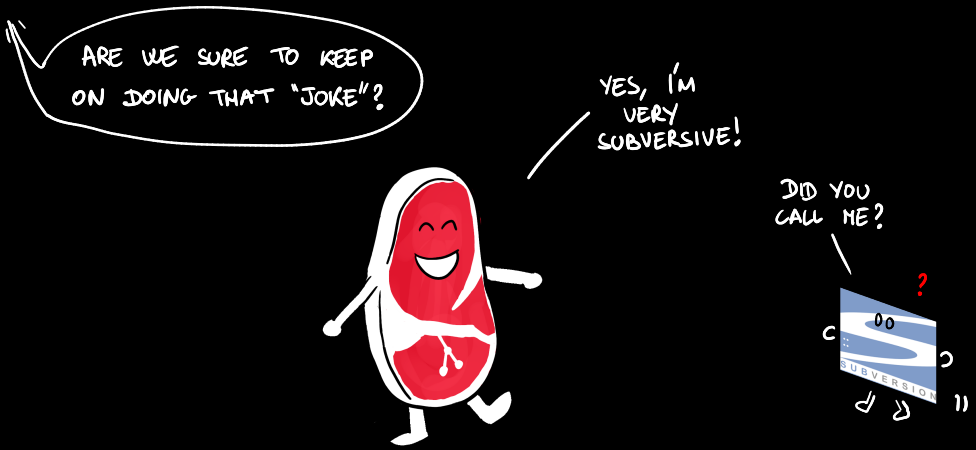
Theoretical Analysis of Git Bisect

Julien COURTIEL (Université de Caen Normandie)
with Paul DORBEC and Romain LECOQ (Université de Caen Normandie)

Journées APR (30 Juin 2024)

Part 1 Looking for the Faulty Commit



QUESTION: What do you use to share files with your coauthors?

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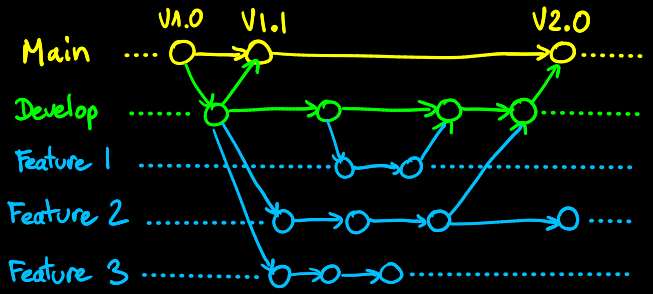
GIT AND ITS COMMIT GRAPHS

git is a distributed version control system where the revisions (or "commits") are arranged as a Directed Acyclic Graph (DAG)



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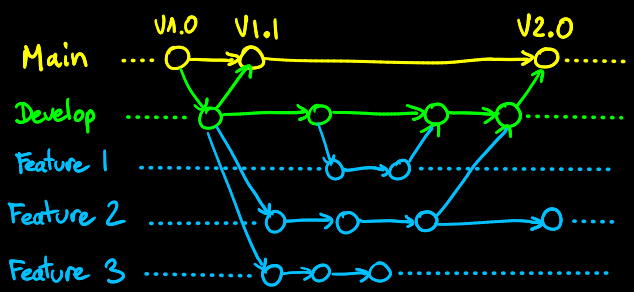
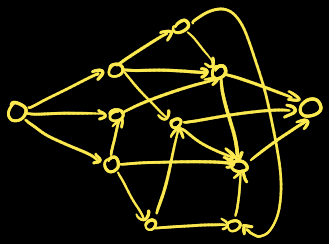


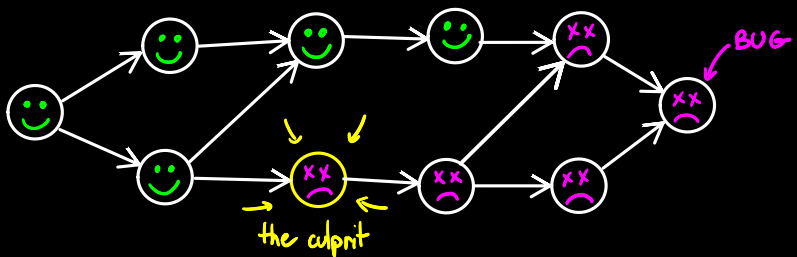
Commit graph

or



Also a legit commit graph!

PROBLEM: FINDING A REGRESSION



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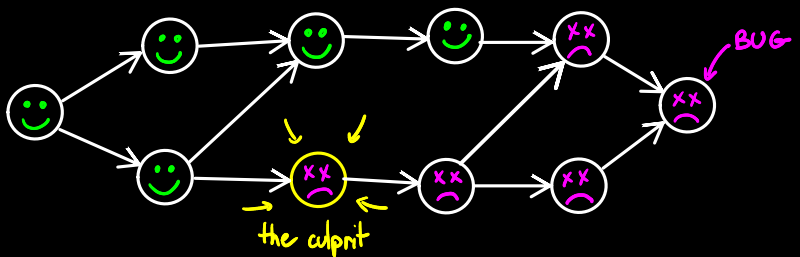

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Assumption If a parent of a commit is bugged, then the commit is bugged.

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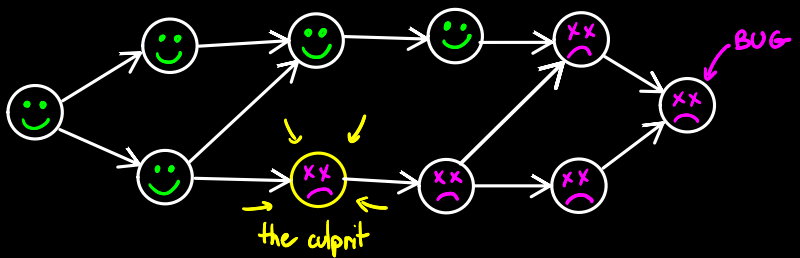

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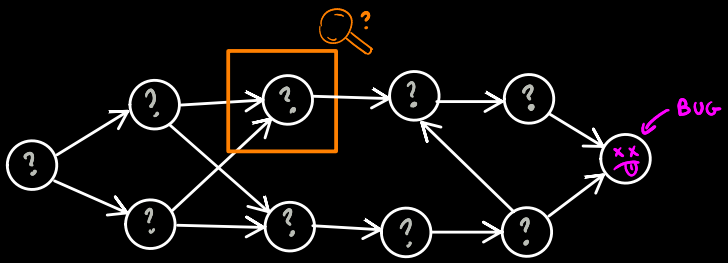
Assumptions
- If a parent of a commit is bugged, then the commit is bugged.
- Only one commit has introduced the bug, namely the faulty commit (or regression)

HOW TO INVESTIGATE

Unique operation: QUERY of a commit with unknown status



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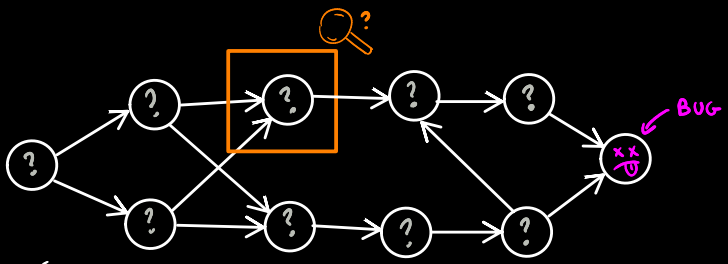
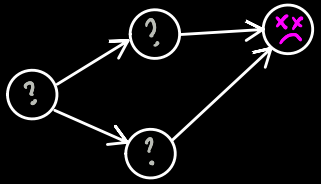


If bugged,

then the faulty commit is an ancestor of this commit



ancestor of a vertex v = v or an ancestor of a parent of v

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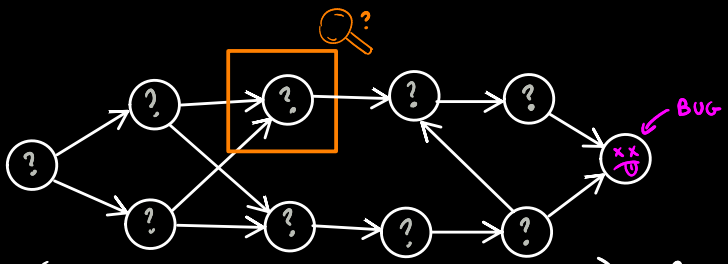

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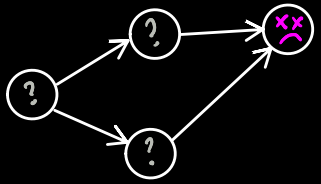

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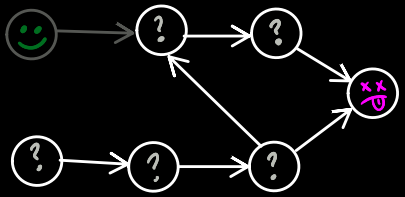

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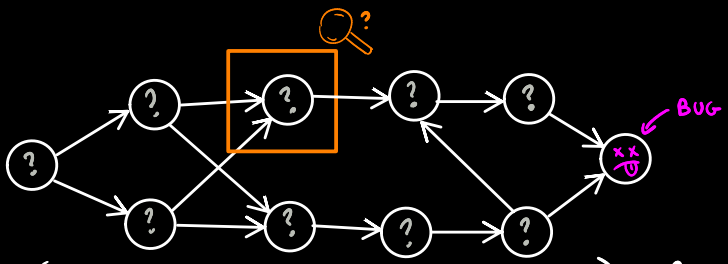

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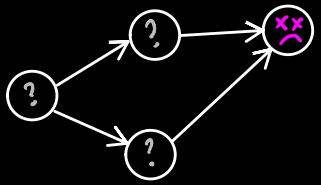

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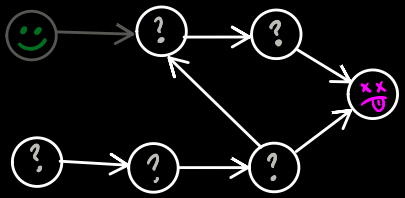
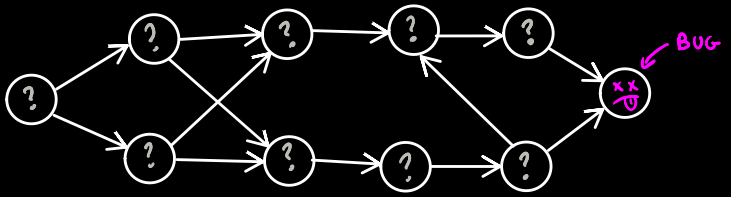


The faulty commit is found whenever there remains only 1 suspect.

REGRESSION SEARCH PROBLEM

Input: a DAG where each vertex has an unknown status, except one, which is bugged.



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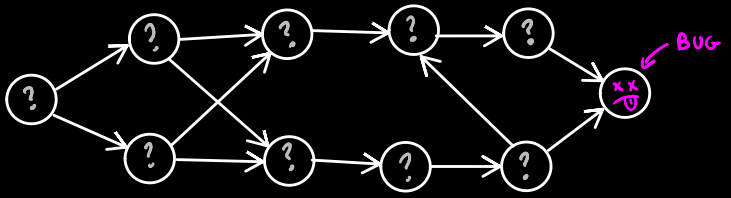

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In real life, queries are costly.

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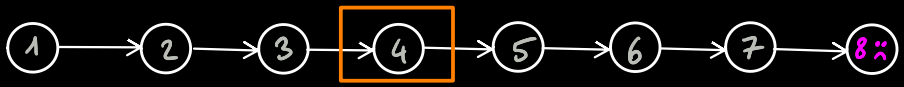

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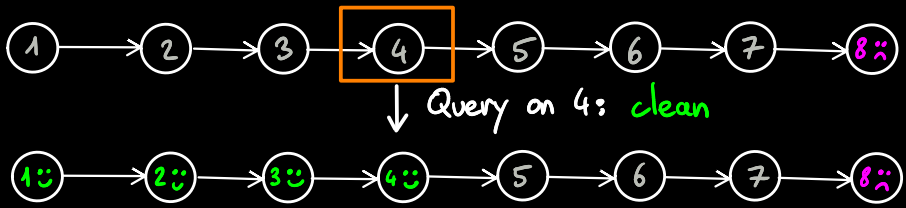

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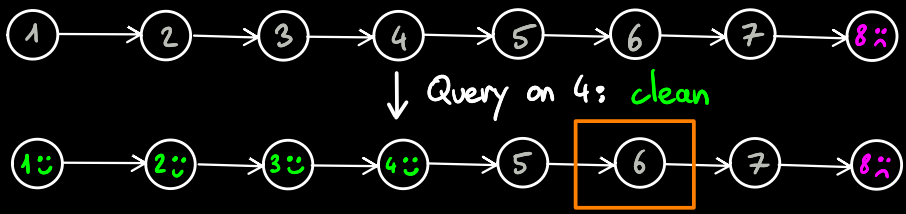

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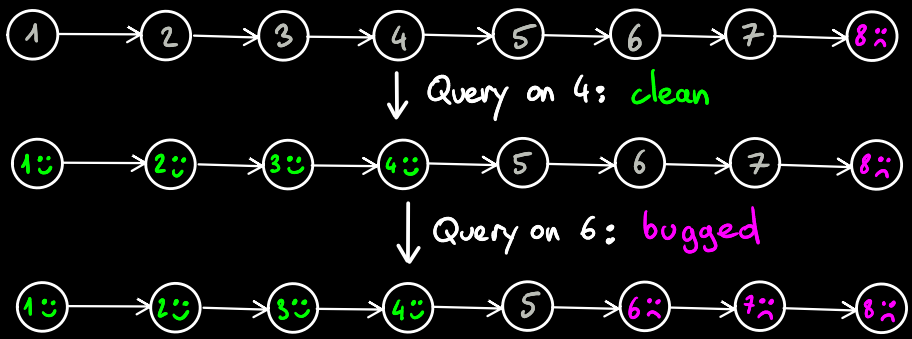

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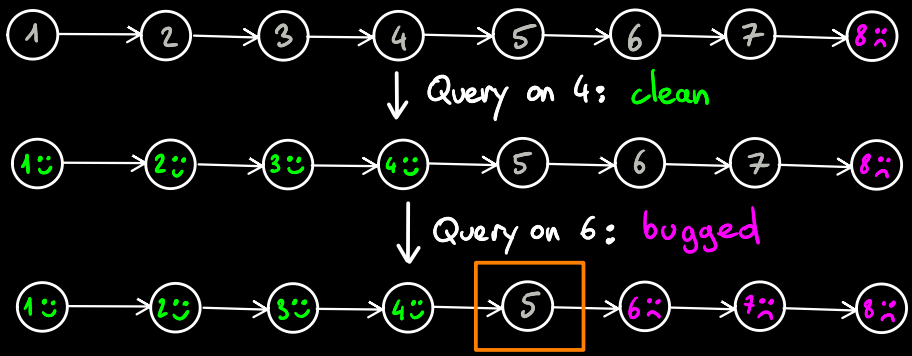

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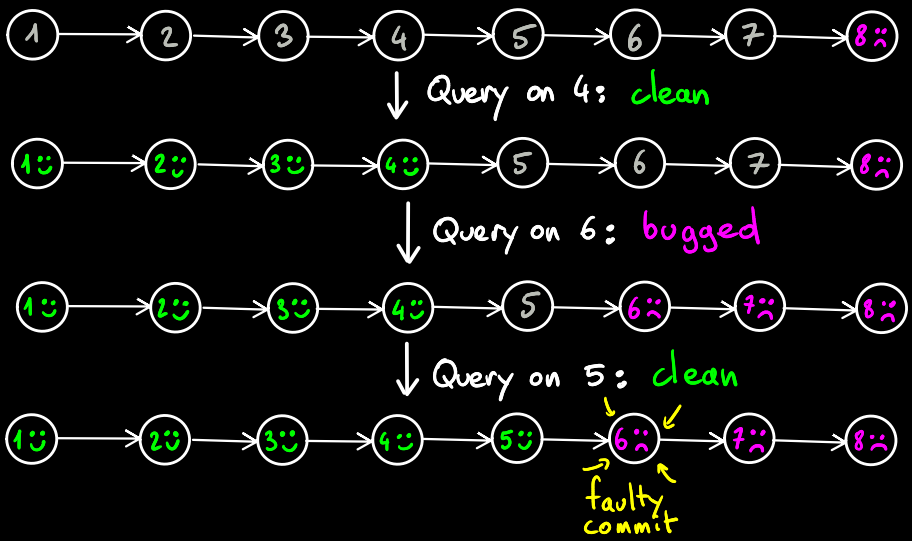

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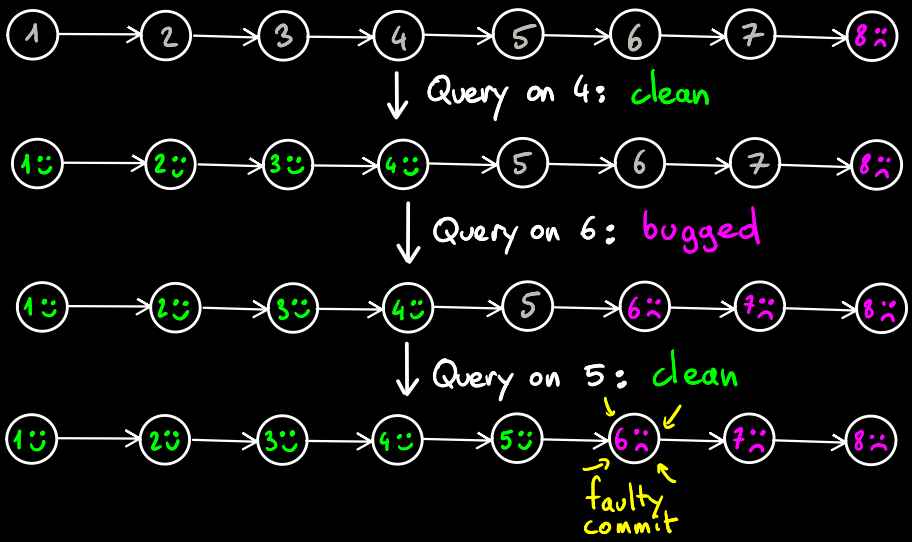

optimal strategy = binary search

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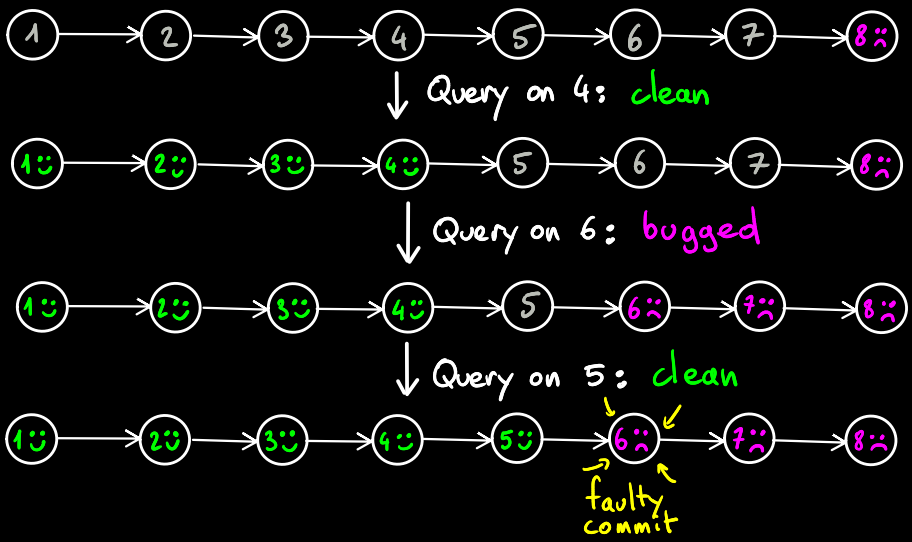
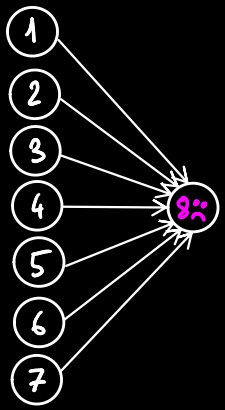


optimal strategy = binary search

More generally, number of queries in an optimal strategy in a chain of length $n = \lceil \log_2(n) \rceil$

SECOND EXAMPLE : OCTOPUSES



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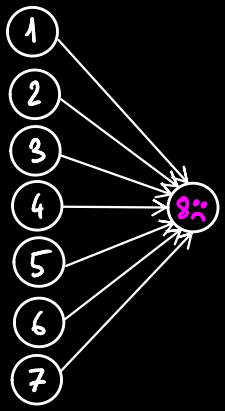


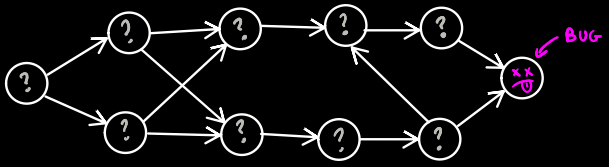
optimal strategy = whatever

More generally, number of queries in an optimal strategy in an octopus of size n = $n-1$

COMPLEXITY OF THE REGRESSION SEARCH PROBLEM

REGRESSION SEARCH PROBLEM (DECISION VERSION)

Input: a DAG where each vertex has an unknown status, except one, which is bugged + integer $k \geq 0$



Decide: Is there a strategy that finds the faulty commit with at most k queries in every scenario?

NP-complete for general DAGs

[Carmo Donadelli Kohayakawa Laber 2004]

[We've also proved it!]

but polynomial for trees ...

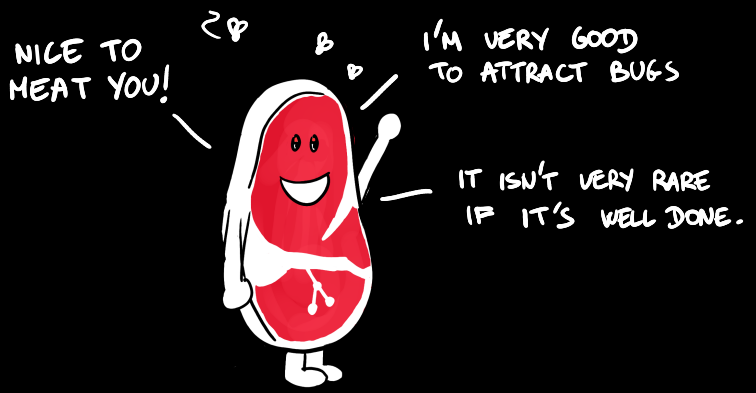
[Ben-Asher Farchi Newman 2000]

...more precisely, linear.

[Mozes Onak Weimann 2008]

The more well-known Decision Tree Problem generalizes the Regression Search Problem but it deals with the average case.

Part 11
Git Bisect



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git uses a heuristic to find the faulty commit: git bisect

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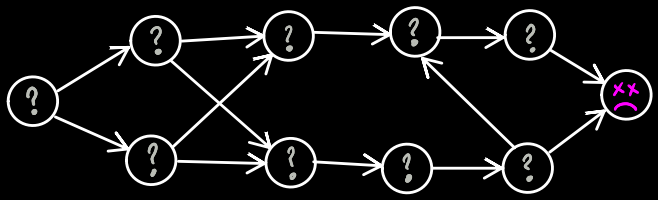

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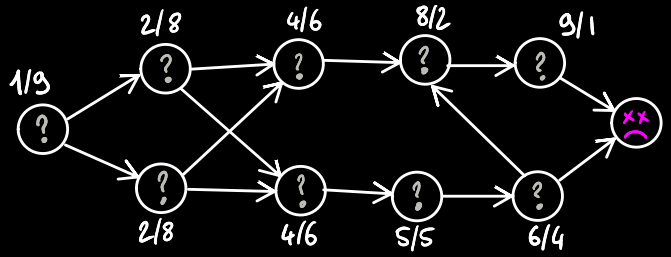

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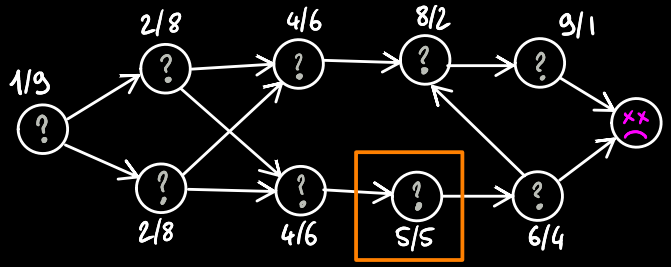

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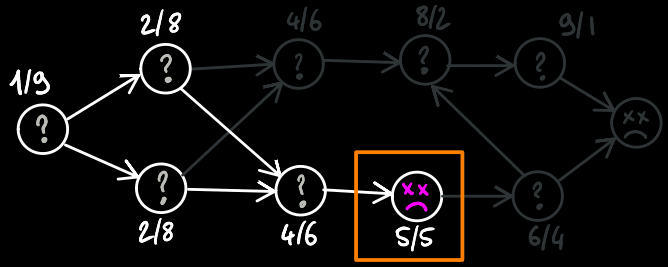

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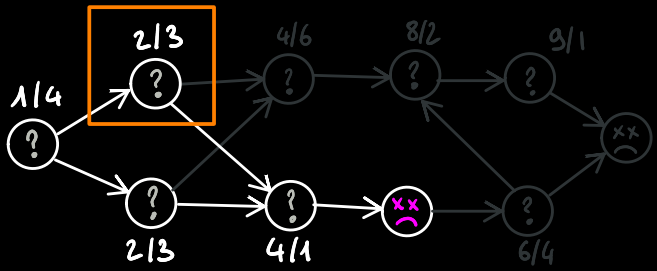

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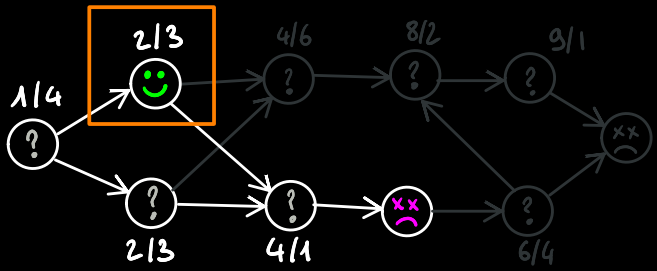

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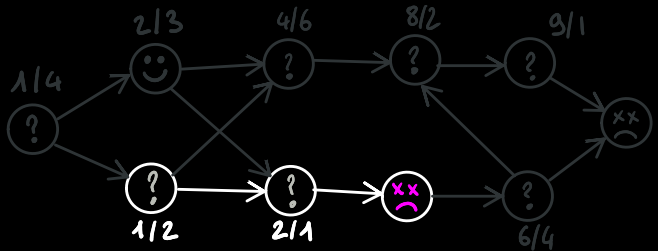

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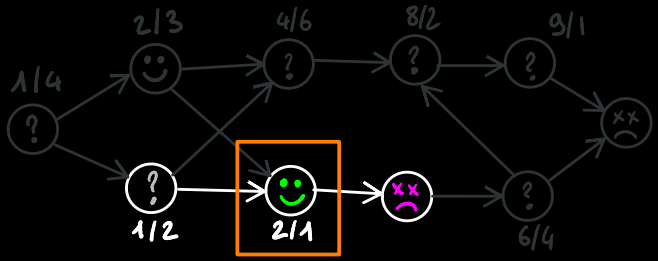

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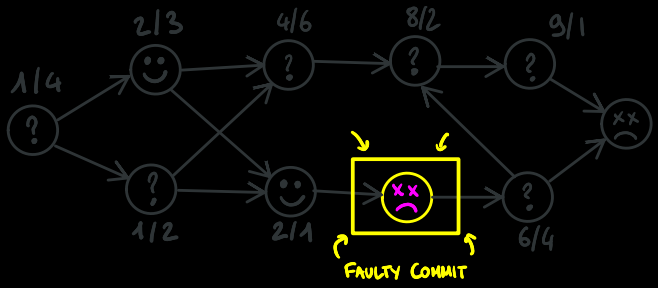

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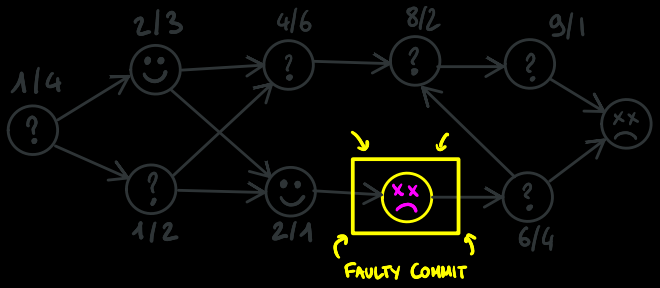

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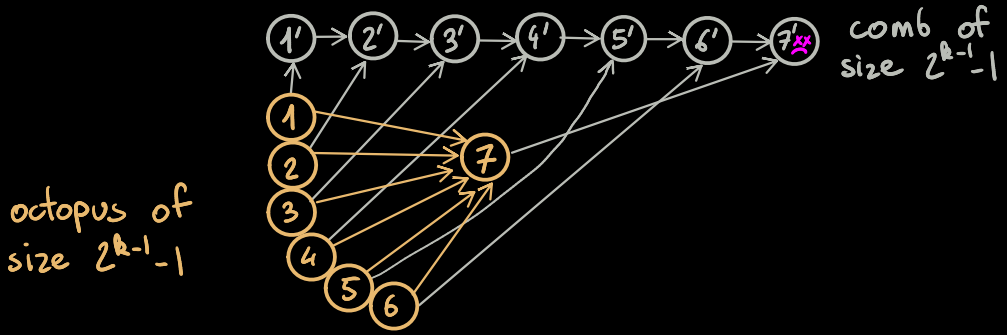
Proof for $k=4$:



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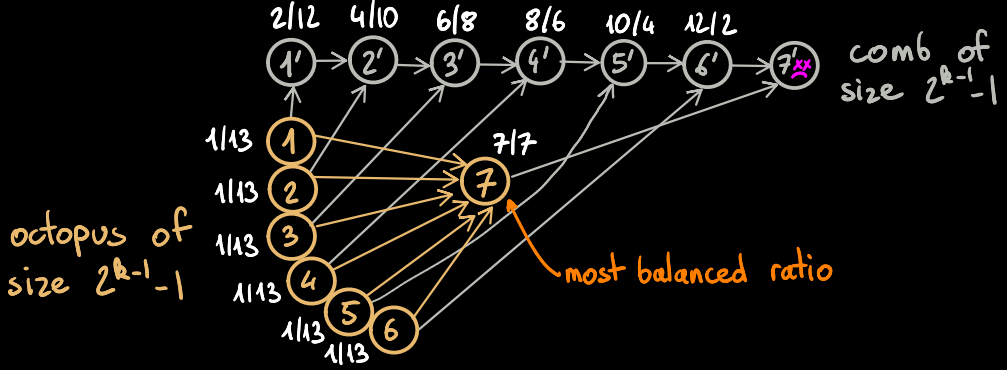
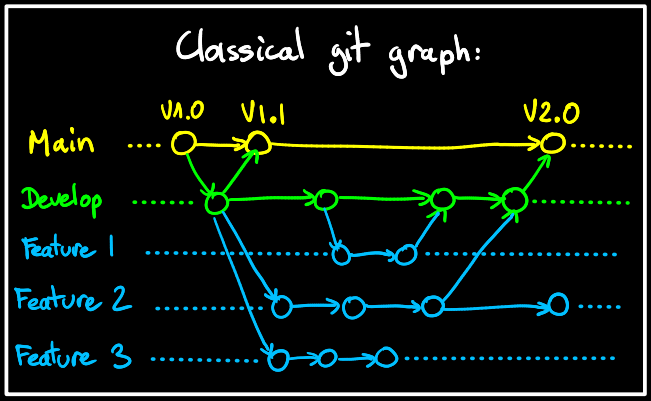


BACK TO REALITY?

Octopus substructures are unrealistic

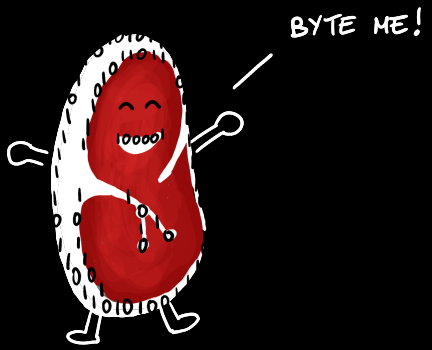


Usually, we never merge more than 2 branches.

(Otherwise it is called an octopus merge

)

Part III - git bisect on binary DAGs

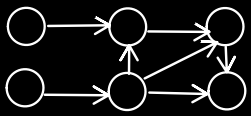


BINARY DAG

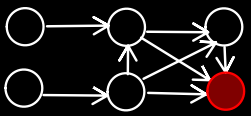
Definition

binary DAG = DAG where the vertices have indegree ≤ 2

Ex:



Good



Bad

Theorem

git bisect is a $\frac{1}{\log_2(\frac{3}{2})}$-approximation algorithm when it is used on binary DAGs.

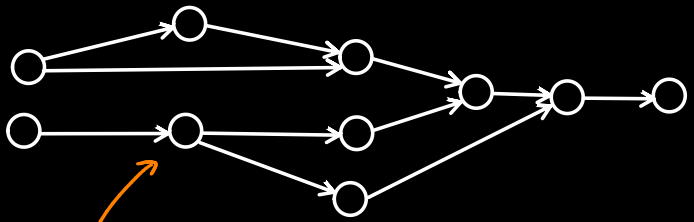
$\frac{1}{\log_2(\frac{3}{2})} \simeq 1{,}71$ is the optimal constant.

EXISTENCE OF A BALANCED VERTEX

Lemma

Any binary DAG with n vertices has a vertex x such that

$$\frac{n}{3} \leq \text{nb of ancestors of } x \leq \frac{2n+1}{3}$$



Where is it?

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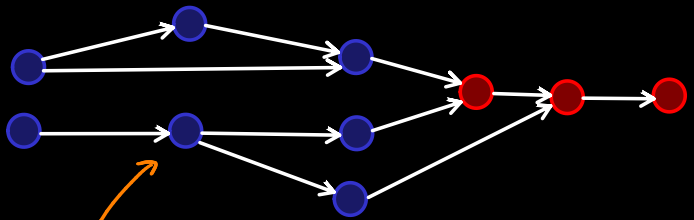

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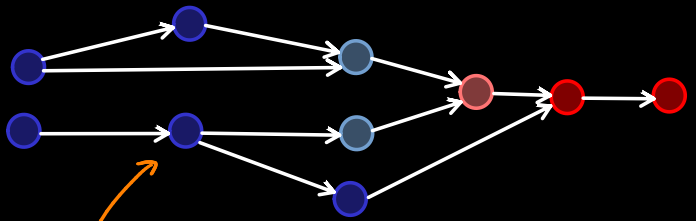

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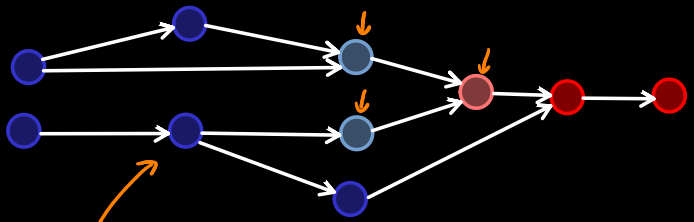
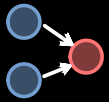


Where is it?

It's in any



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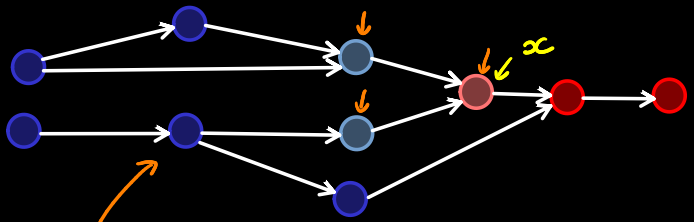

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Proof of the $\frac{1}{\log_2(\frac{3}{2})}$-approximation:

At each query, git bisect eliminates $\geq 1/3$ commits by choosing x or a better vertex

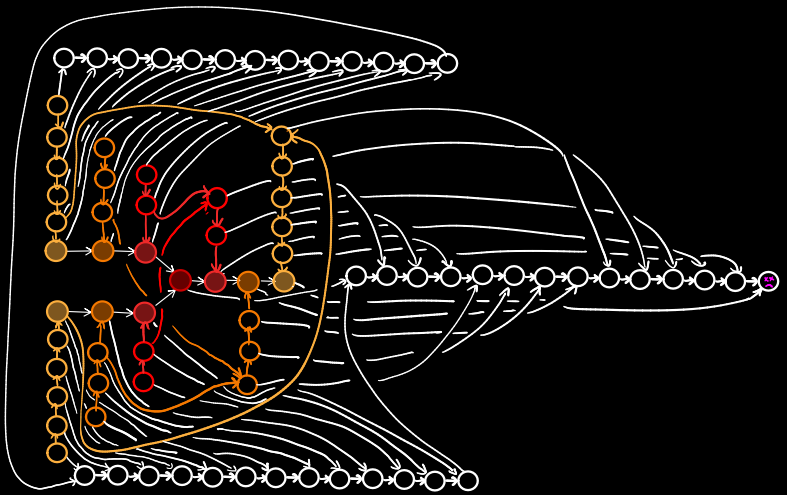
- number of git bisect queries $\simeq \log_{\frac{3}{2}}(n)$
- optimal number of queries $\geq \log_2(n)$

Problematic binary DAGs for git bisect

For every $k > 0$, there exists a binary DAG with:

- $\simeq 6k \left(\frac{3}{2}\right)^k$ vertices,
- $\geqslant k$ git bisect queries,
- $\simeq \log_2\left(\frac{3}{2}\right) \times k$ queries in the optimal strategy.

e.g. for $k = 3$:



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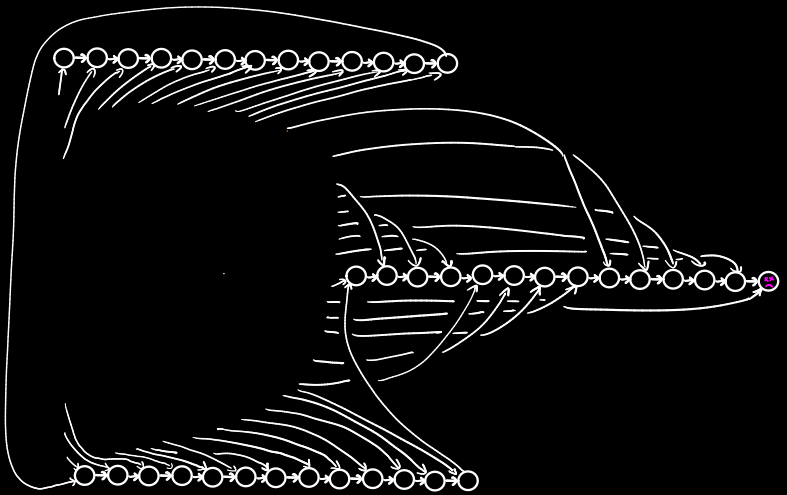

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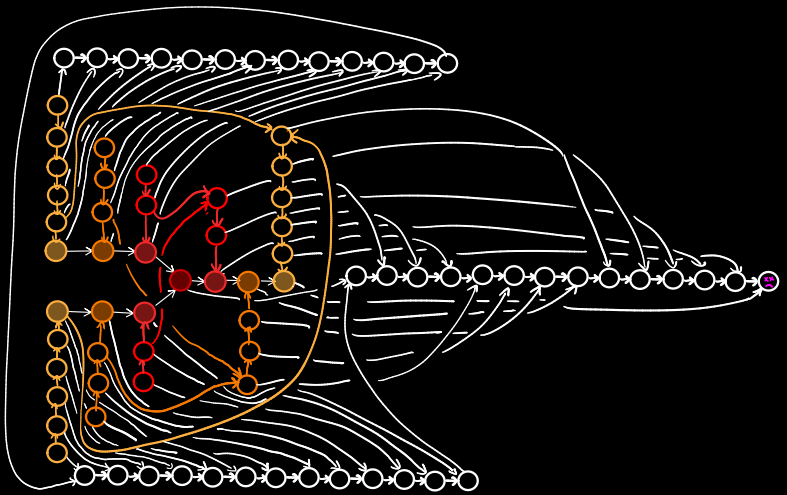

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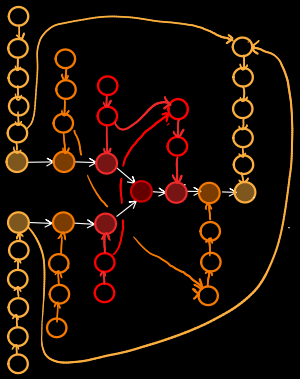

A BETTER ALGORITHM? GOLDEN BISECT

theoritical analysis of git bisect → new (better?) algorithm

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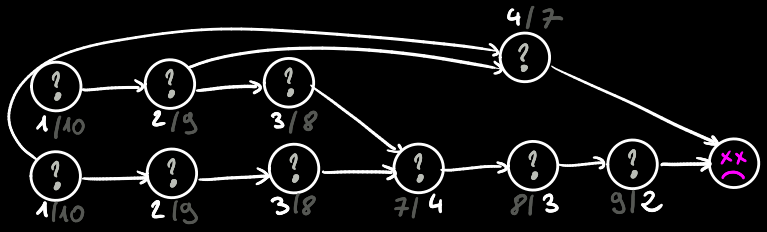
☆ GOLDEN BISECT ☆

Step 1: Compute the number of ancestors/number of non-ancestors for each vertex and keep the smaller of the 2 numbers.



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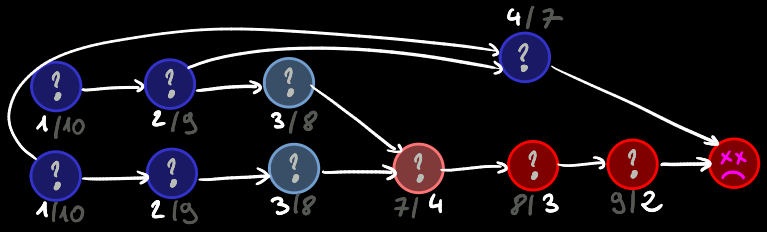

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ϕ = golden ratio = $\frac{1+\sqrt{5}}{2}$

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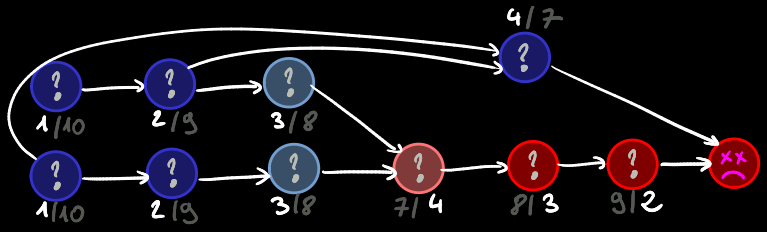

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- 🟣 = 🔴 where all parents are 🔵
- 🟣 = 🔵 parent of a 🔴

Step 3: Delete the innocent commits and recurse.

THEORETICAL ANALYSIS OF GOLDEN BISECT

Theorem

golden bisect is a $\frac{1}{\log_2(\phi)}$ - approximation algorithm for binary DAGs, where ϕ = golden ratio.

$\frac{1}{\log_2(\phi)} \simeq 1{,}44$ is the optimal constant.

But sometimes git bisect is better than golden bisect!

OPEN QUESTIONS

→ Is the Regression Search Problem NP-complete when restricted to binary DAGs?

(We proved that a variant, the Confined Regression Search Problem is NP-complete for binary DAGs)

→ study of git bisect in average case?

but what is a random "git graph"?

(⇒ definition of git graph in [Lecoq's PhD], random generation in [C., Pépin])

→ Is git-bisect a 2-approximation algorithm for trees?

THANK YOU!