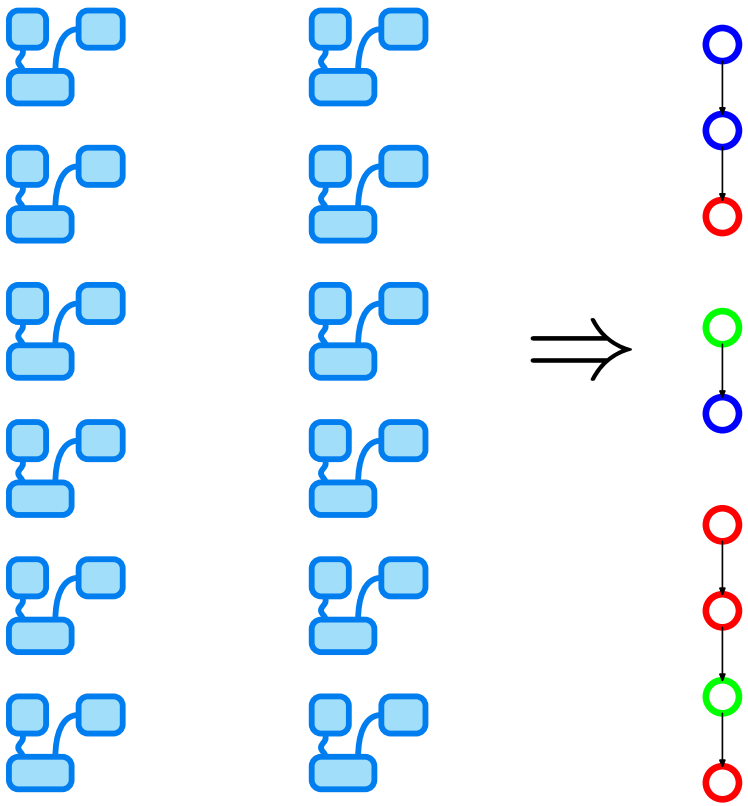

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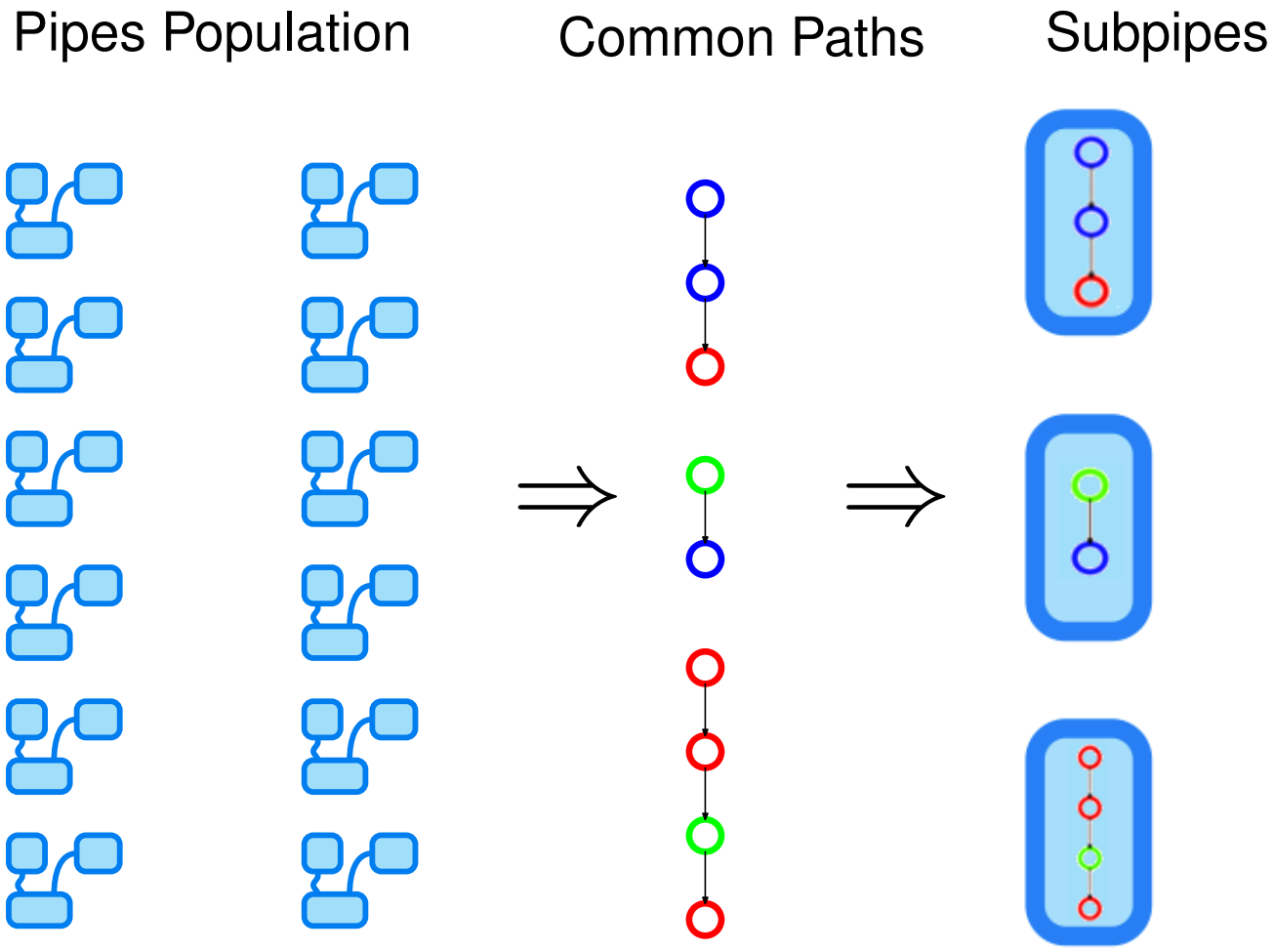

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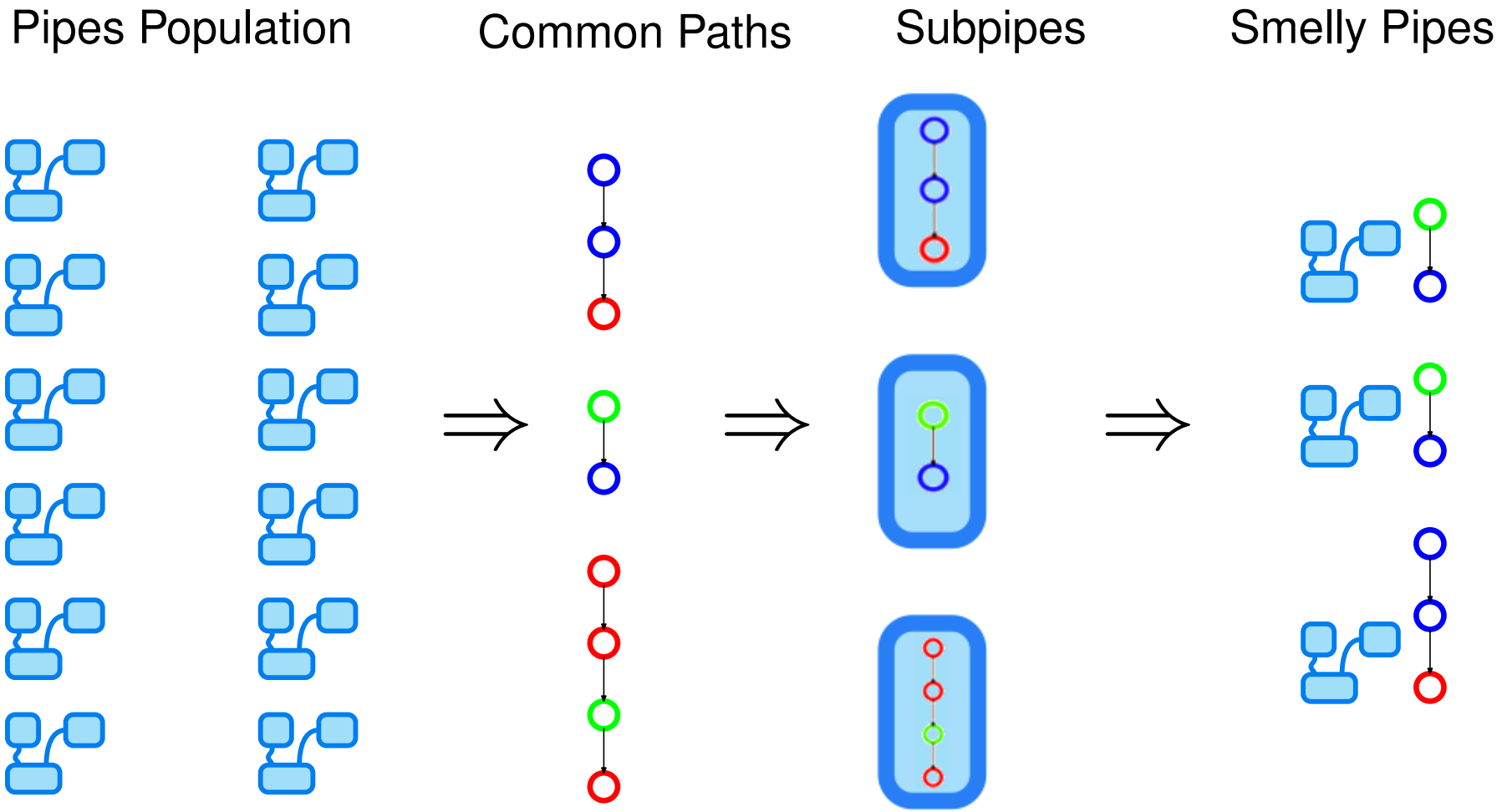

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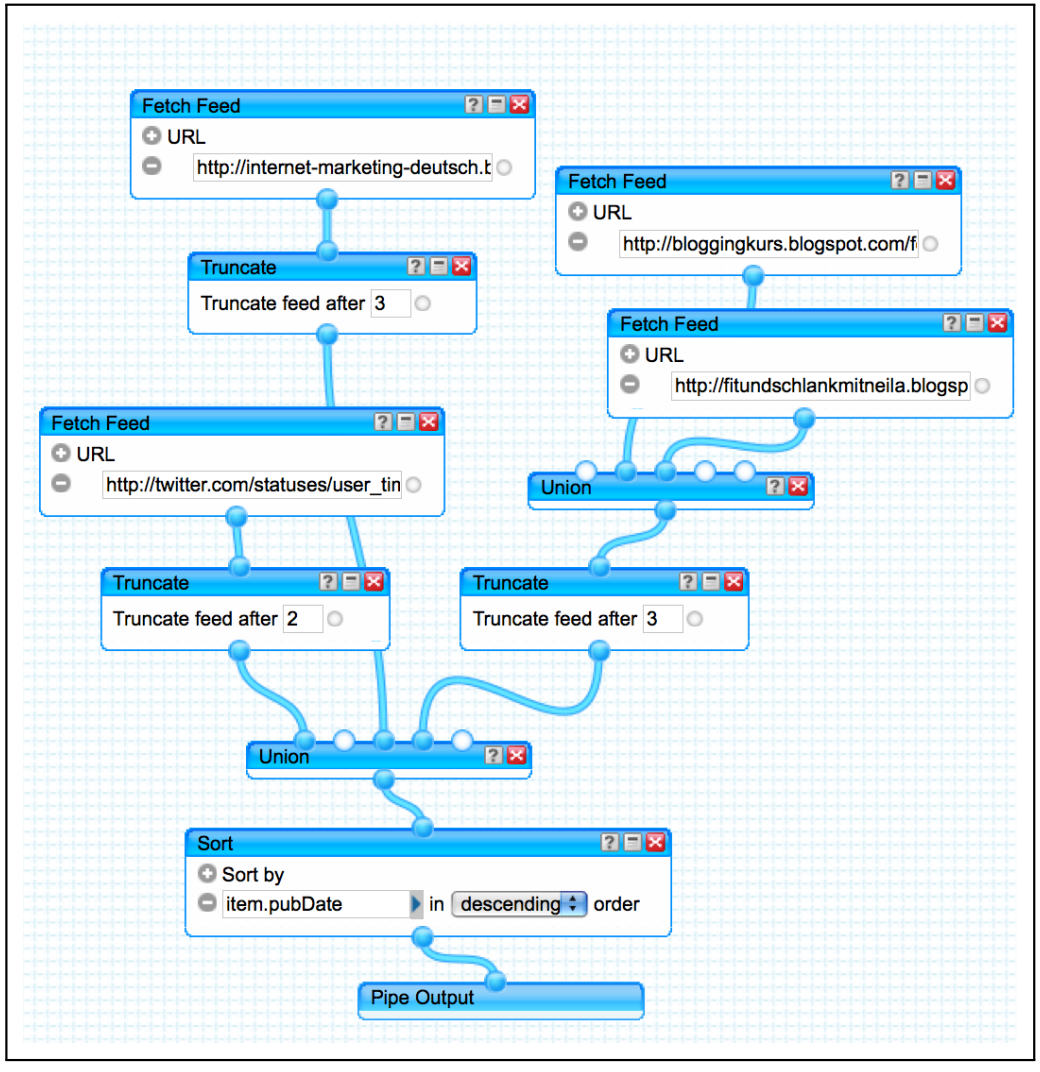

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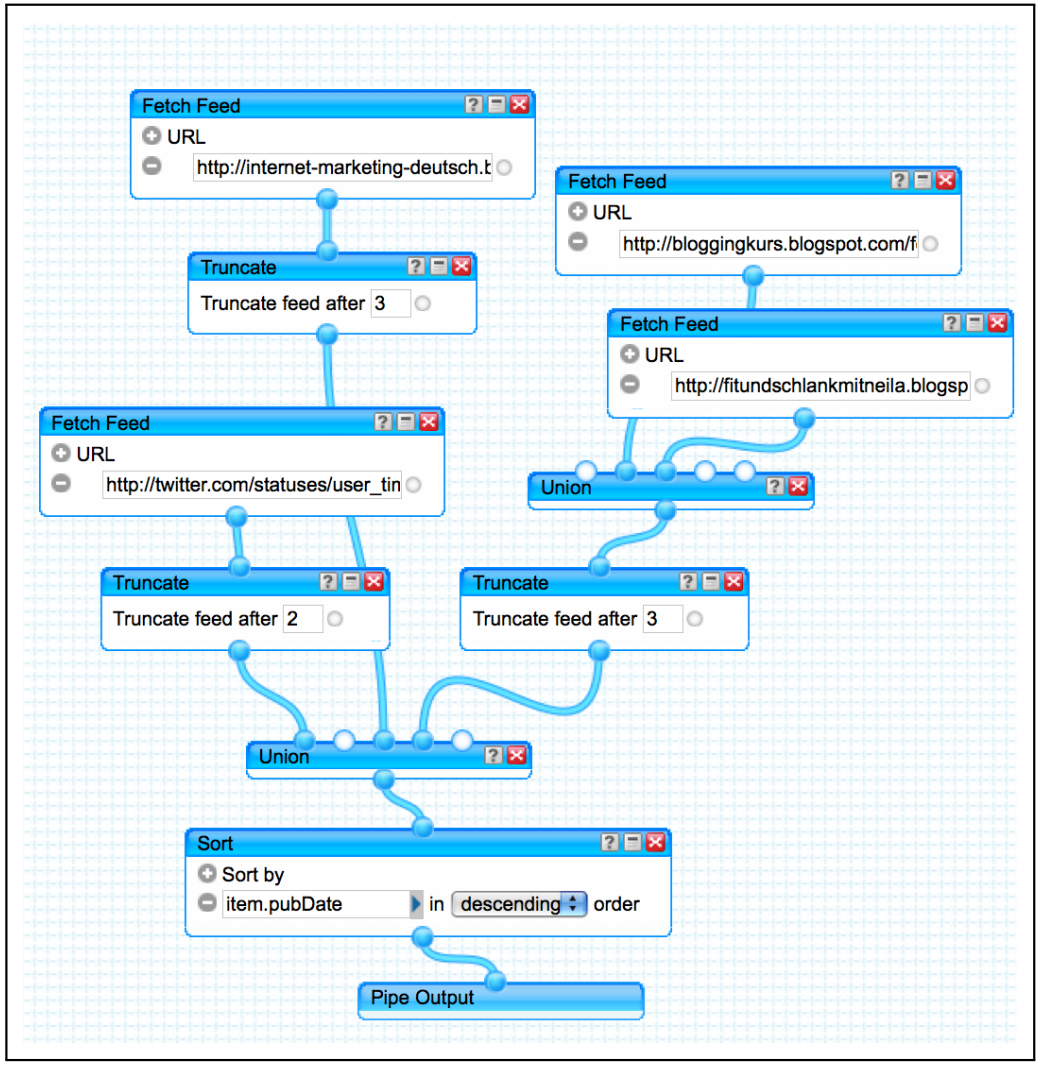

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End User Study

Research Question I

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

Research Question II

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

End User Study

Empirical Study with 14 participants

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

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Yes: 63% No: 24% Same: 13%. (8 tasks)

Research Question II

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Empirical Study with 14 participants

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

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Research Question II

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

Correct: 80% vs. 67% on Non-smelly vs. Smelly pipes (2 tasks)

Refactorings for Pipes

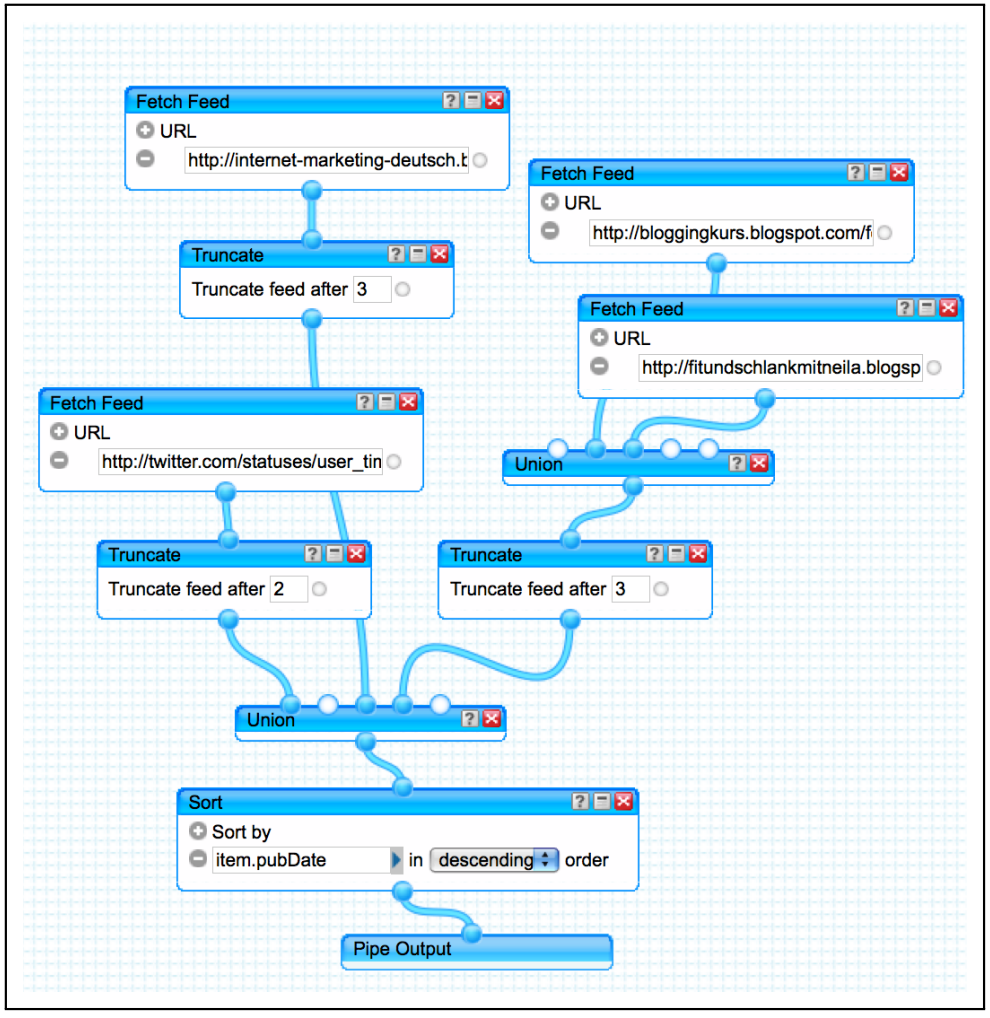
Targeted Smells	Refactoring Type	Refactoring
Laziness	**Reductions**	Clean Up Module Remove Non-Contributing Module Push Down Abstraction
Redundancy	**Consolidations**	Merge Redundant Modules Collapse Duplicate Paths
	Abstractions	Pull Up Module Extract Local Subpipe
Environmental	**Deprecations**	Replace Deprecated Modules Remove Invalid Sources
Population-Based	**Population-Based**	Normalize Operations Extract Global Subpipe

Consolidation: Collapse Duplicate Paths

Collapse Duplicate Paths

Consolidate paths that are aggregated using the same module

Before



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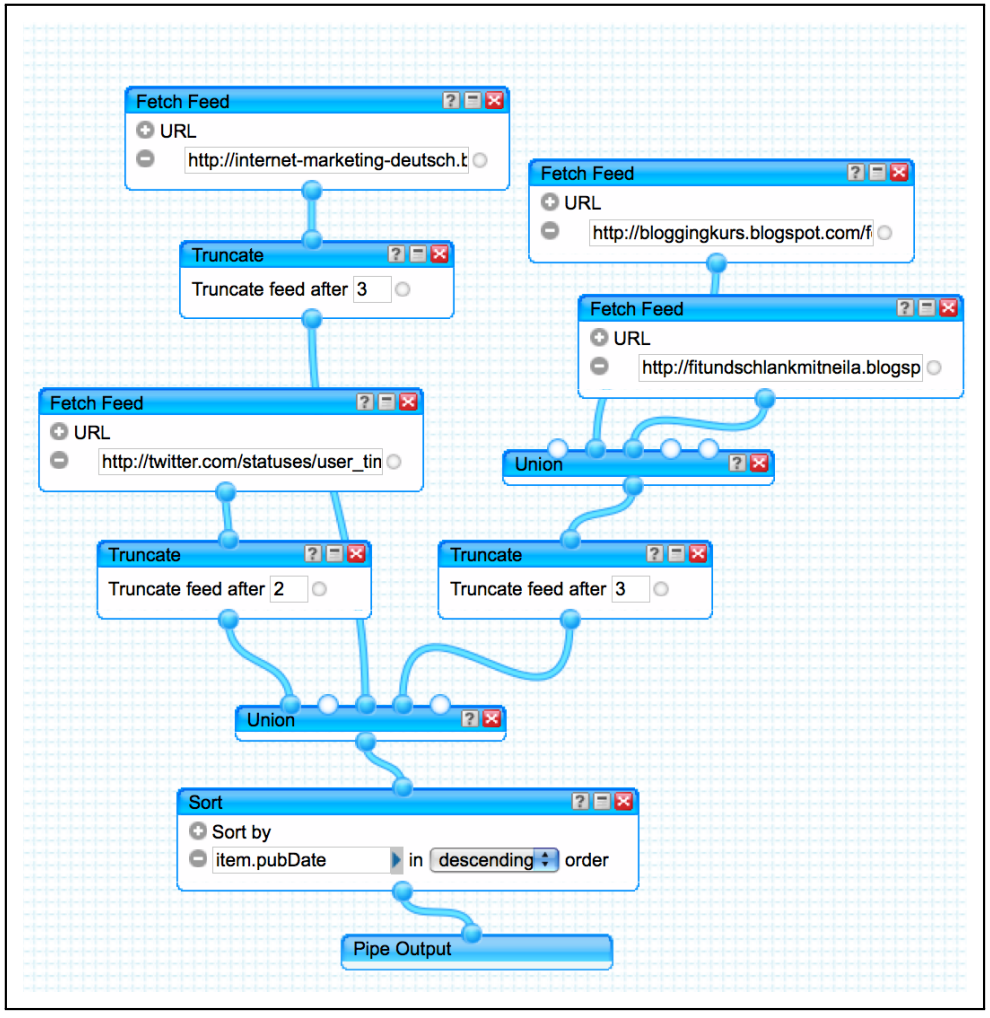
Consolidate paths that are aggregated using the same module

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
	remove n
P_{after}	$n, w \notin Pipe$
	$m'.\mathcal{F} = n.\mathcal{F} \cup m.\mathcal{F}$

Before



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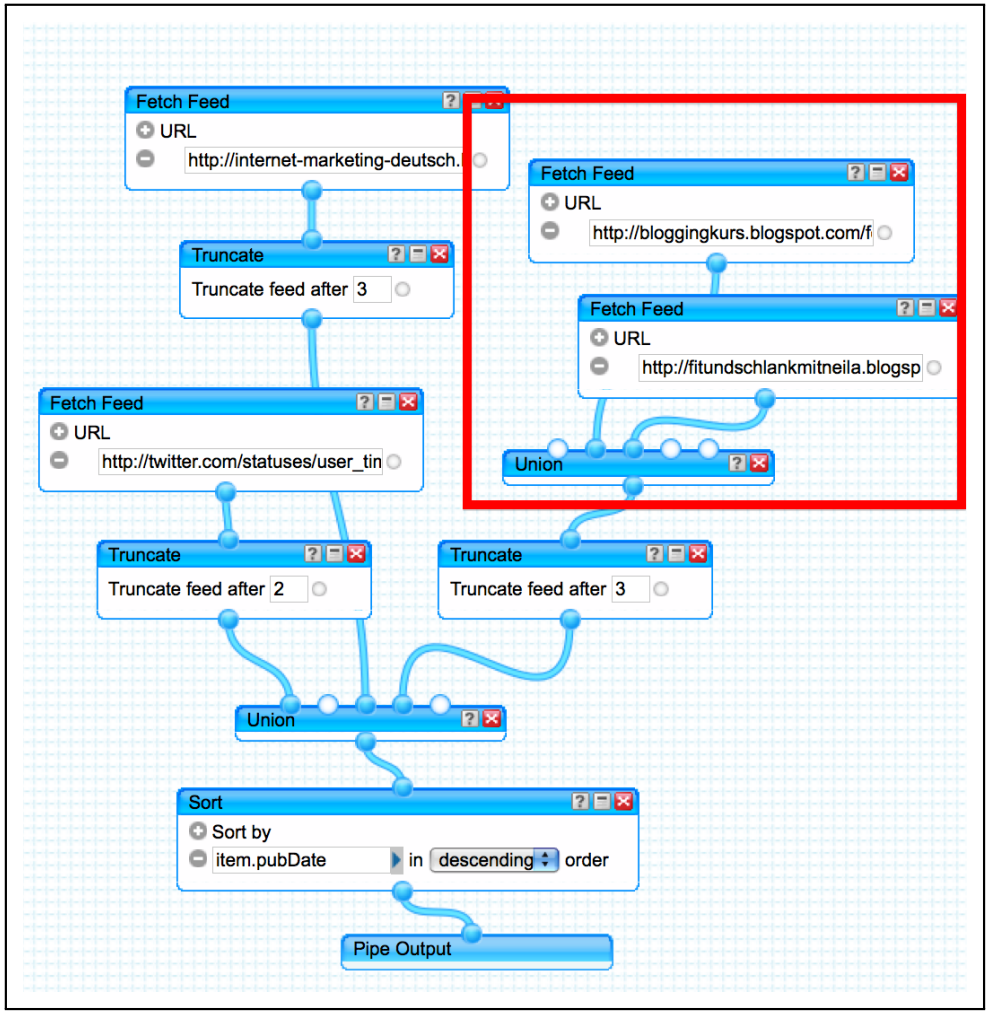

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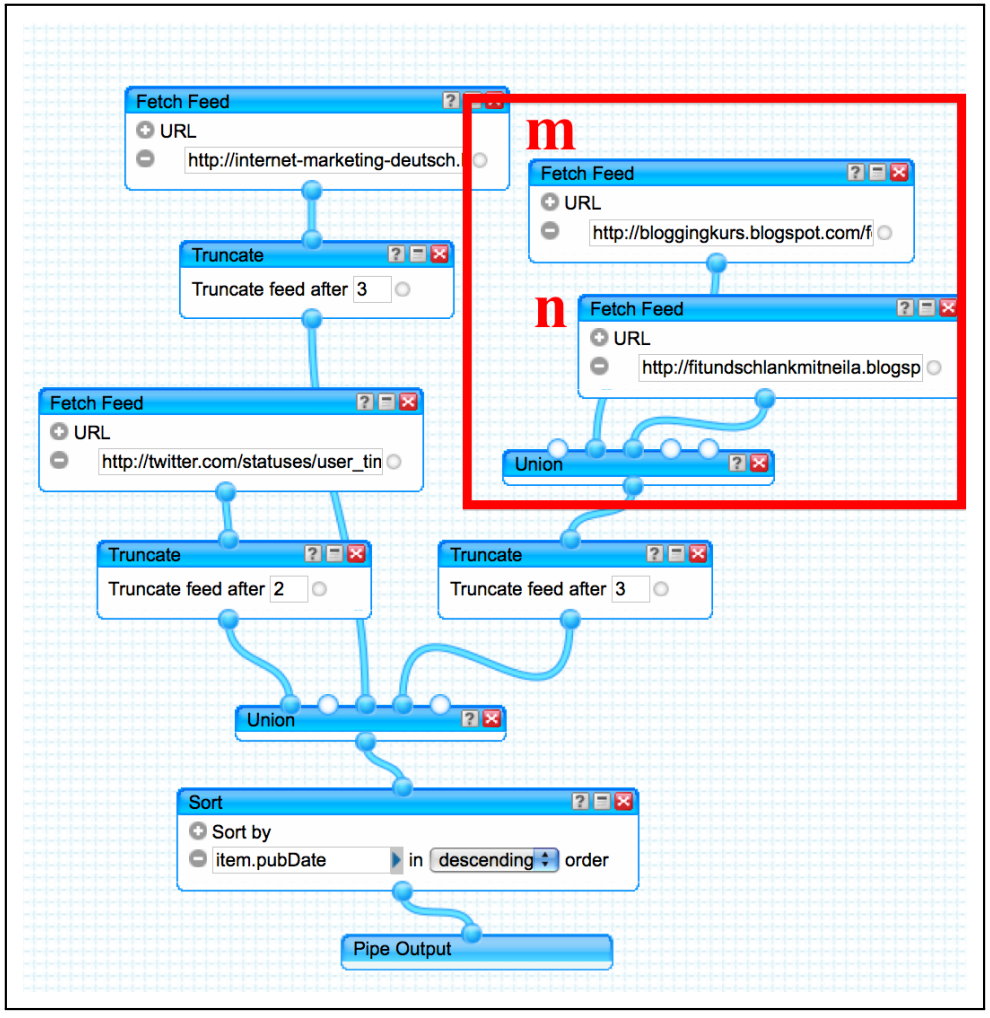

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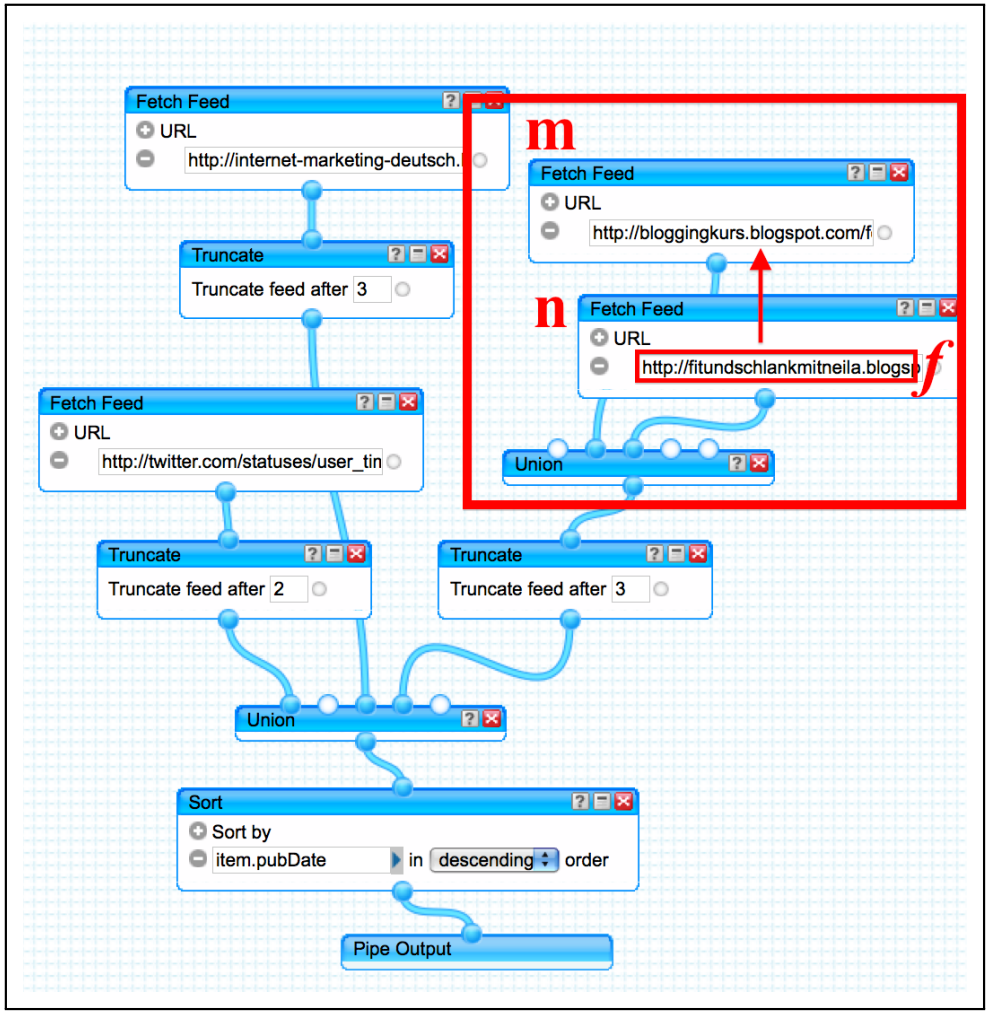

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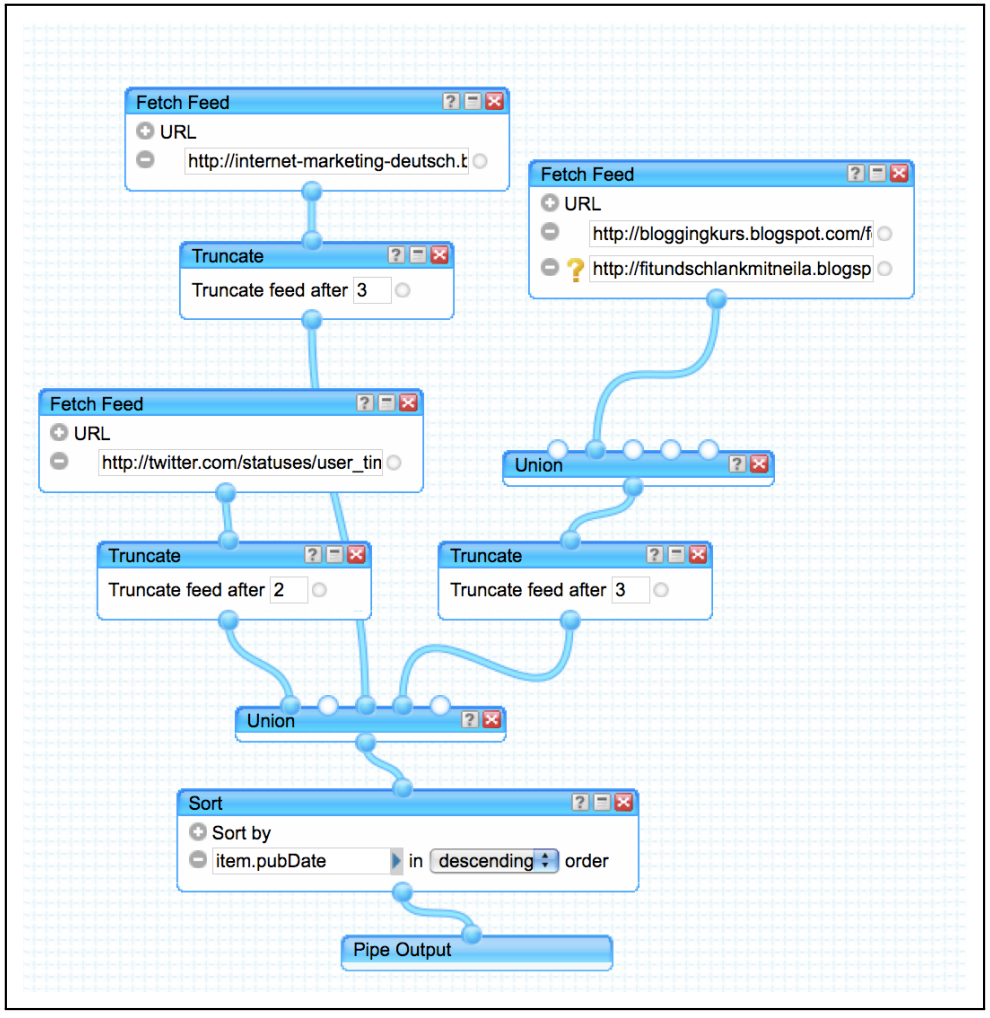
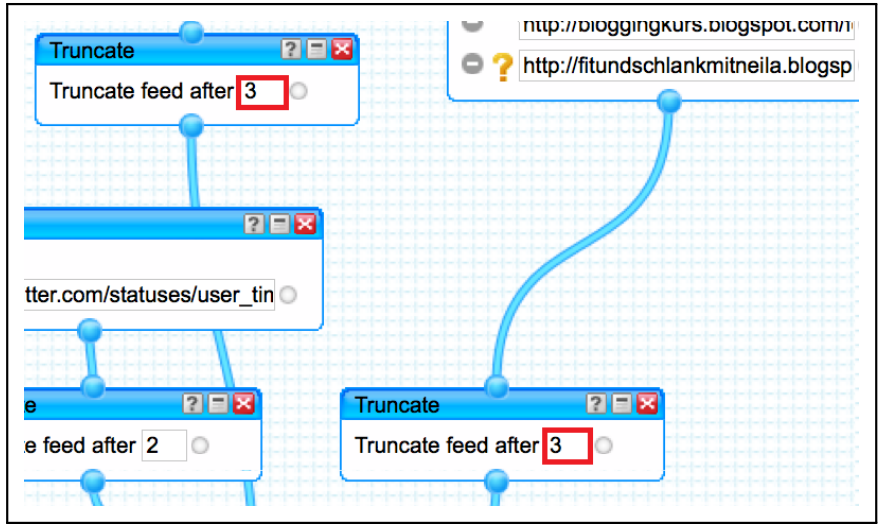


Abstraction: Pull Up Module

Pull Up Module

Pulls duplicate strings into new module

Before



Abstraction: Pull Up Module

Pull Up Module

Pulls duplicate strings into new module

Definition

P_{before}	Duplicate Strings
Params	$Pipe = (\mathcal{M}, \mathcal{W}, \mathcal{F}, owner)$, fields f and g
Transf.	add module m to $Pipe.\mathcal{M}$ | $setter\_str(m)$ add field h to $m.\mathcal{F}$ set $h.value = f.value$ add wire w to $Pipe.\mathcal{W}$ | $joined\_fld(m, f, w)$ add wire x to $Pipe.\mathcal{W}$ | $joined\_fld(m, g, x)$
P_{after}	$m, w, x, h \in Pipe$ | $h.value = f.value \wedge$ $joined\_fld(m, f, w) \wedge$ $joined\_fld(m, g, x)$

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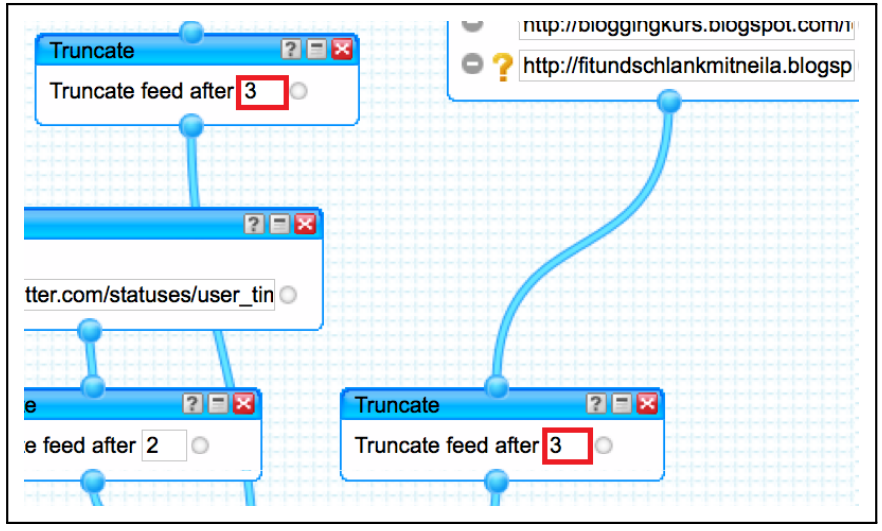

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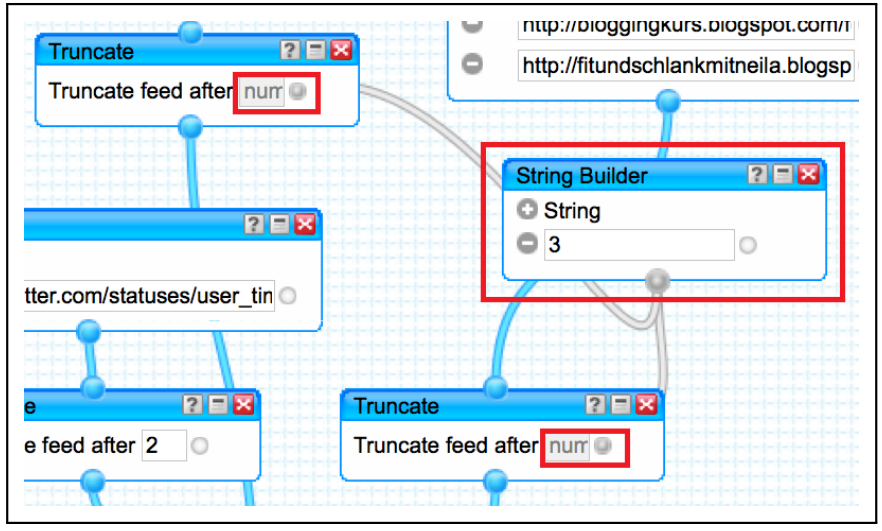

Population-Based: Extract Global Subpipe

Extract Global Subpipe

Replaces a path *p* with a subpipe if *p* is isomorphic to a path in the set of popular global paths extracted from the population.

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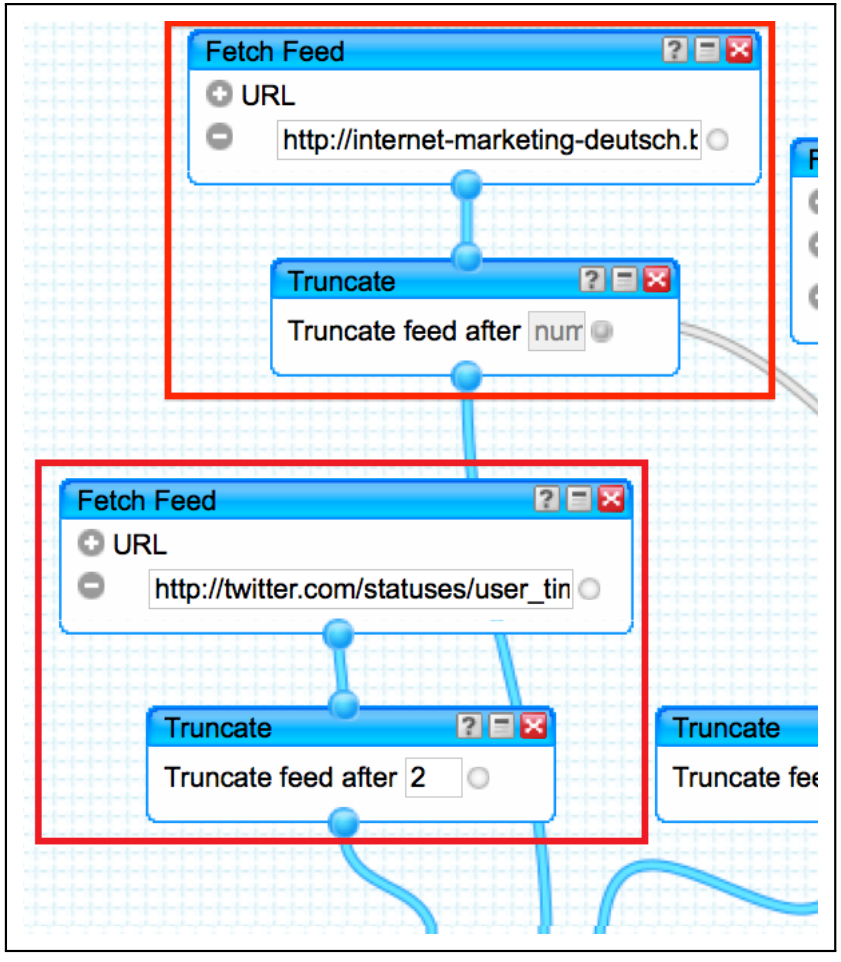

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Definition

P_{before}	Global Isomorphic Paths
Params	$Pipe = (\mathcal{M}, \mathcal{W}, \mathcal{F}, owner)$, isomorphic *Paths*
Transf.	for($p \in Paths$) $subPipe = getSubPipe(p)$ connect *subPipe* to *Pipe* copy/rewire params from *p* into *subPipe* remove *p*
P_{after}	$\forall p \in Paths \mid p \notin Pipes$, $\exists_1 getSubPipe(p) \in Pipe$

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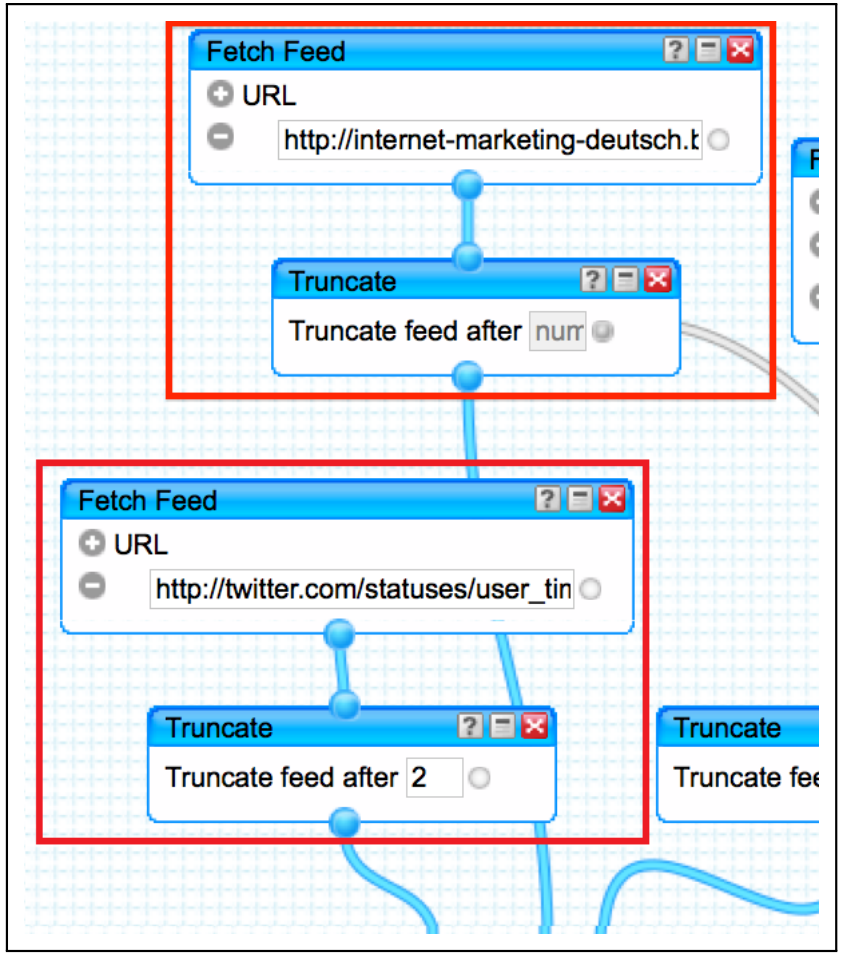

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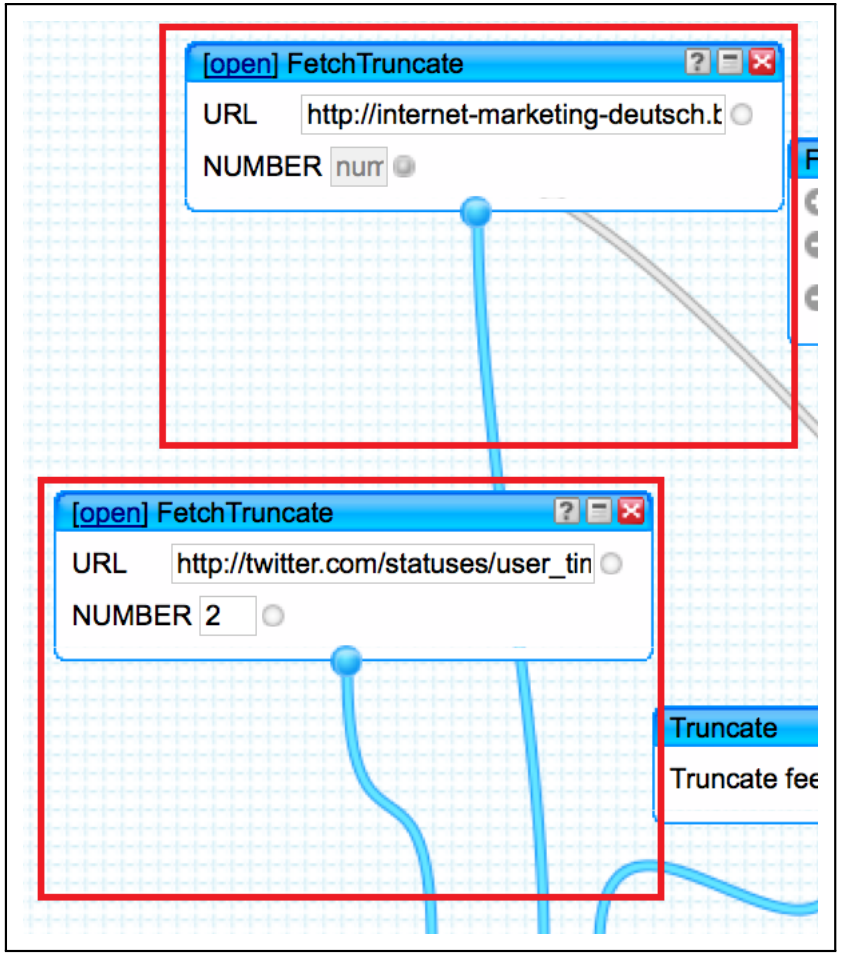


Study Design

Research Questions III

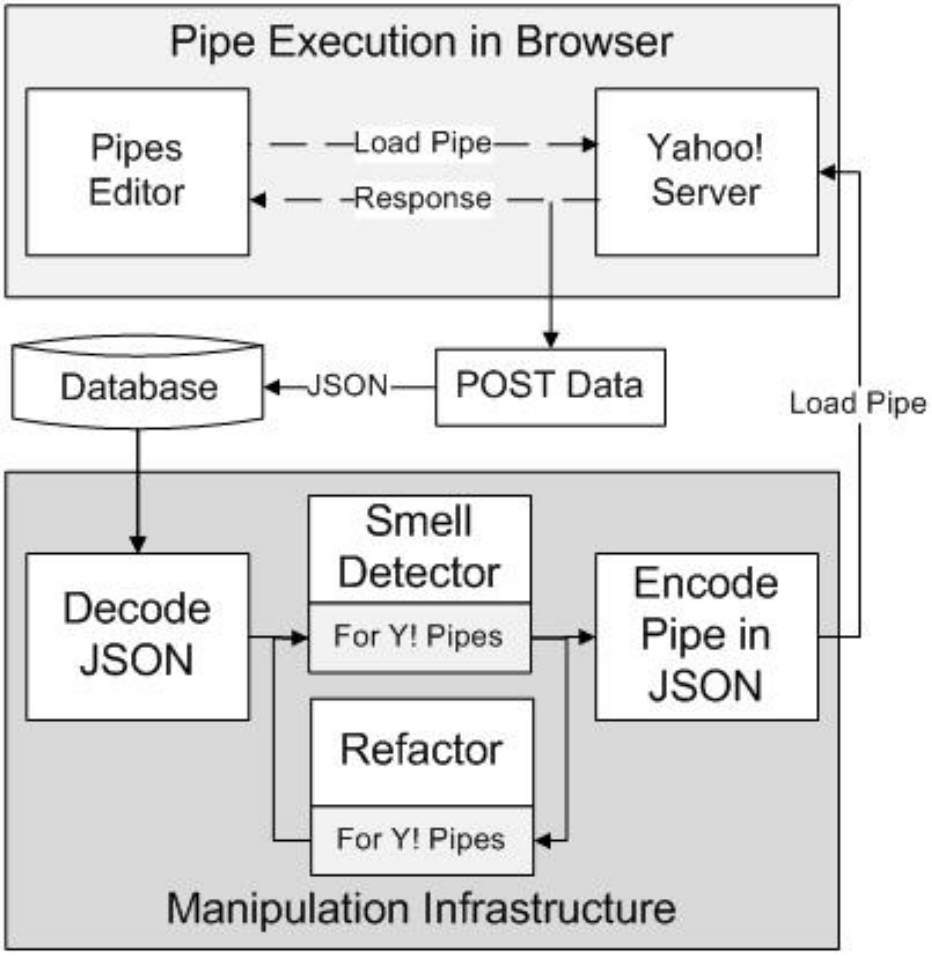
How often do the smells occur in the population of Yahoo! Pipes?

Research Questions IV

How effective are the refactorings at removing smells?

- Built infrastructure to detect smells and transform pipes
- Studied 8,051 Pipes developed by 5,957 authors

Study Infrastructure and Results



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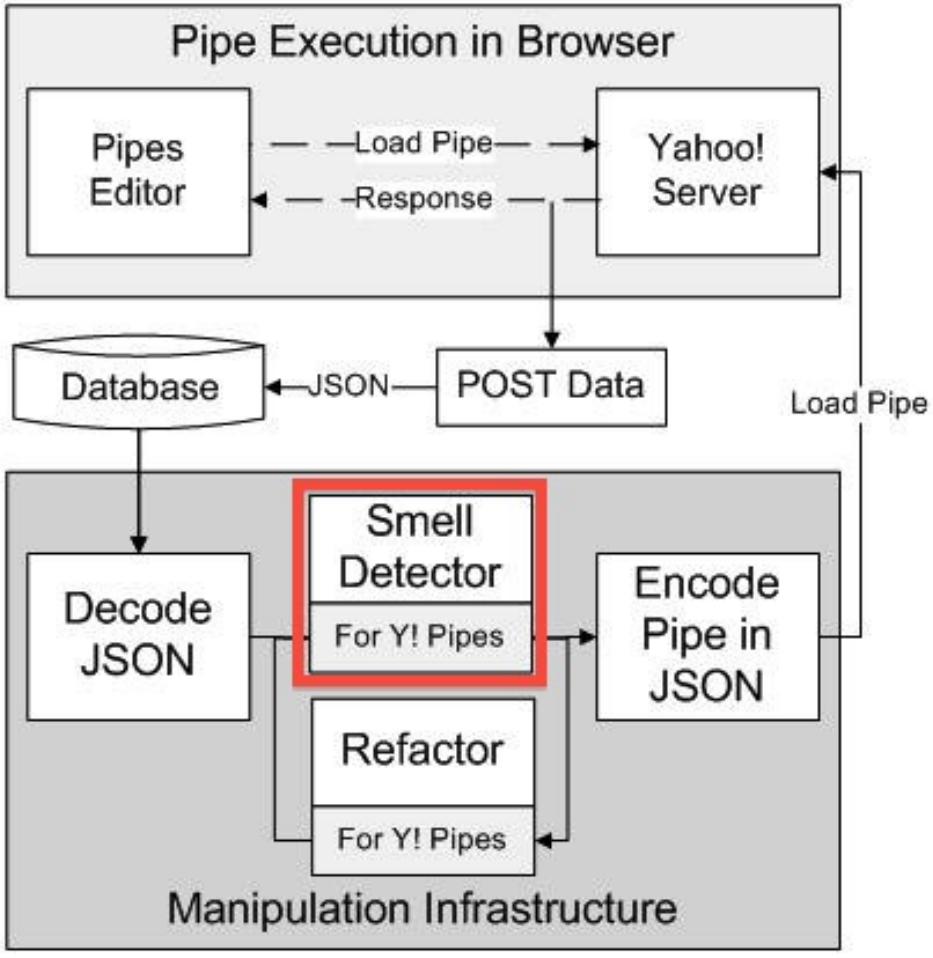

- 81% of 8,000+ pipes contains at least one smell instance

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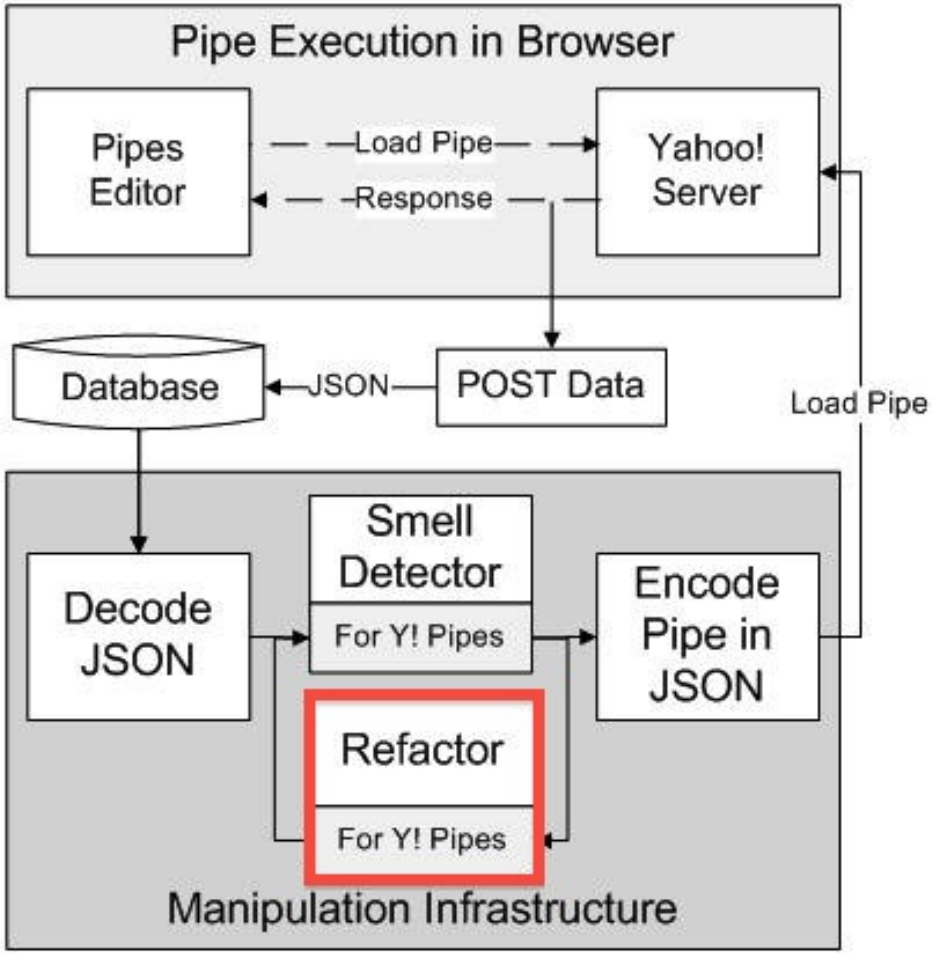

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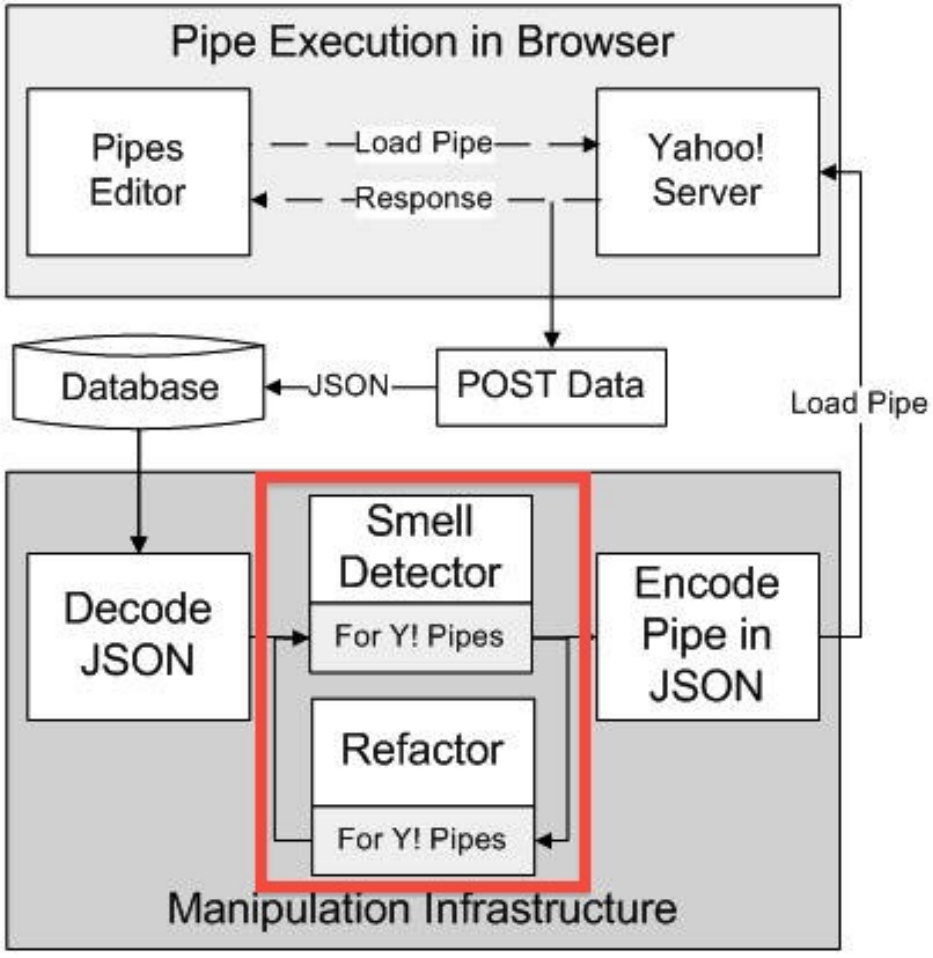

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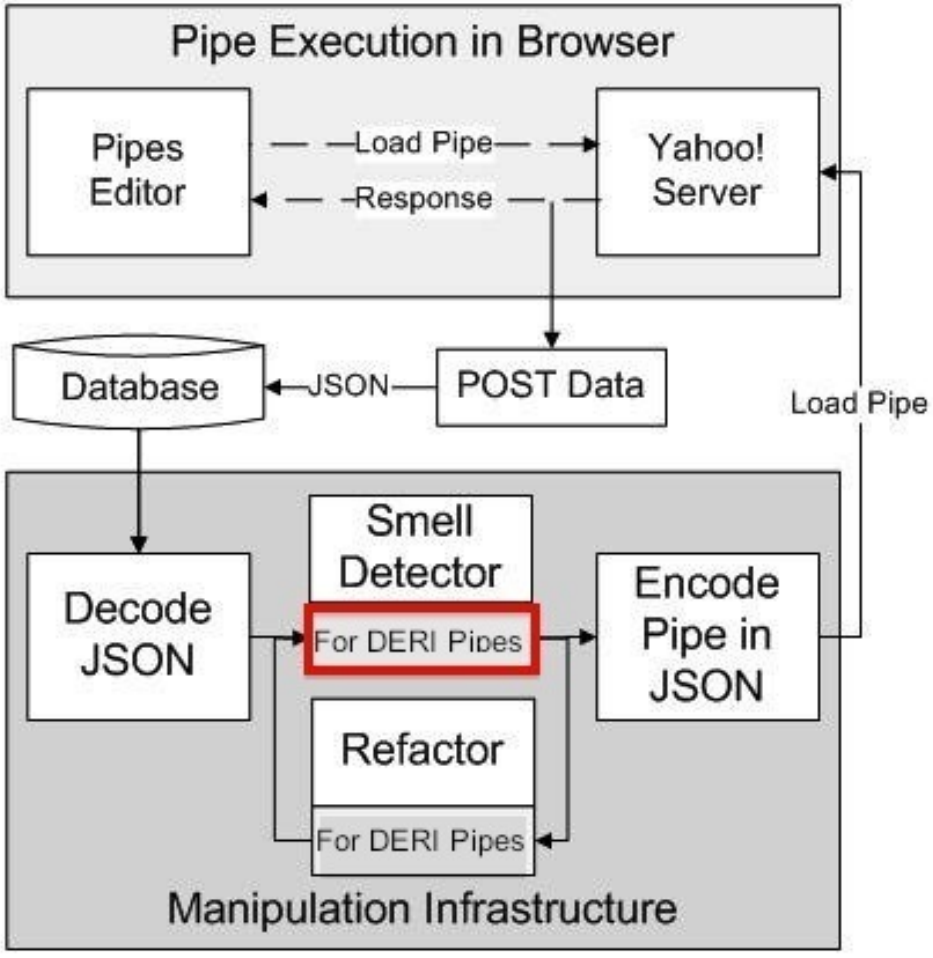

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- 7 / 11 refactorings completely removed their targeted smells from the population
- Refactorings reduced the number of “smelly” pipes in the population from 81% to 16%
- Analysis of 77 DERI Pipes: 45% contain at least one smell

Summary

1. End users are creating mashups in increasing numbers
2. Mashups are often reused, yet suffer from many deficiencies
3. Smells are present in 81% of a sampling of 8,000+ pipes
4. End users generally prefer pipes that lack the smells
5. Refactoring are effective at removing smells
6. Definitions extend to other pipe-like mashup languages
7. Extends challenges and opportunities for refactoring

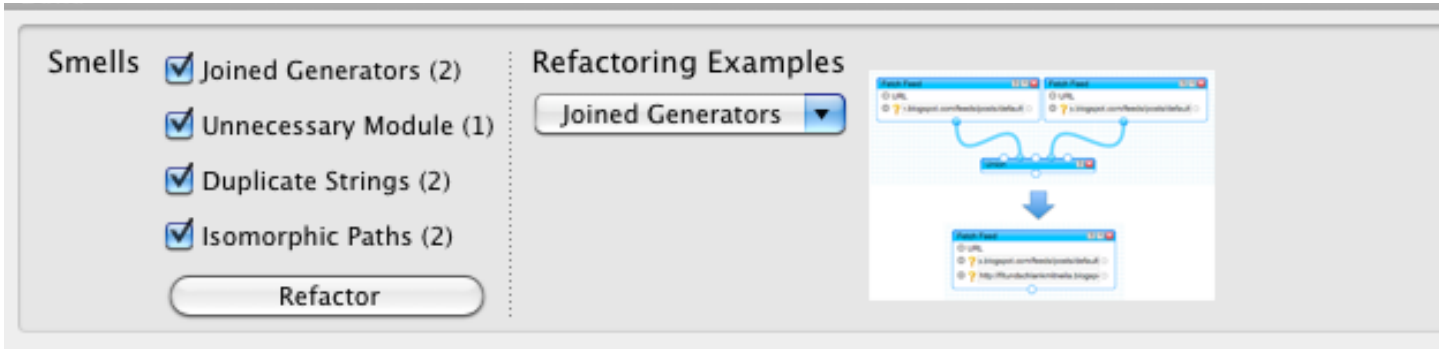
Future Work

- Evaluate if a refactoring tool would make development easier for end users
- Broaden the family of refactorings to target fault-proneness and to better utilize community information
- Adapt the refactorings to other domains of end user languages (e.g., Taverna, Scratch, Kodu, . . .)
- Utilize community information to support end users earlier in the development lifecycle

This work was supported in part by NSF Graduate Research Fellowship CFDA#47.076, NSF Award #0915526, and AFOSR Award #9550-10-1-0406.

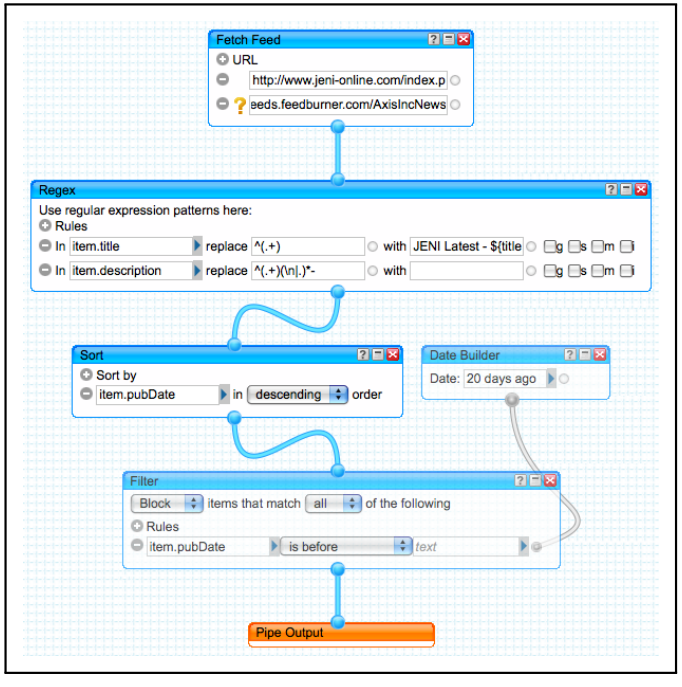
{kstolee, elbaum} @ cse.unl.edu

Potential Refactoring Tool

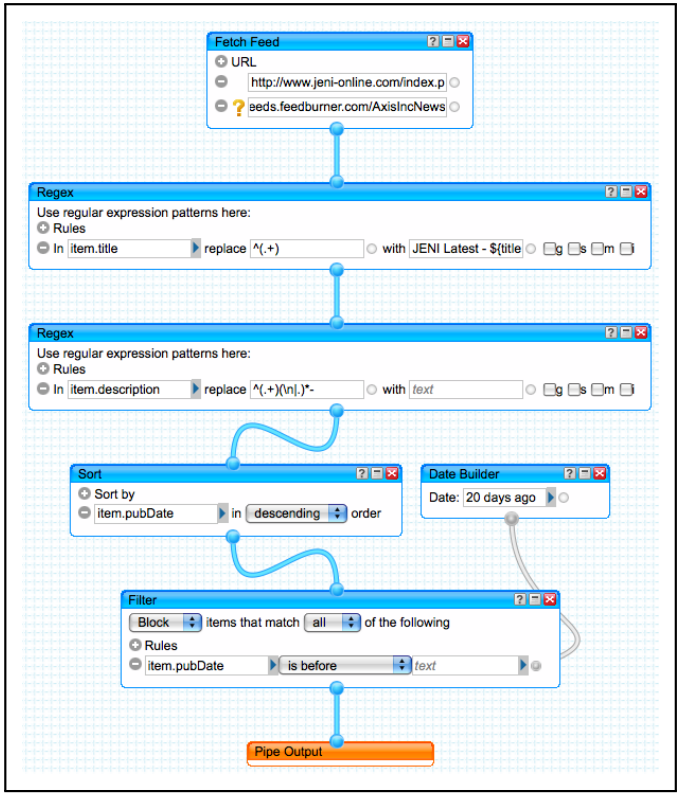


Example Task: Preference

A

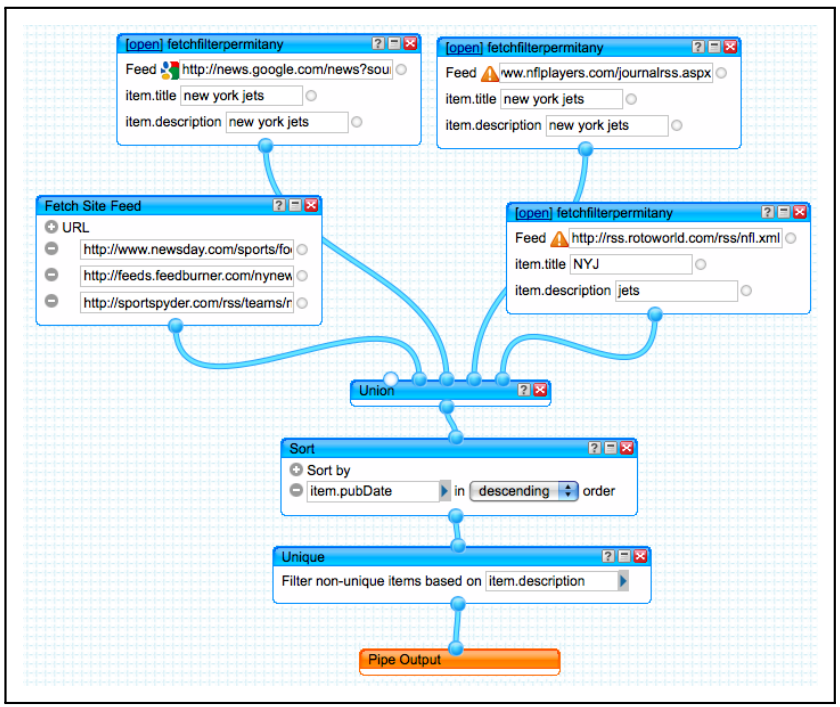


B



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

Example Task: Understanding



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.

Refactoring Study Results

	Frequency	Max % Removed Individually	Max % Removed 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%**

End User Study – Detailed Results (Preference)

Task	Smell	Subjects	% Smelly	% Non-Smelly	% Same
1	Joined Generator	10	10%	90%	0%
2	Duplicate String	10	10%	90%	0%
3	Redund. ops	10	20%	50%	30%
4	Invalid Src.	8	25%	38%	38%
5	Deprecated. Mod.	9	56%	33%	11%
6	Noisy Mod.	11	9%	73%	18%
7	Global Iso. Path	9	56%	33%	11%
8	Operator Order	8	13%	88%	0%

End User Study – Detailed Results (Understanding)

Task	**Smell**	**Type**	**Subjects**	% **Correct**	% **Incorrect**
9	Local Iso. Path	Clean	6	83%	17%
		Smelly	1	100%	0%
10	Joined Generators	Clean	4	75%	25%
		Smelly	5	60%	40%