Program Boosting: Program Synthesis via Crowd-Sourcing

Robert A. Cochran, Loris D’Antoni, Benjamin Livshits, David Molnar and Margus Veanes

Presented by: Sam Witty, Shehzaad Dhuliawala and Samer Nashed

Outline

Introduction (Research Question, Key Ideas, Contributions)

Background (Genetic Programming and Regular Expressions)

Motivating Example

Evaluation

Discussion

Research Question

Can Crowd-Sourced solutions to programming tasks be combined automatically to boost performance?

Key Idea

Many common programming tasks are

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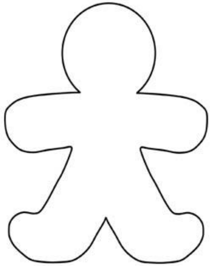
Many common programming tasks are

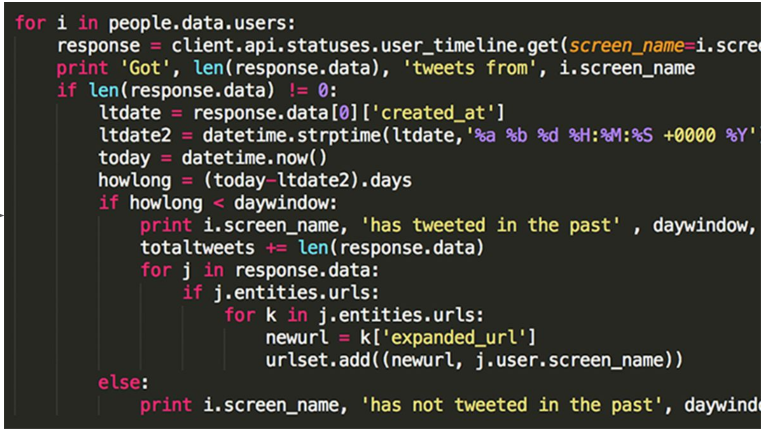
1. Surprisingly complex, such that even expert programmers may struggle
2. Easily specified (at least to a good approximation) in English
3. Nuanced enough that different programmers will fail in different ways

These attributes make tasks prime candidates for genetic programming towards program synthesis

Conventional Programming



Blood, sweat, and tears



```
for i in people.data.users:
    response = client.api.statuses.user_timeline.get(screen_name=i.scre
    print 'Got', len(response.data), 'tweets from', i.screen_name
    if len(response.data) != 0:
        ltdate = response.data[0]['created_at']
        ltdate2 = datetime.strptime(ltdate,'%a %b %d %H:%M:%S +0000 %Y'
        today = datetime.now()
        howlong = (today-ltdate2).days
        if howlong < daywindow:
            print i.screen_name, 'has tweeted in the past' , daywindow,
            totaltweets += len(response.data)
            for j in response.data:
                if j.entities.urls:
                    for k in j.entities.urls:
                        newurl = k['expanded_url']
                        urlset.add((newurl, j.user.screen_name))
        else:
            print i.screen_name, 'has not tweeted in the past', daywind
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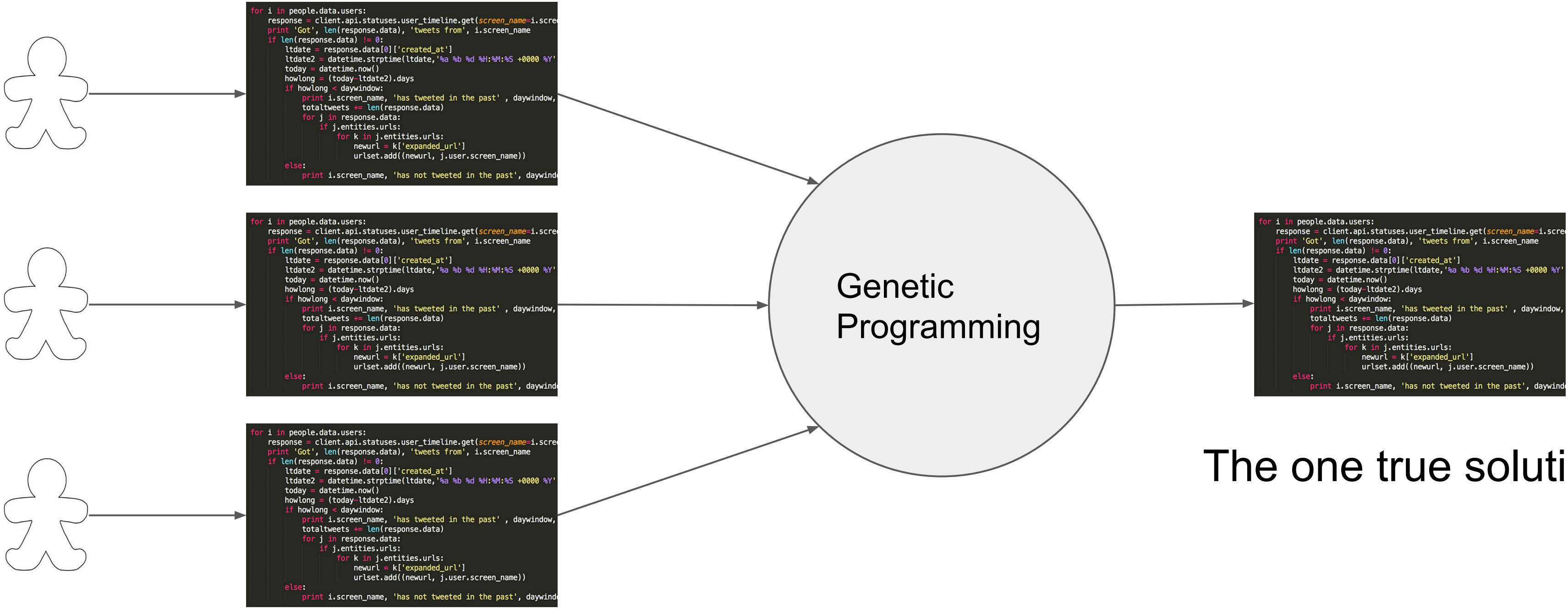
Mostly working program

Image sources - 4H, The Economist

Program Boosting



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Genetic Programming

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The one true solution

Flawed programs

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Contributions

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5. First use of genetic programming on automata over complex alphabets, in this case UTF-16
6. Evaluation of the proposed method on 465 regular expressions

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Three main components

Crossover - Merge candidate programs

Mutation - Stochastically alter candidate programs

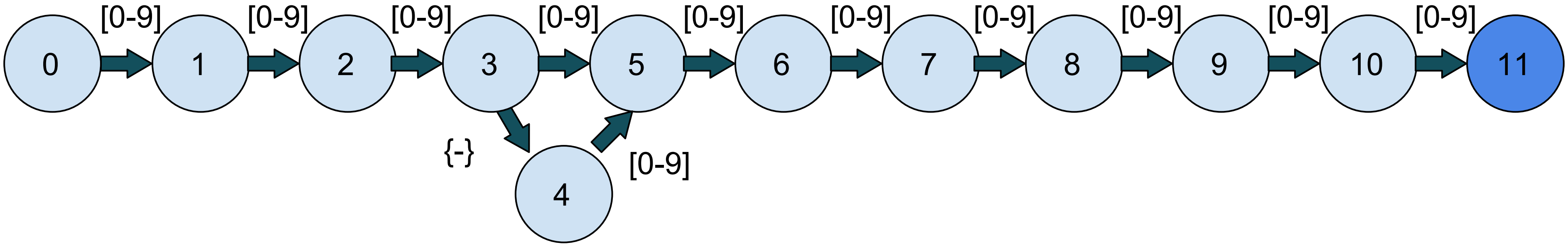
Fitness - Evaluate candidate programs

Animation

Click Me

Source: Rafael Matsunaga

Background: SFA and Regex



Corresponding regex: [0-9]{3}(-)?[0-9]{7}

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Motivating Example

Determine whether a string is a valid phone number.

Ex: 111-111-1111, 1111111111

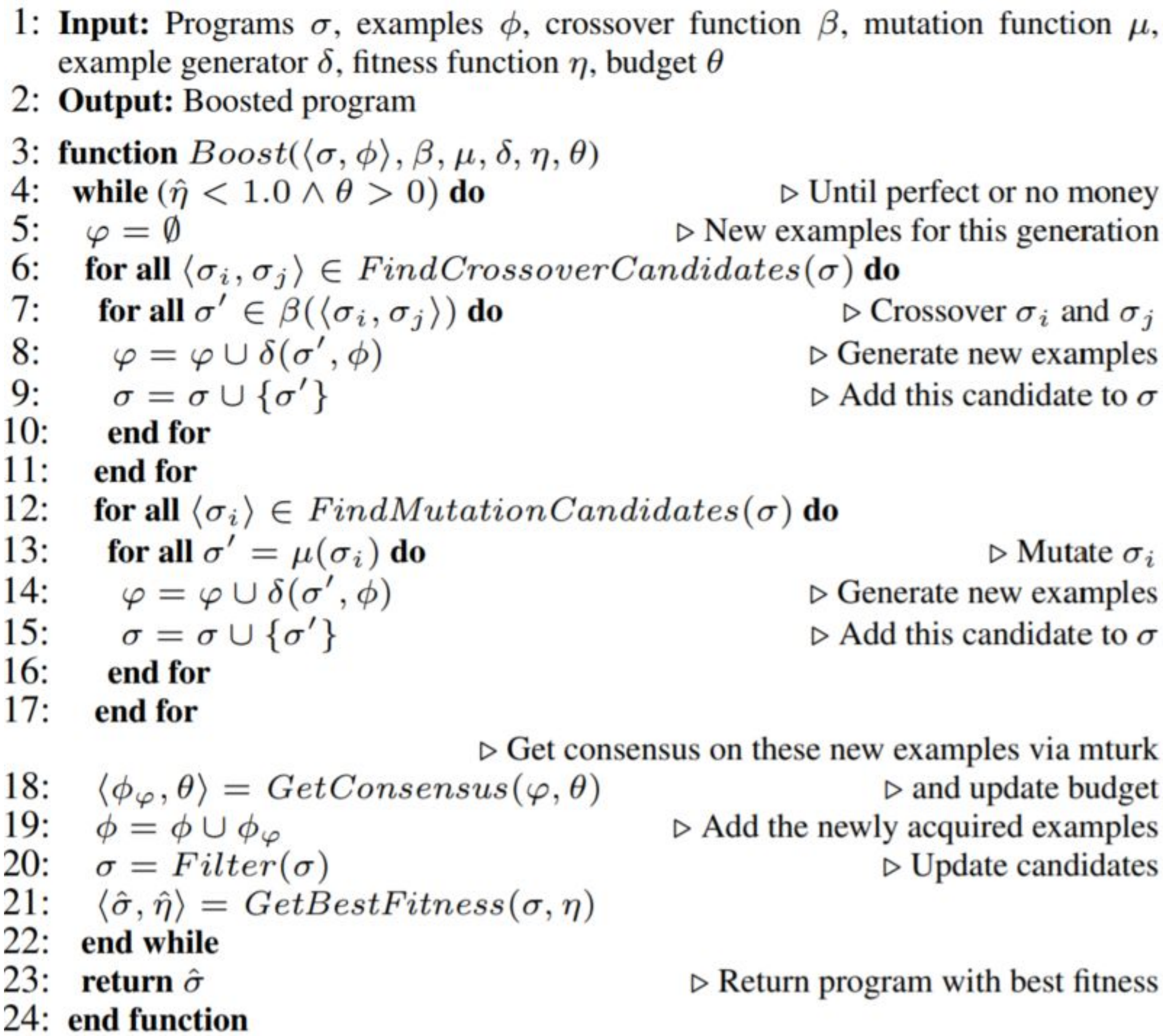
Method Overview

Crossover

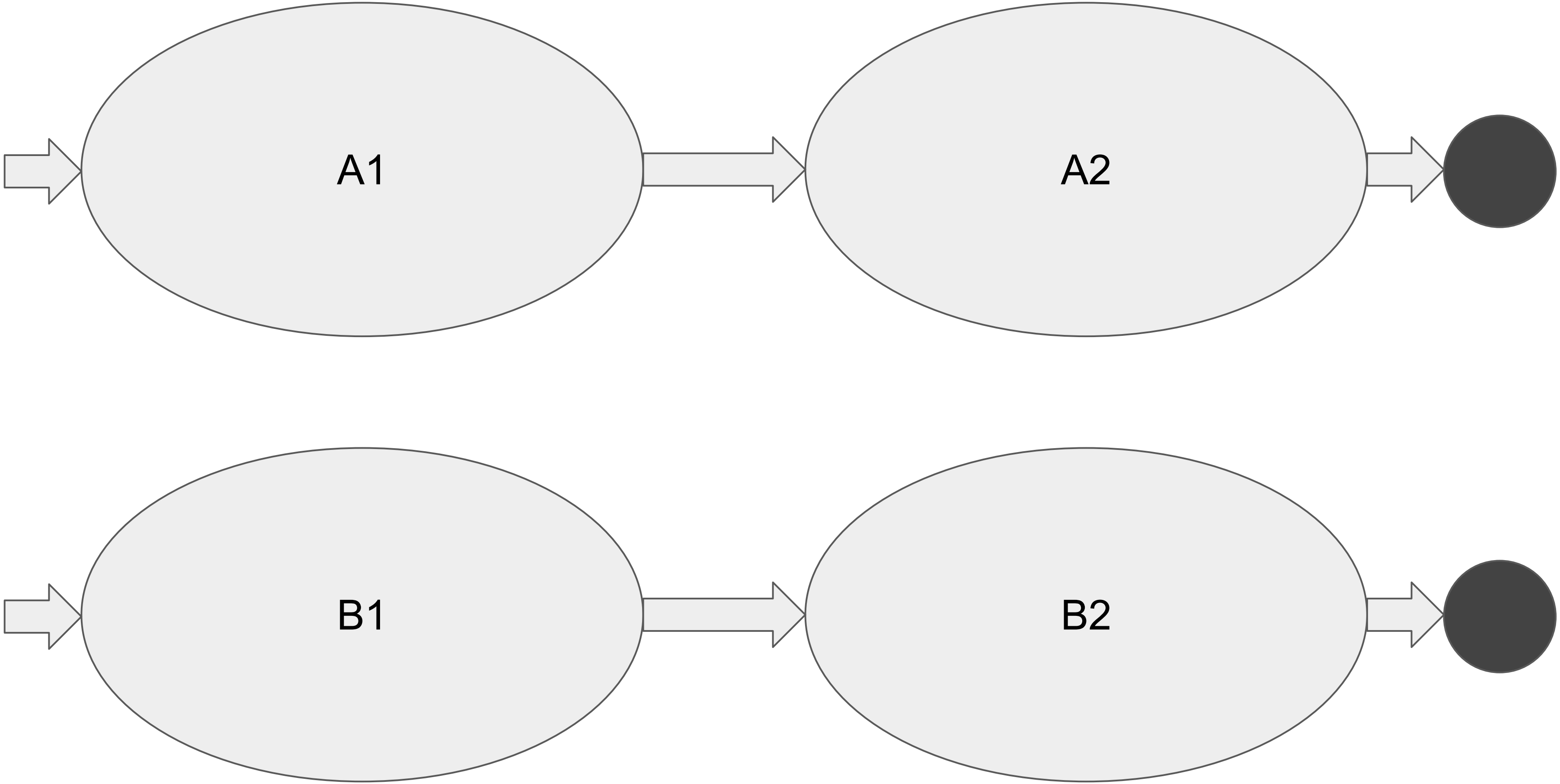
Mutation

Crowdsource the fitness

Evaluate New Gen



```
Input: Programs $\sigma$, examples $\phi$, crossover function $\beta$, mutation function $\mu$,
    example generator $\delta$, fitness function $\eta$, budget $\theta$
Output: Boosted program
function $Boost(\langle\sigma, \phi\rangle, \beta, \mu, \delta, \eta, \theta)$
  while $(\hat{\eta} < 1.0 \wedge \theta > 0)$ do                          ▷ Until perfect or no money
    $\varphi = \emptyset$                                                    ▷ New examples for this generation
    for all $\langle\sigma_i, \sigma_j\rangle \in FindCrossoverCandidates(\sigma)$ do
      for all $\sigma' \in \beta(\langle\sigma_i, \sigma_j\rangle)$ do       ▷ Crossover $\sigma_i$ and $\sigma_j$
        $\varphi = \varphi \cup \delta(\sigma', \phi)$                       ▷ Generate new examples
        $\sigma = \sigma \cup \{\sigma'\}$                                   ▷ Add this candidate to $\sigma$
      end for
    end for
    for all $\langle\sigma_i\rangle \in FindMutationCandidates(\sigma)$ do
      for all $\sigma' = \mu(\sigma_i)$ do                                   ▷ Mutate $\sigma_i$
        $\varphi = \varphi \cup \delta(\sigma', \phi)$                       ▷ Generate new examples
        $\sigma = \sigma \cup \{\sigma'\}$                                   ▷ Add this candidate to $\sigma$
      end for
    end for
                                                 ▷ Get consensus on these new examples via mturk
    $\langle\phi_\varphi, \theta\rangle = GetConsensus(\varphi, \theta)$     ▷ and update budget
    $\phi = \phi \cup \phi_\varphi$                                          ▷ Add the newly acquired examples
    $\sigma = Filter(\sigma)$                                                ▷ Update candidates
    $\langle\hat{\sigma}, \hat{\eta}\rangle = GetBestFitness(\sigma, \eta)$
  end while
  return $\hat{\sigma}$                                                      ▷ Return program with best fitness
end function
```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B1
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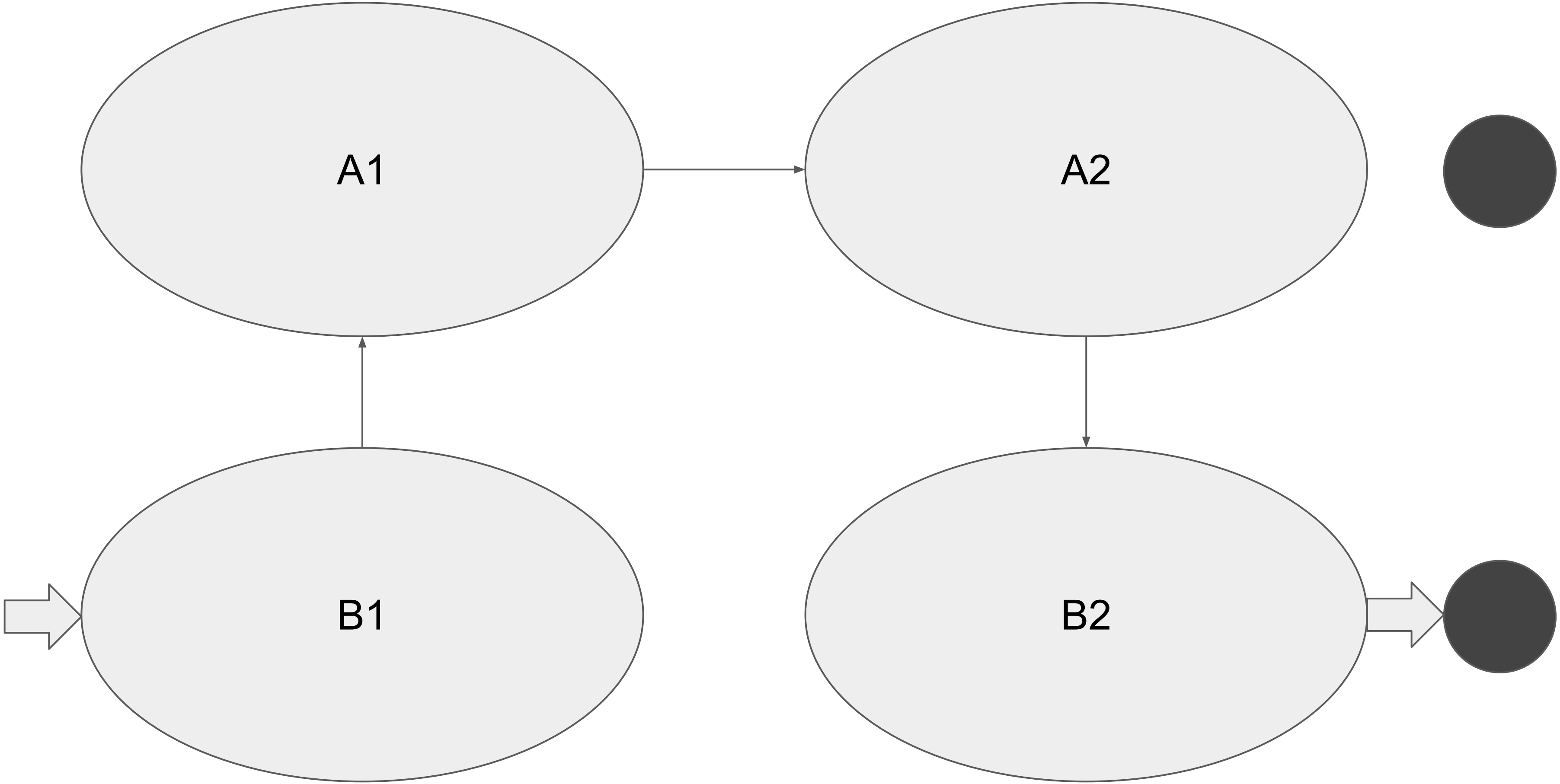
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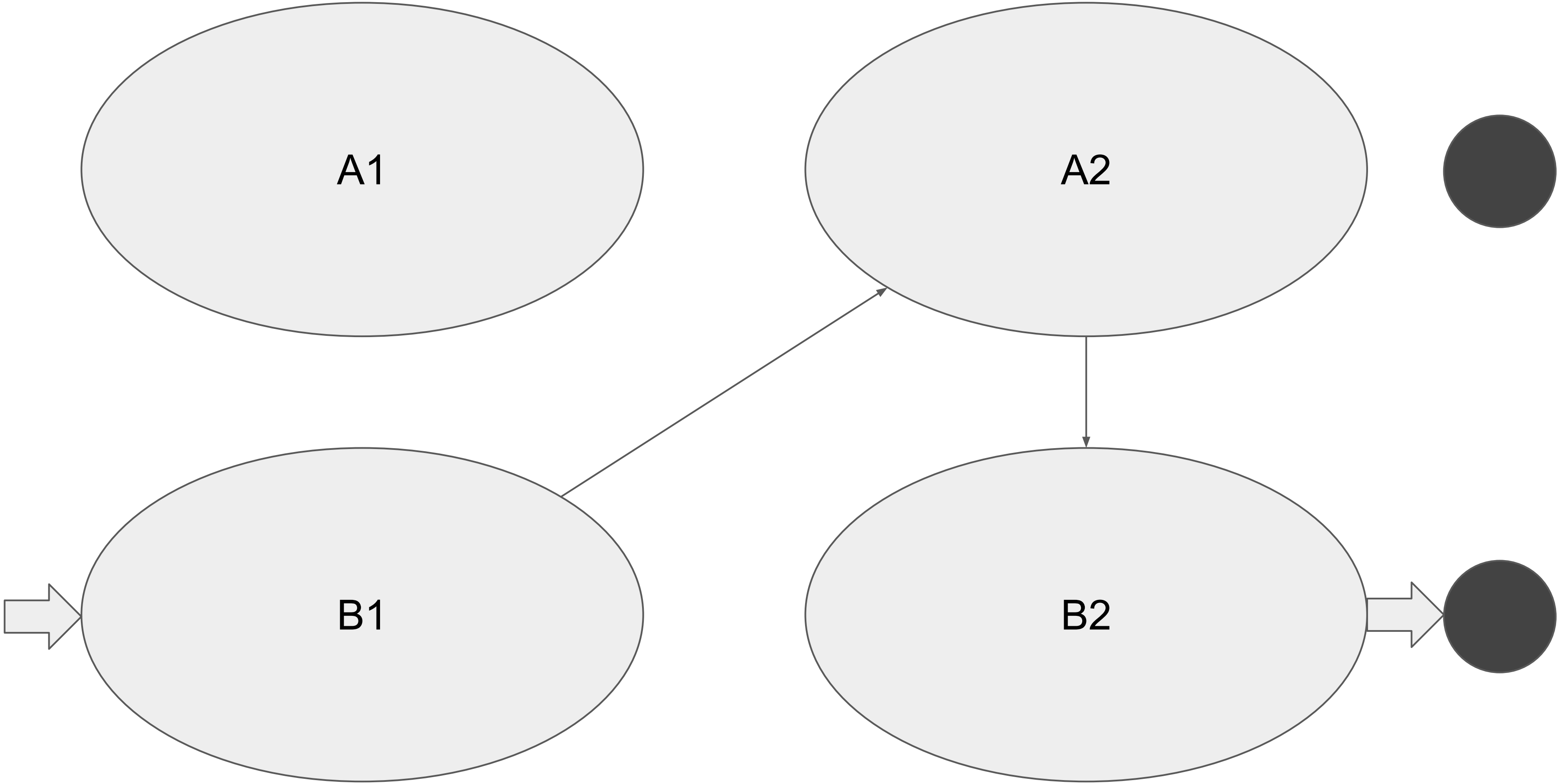
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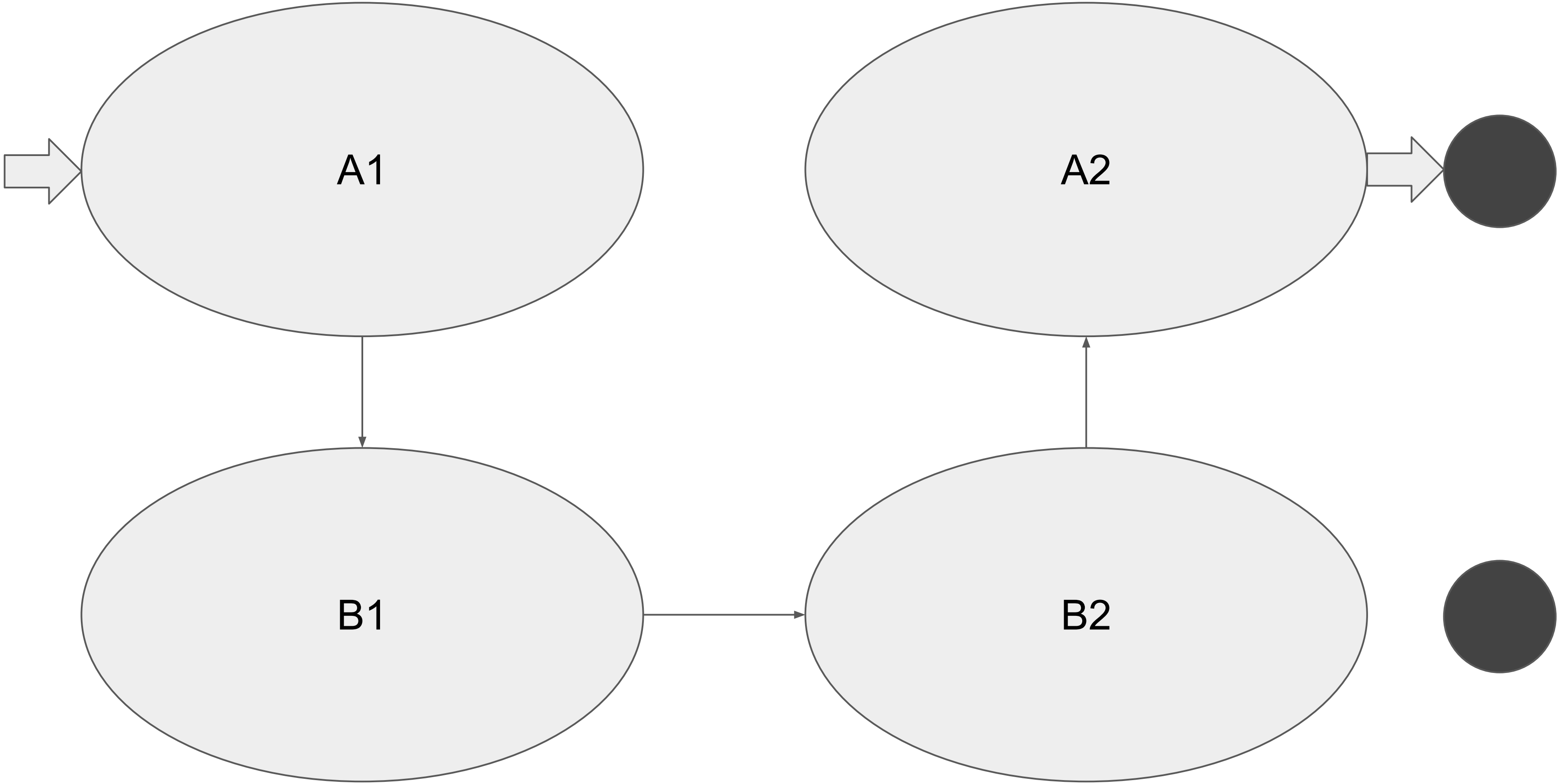
A1
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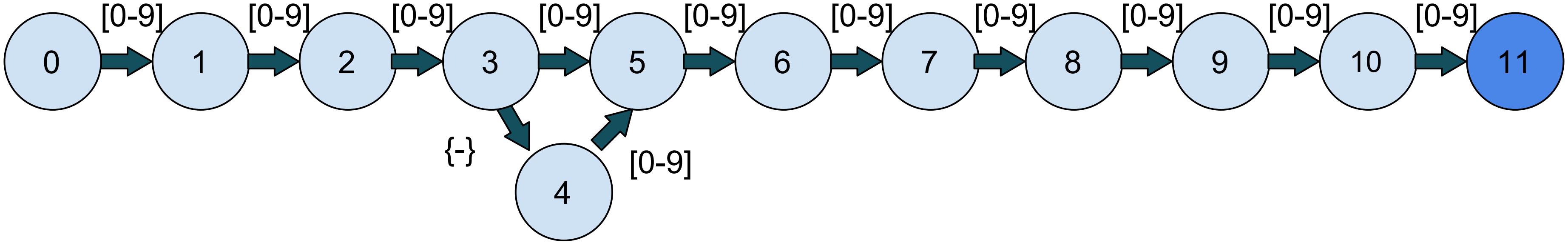
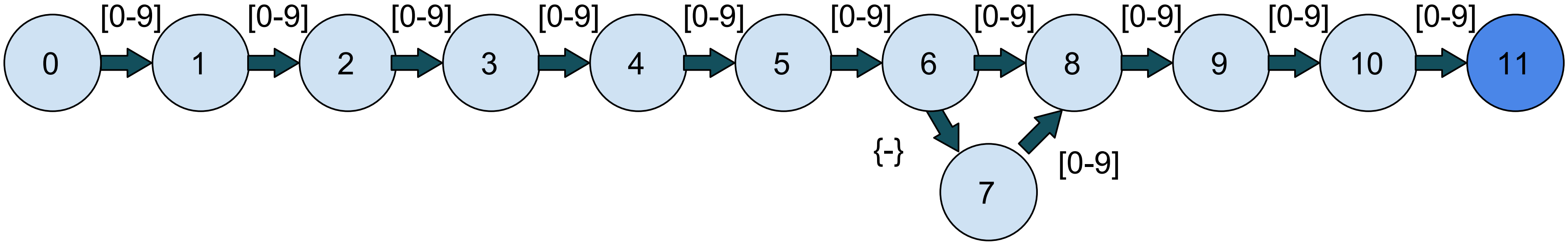
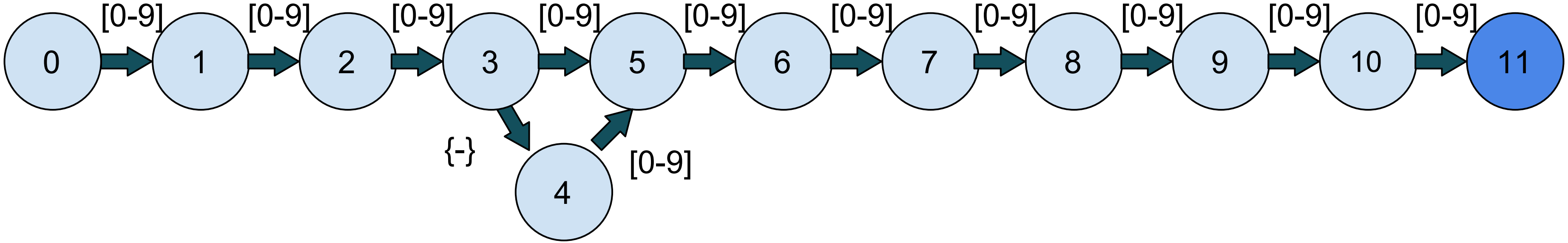
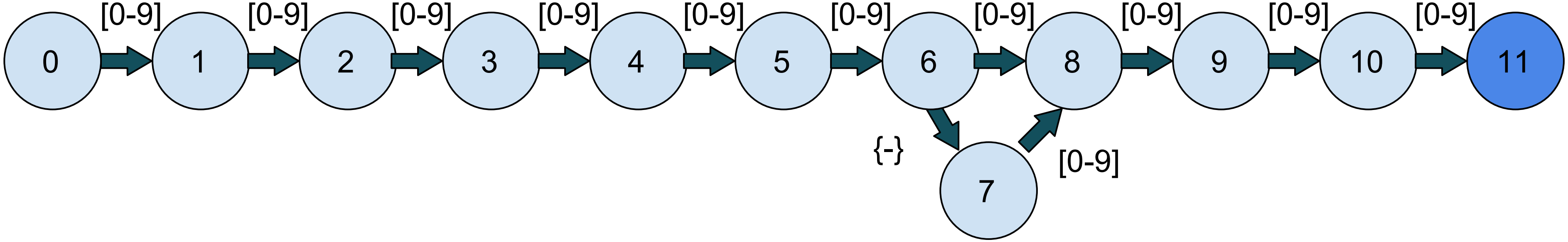
Identifying *components*



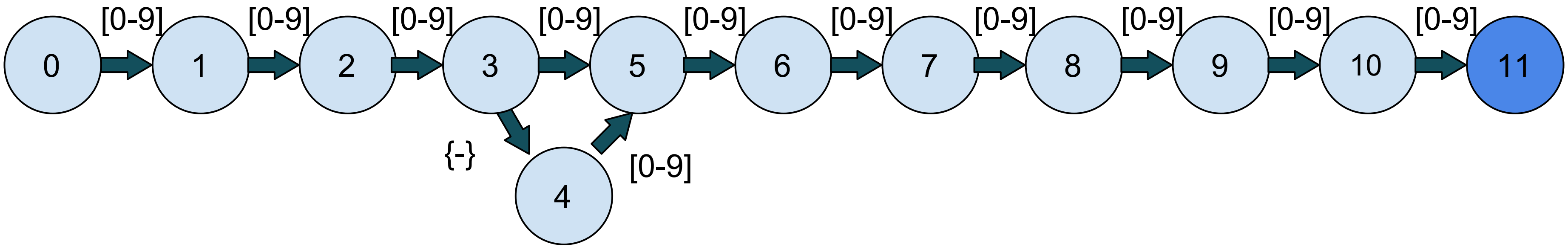


Strongly Connected Components





Stretches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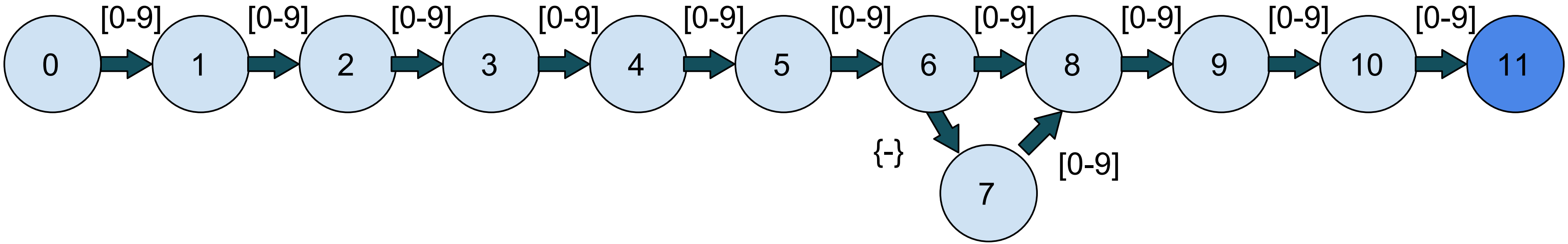
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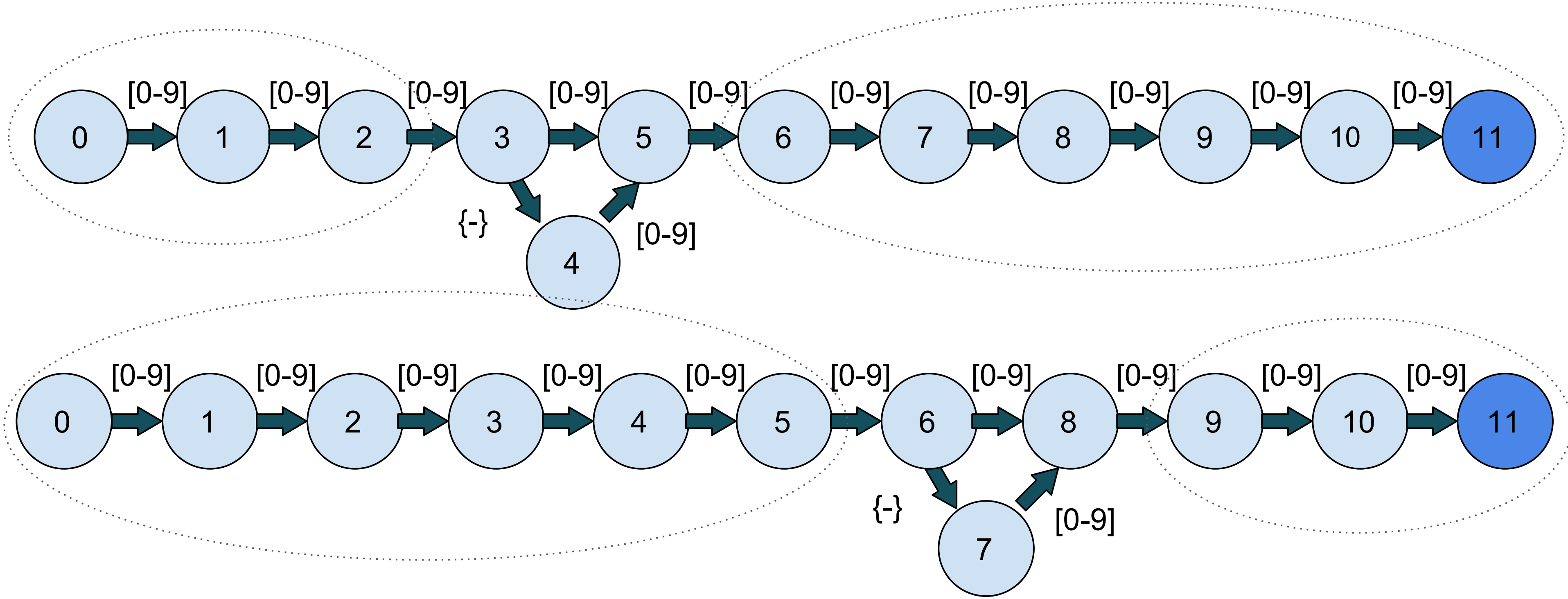
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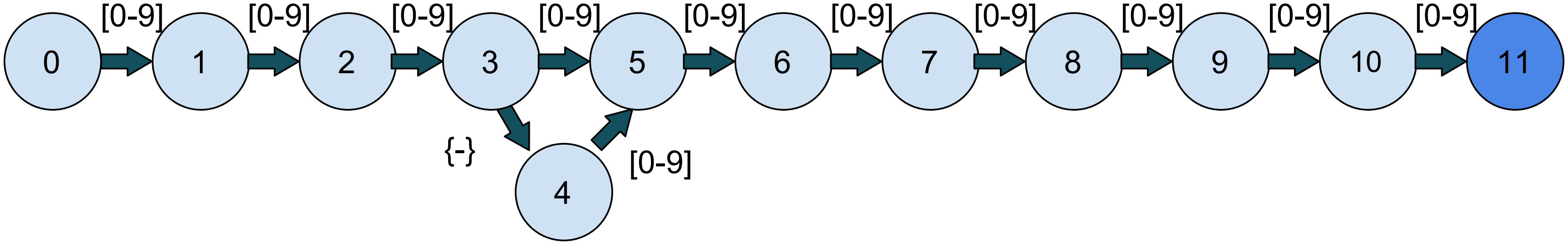
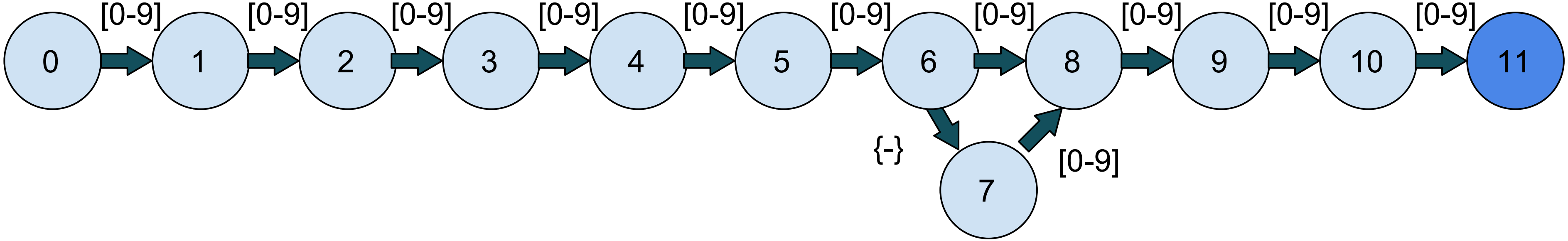
Single Entry - Single Exit





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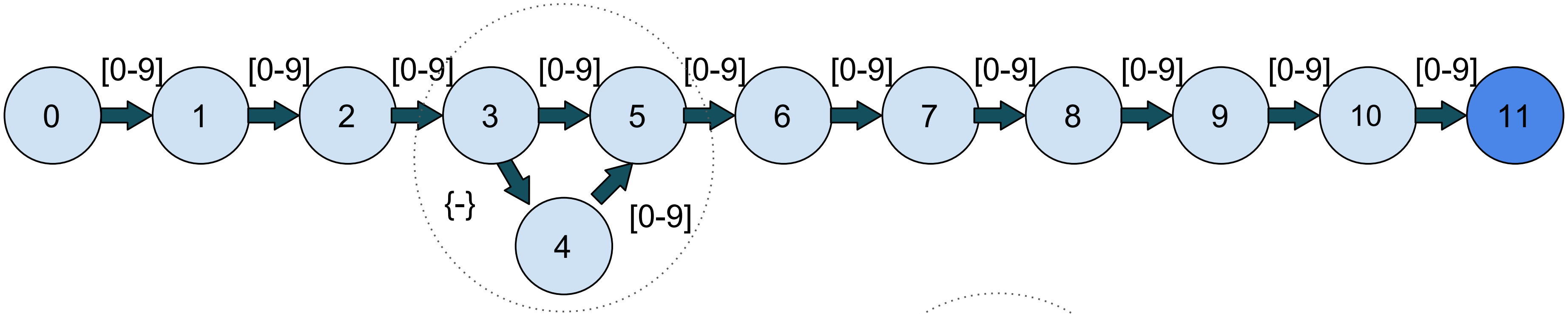

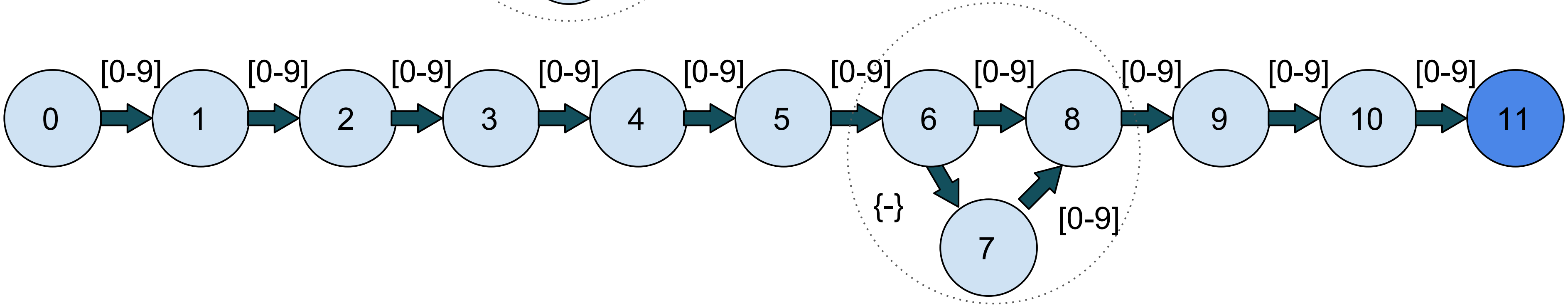

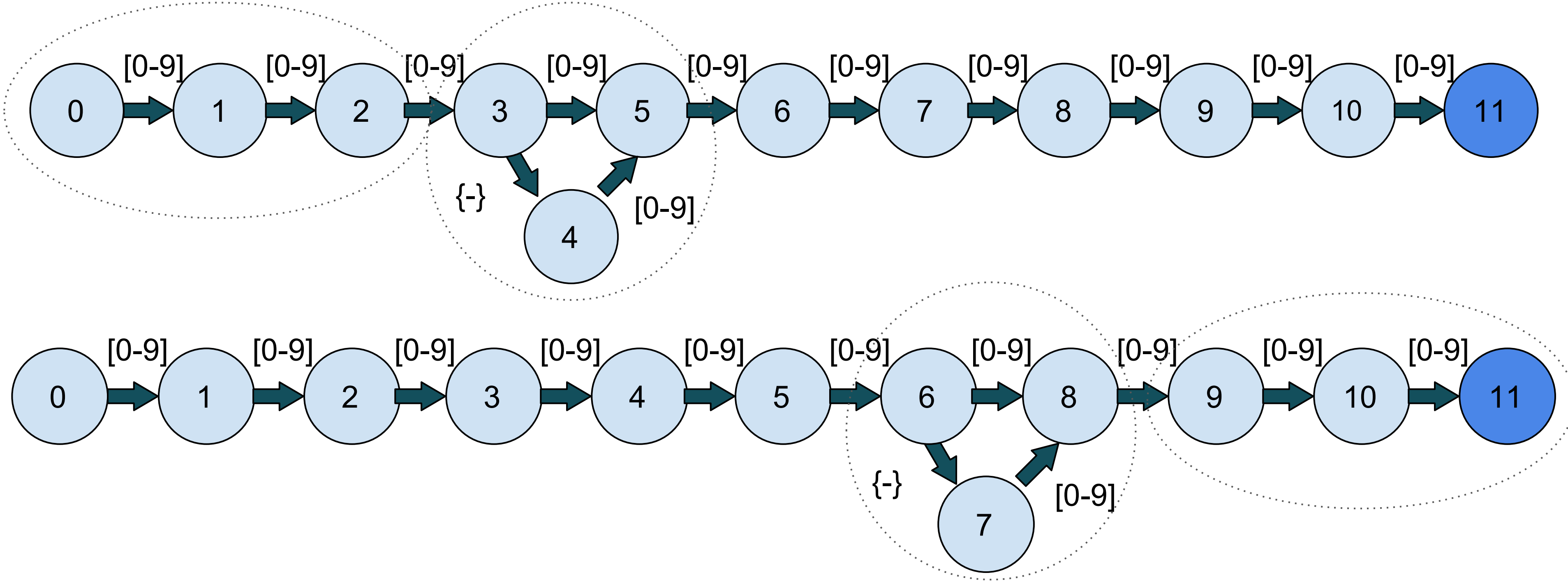
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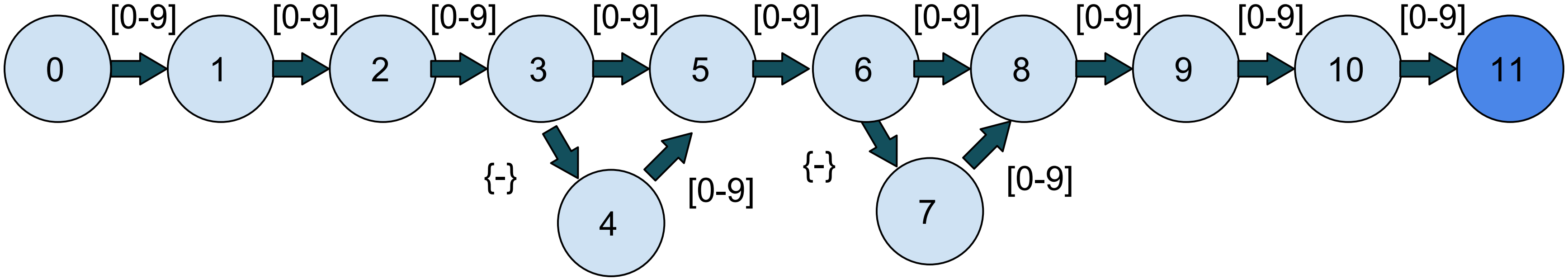
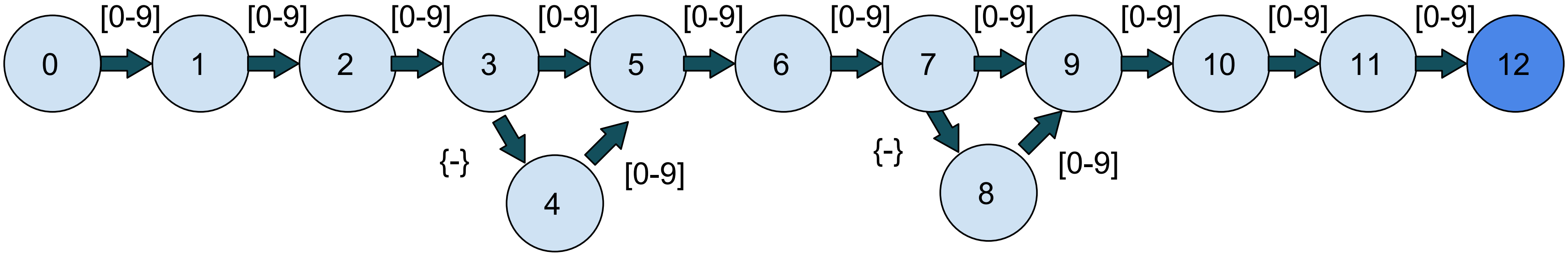


Resulting Regex: [0-9]{3}-?[0-9]{2}-?[0-9]{4}

Mutations

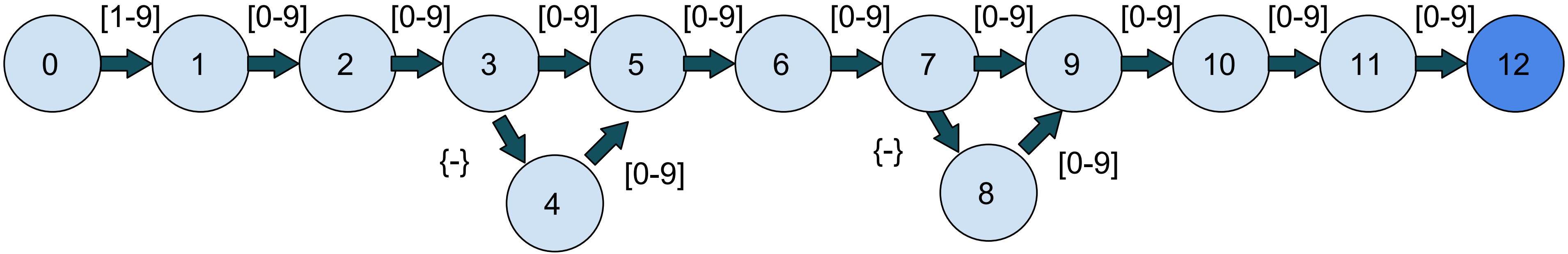
1. Diminishing
2. Augmenting

Example Mutation



Negative example: 012-456-7890
Assume numbers cannot begin with 0

Example Mutation



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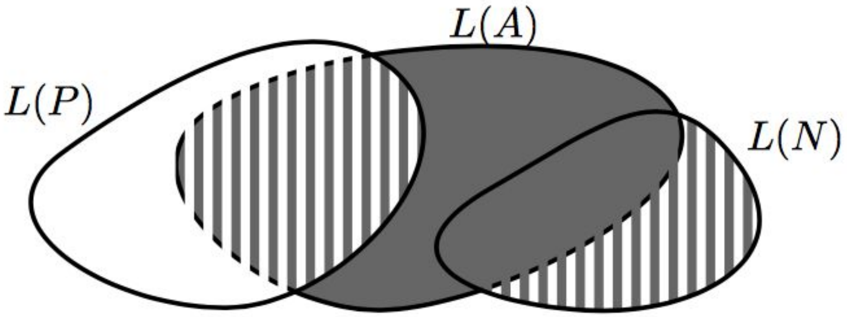
$$\text{Fitness}(A) = (L(A \cap P) + L(N - A))/ L(P \cup N)$$



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Mechanical turk was used to generate new examples, thus evolving the fitness function. Examples were accepted of 60% of turkers reached consensus

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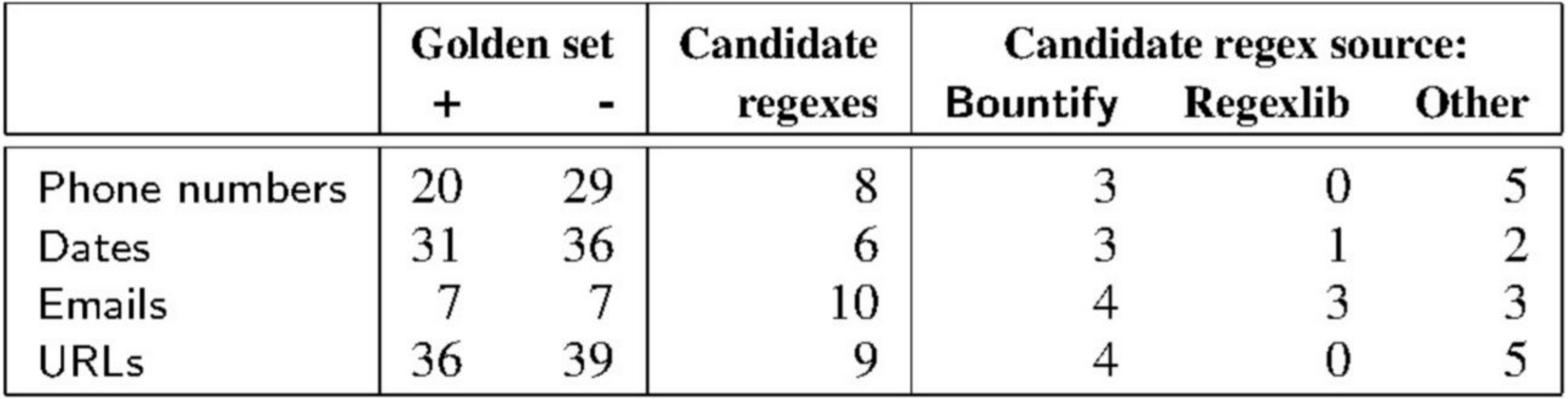
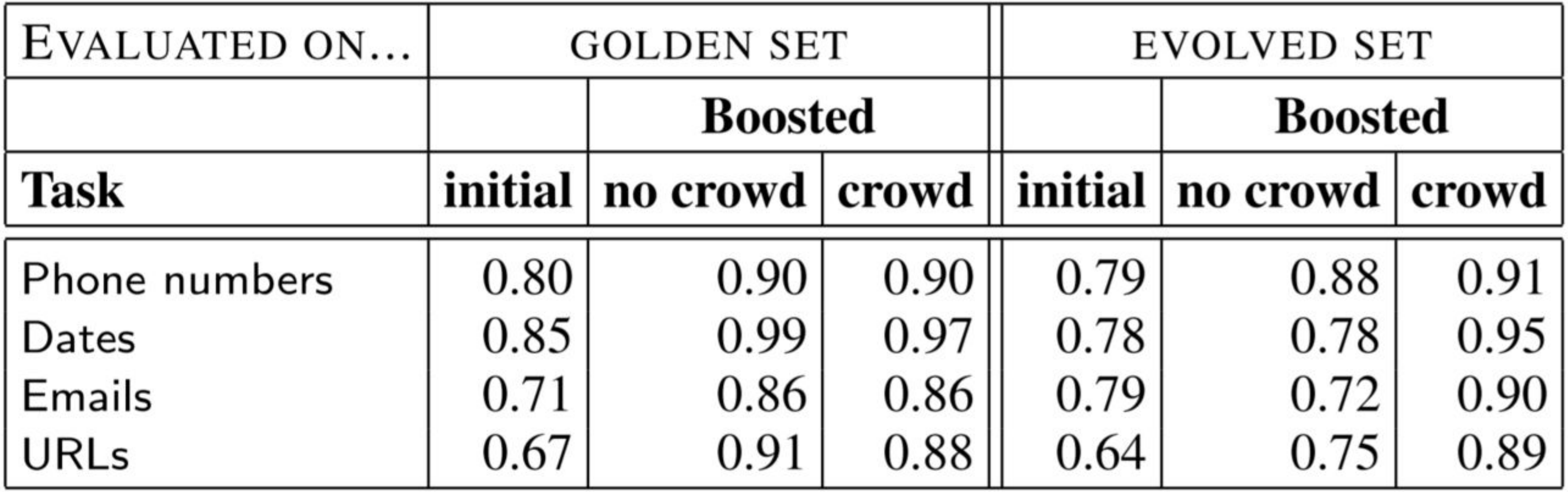


	Golden set		Candidate	Candidate regex source:		
	+	-	regexes	Bountify	Regexlib	Other
Phone numbers	20	29	8	3	0	5
Dates	31	36	6	3	1	2
Emails	7	7	10	4	3	3
URLs	36	39	9	4	0	5

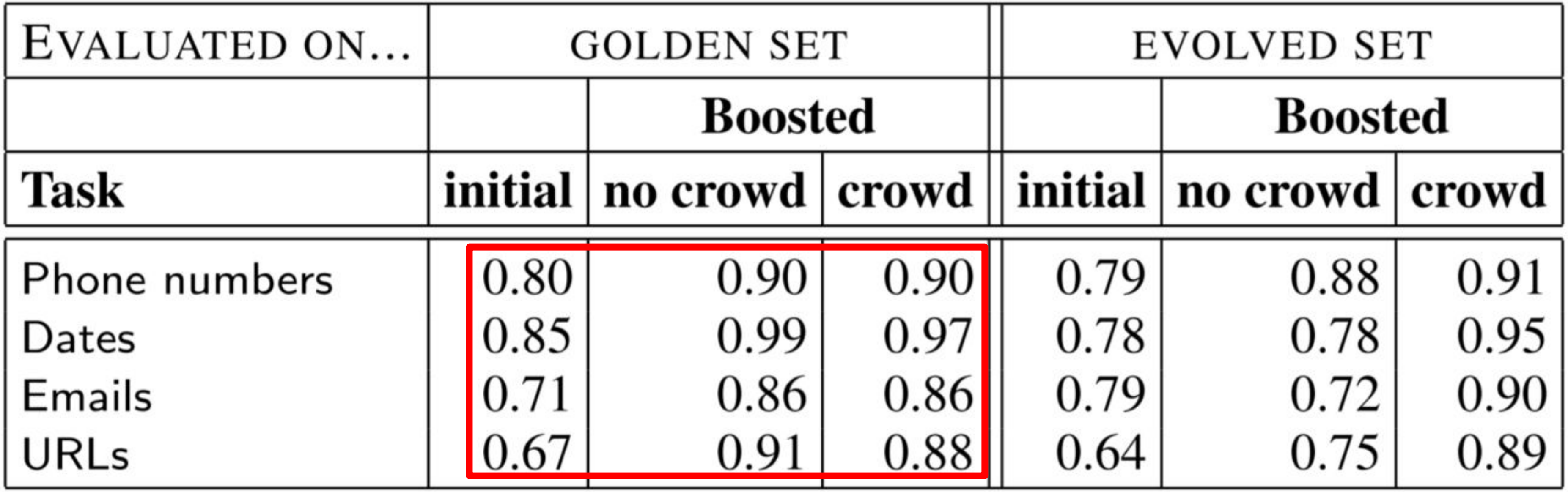
Results - Accuracy



EVALUATED ON...	GOLDEN SET			EVOLVED SET		
		Boosted			**Boosted**	
Task	**initial**	**no crowd**	**crowd**	**initial**	**no crowd**	**crowd**
Phone numbers	0.80	0.90	0.90	0.79	0.88	0.91
Dates	0.85	0.99	0.97	0.78	0.78	0.95
Emails	0.71	0.86	0.86	0.79	0.72	0.90
URLs	0.67	0.91	0.88	0.64	0.75	0.89

Results - Accuracy

Crowd Boosting does not help with the Golden Set



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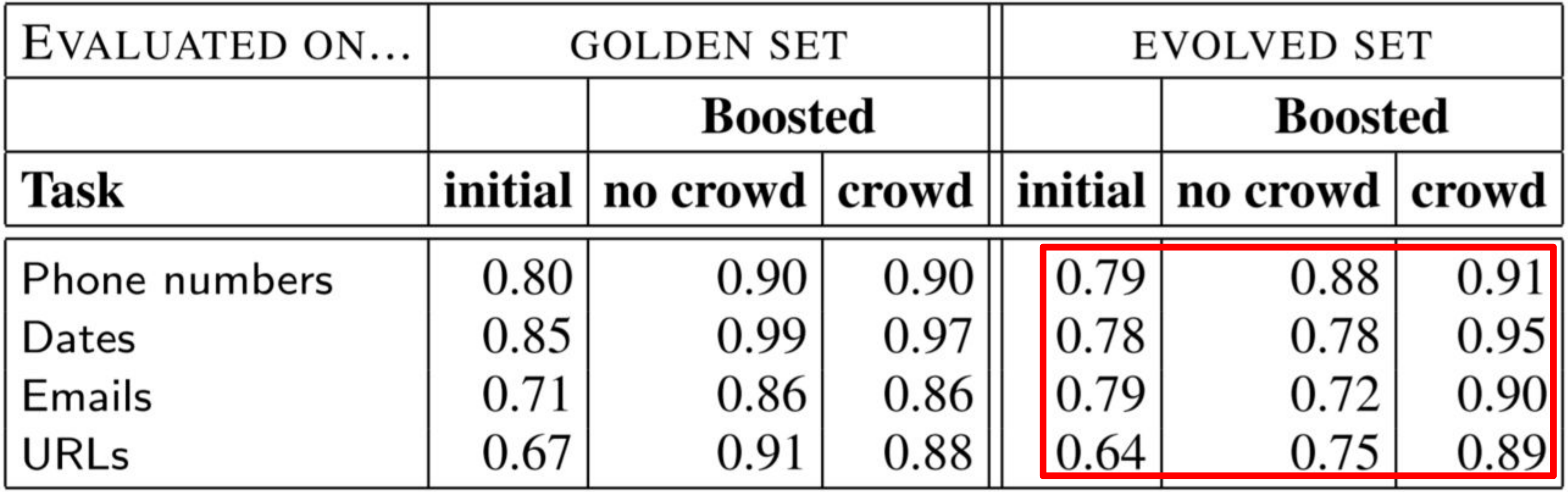

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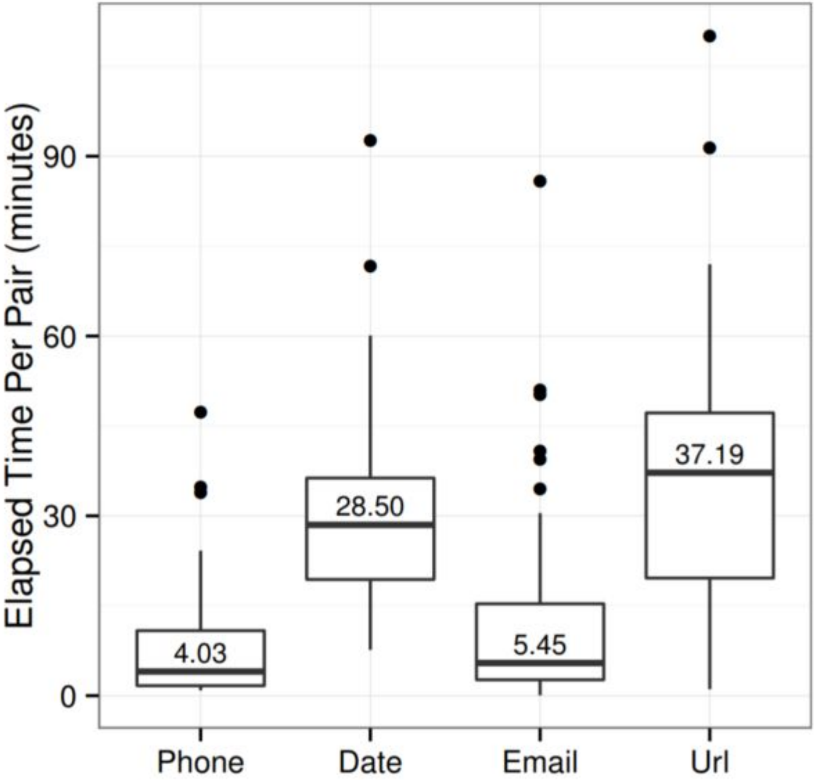
Results - Runtime

Runtimes are reasonable, especially for synthesizing a program



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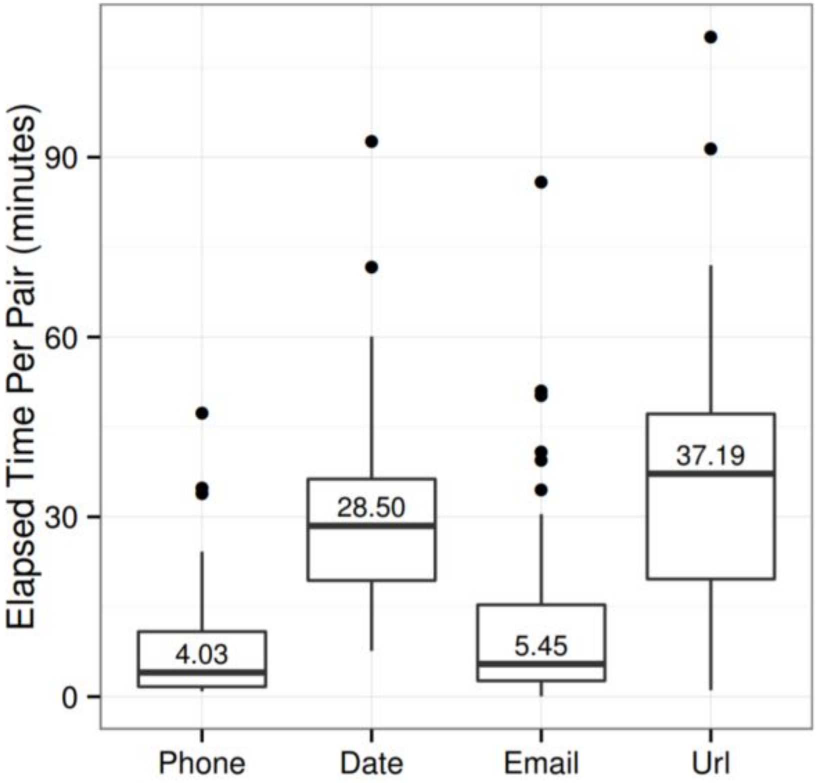
This does **not** include the time required to source the RegExs

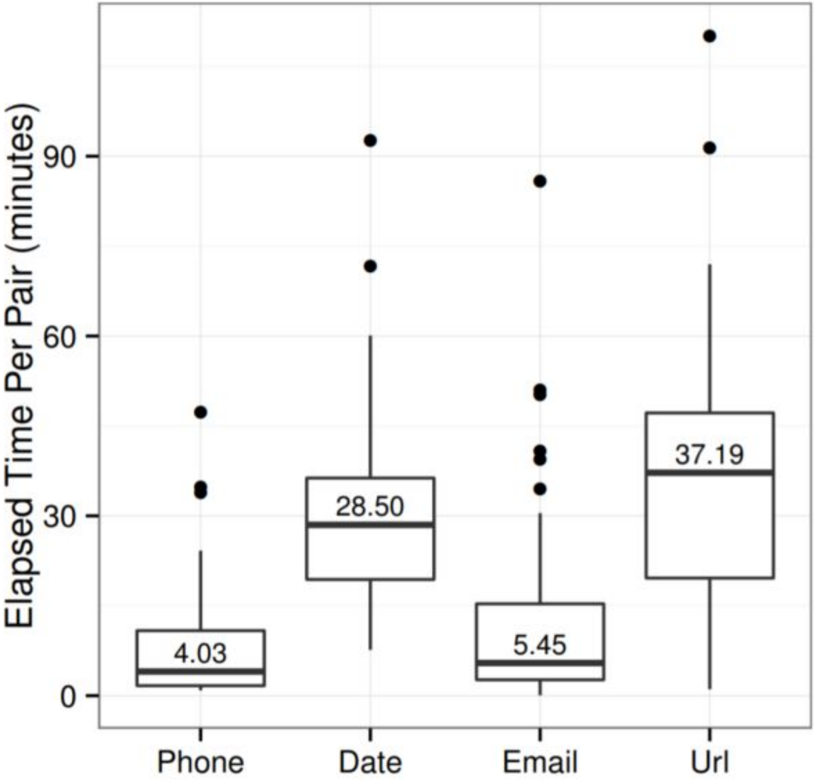


Results - Runtime

Runtimes are reasonable, especially for synthesizing a program

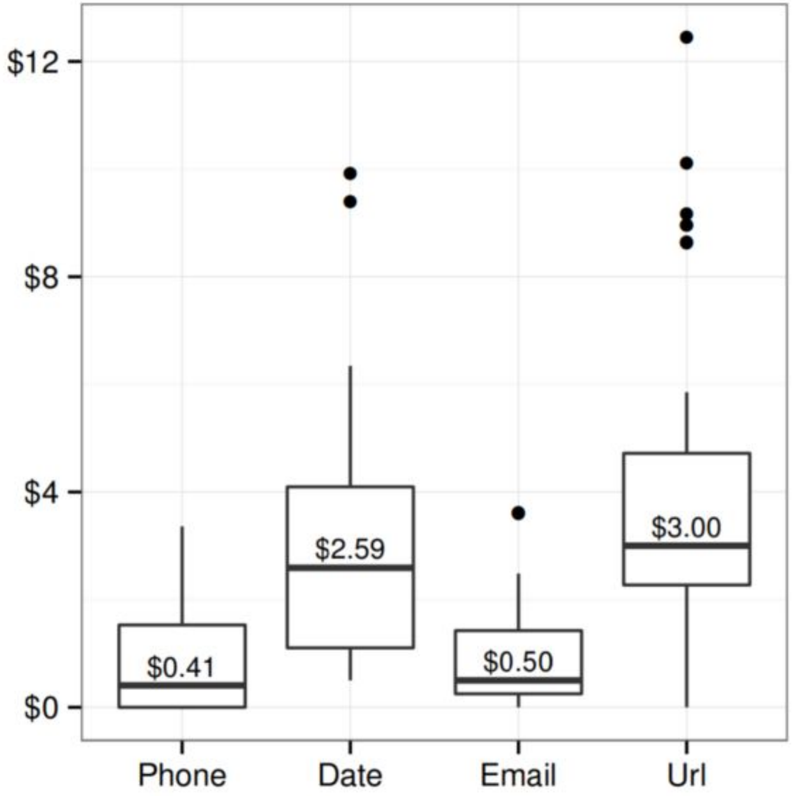
This does **not** include the time required to source the RegExs

It is not clear from the paper whether this result includes time required for mechanical turkers



Results - Cost

Overall, costs are reasonable



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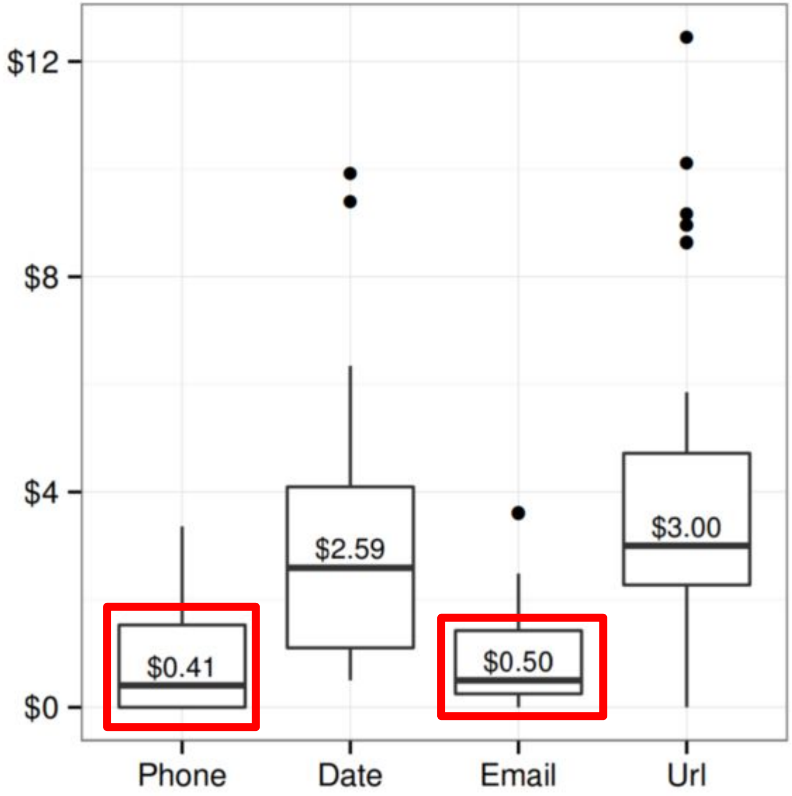

Phone and email are cheap. Why?

Outline

Introduction (Research Question, Key Ideas, Contributions)

Background (Genetic Programming and Regular Expressions)

Motivating Example

Evaluation

Discussion

Discussion Questions

1. What kind of ethical issues might arise by involving crowd sourcing in development?

Discussion Questions

2. What are some practical limitations of using large numbers of untrained workers such as mechanical turkers?

Discussion Questions

3. What are some new research questions posed by this new paradigm wherein the fitness function is evolves along with the population?

Discussion Questions

4. What are some weaknesses of genetic programming that persist even through crowd-sourcing?

Discussion Questions

5. What other open problems might you imagine applying a similar (crowdsourcing followed by some form of program synthesis) approach to?