Git's merge algorithm seems to have inexplicable semantics leading to some interesting cases. I describe a couple of examples below. The bottom line is that:

1. Git merge is inconsistent: Merge result seems to depend not just on *what* versions were merged, but also *how* they were merged. Thus two branches that pulled the same set of user commits may end up with different versions.
2. Git merge is unintuitive: The result of a successful (auto) merge may not necessarily be what we expect.

Note that I distinguish between user commits and merge commits in this post. Assuming that all merges are automerges (i.e., there are no merge conflicts), I expect two branches with same history of user commits to be consistent, i.e., have the same final version.

Example 1

This example shows that Git automerging leads to inconsistent results. Thus if you and your colleague are working on parallel branches with exact same set of user commits, your code may still have vulnerabilities and bugs that your colleague's code doesn't. So you have to independently review your code notwithstanding

your colleague's assurances.

To demonstrate this point, let's start with a file `foo.js` containing Javascript/JQuery pseudo-code:

```
/*some computation on data happens here */

$.ajax({
  type: "POST",
  url: url,
  data: encrypt(data),
  success: function(response) {
    $(".result").html(response);
  }),
  dataType: "text"
});
```

Let's commit it to master:

```
git init; git add foo.js; git commit -m "foo.js added"
```

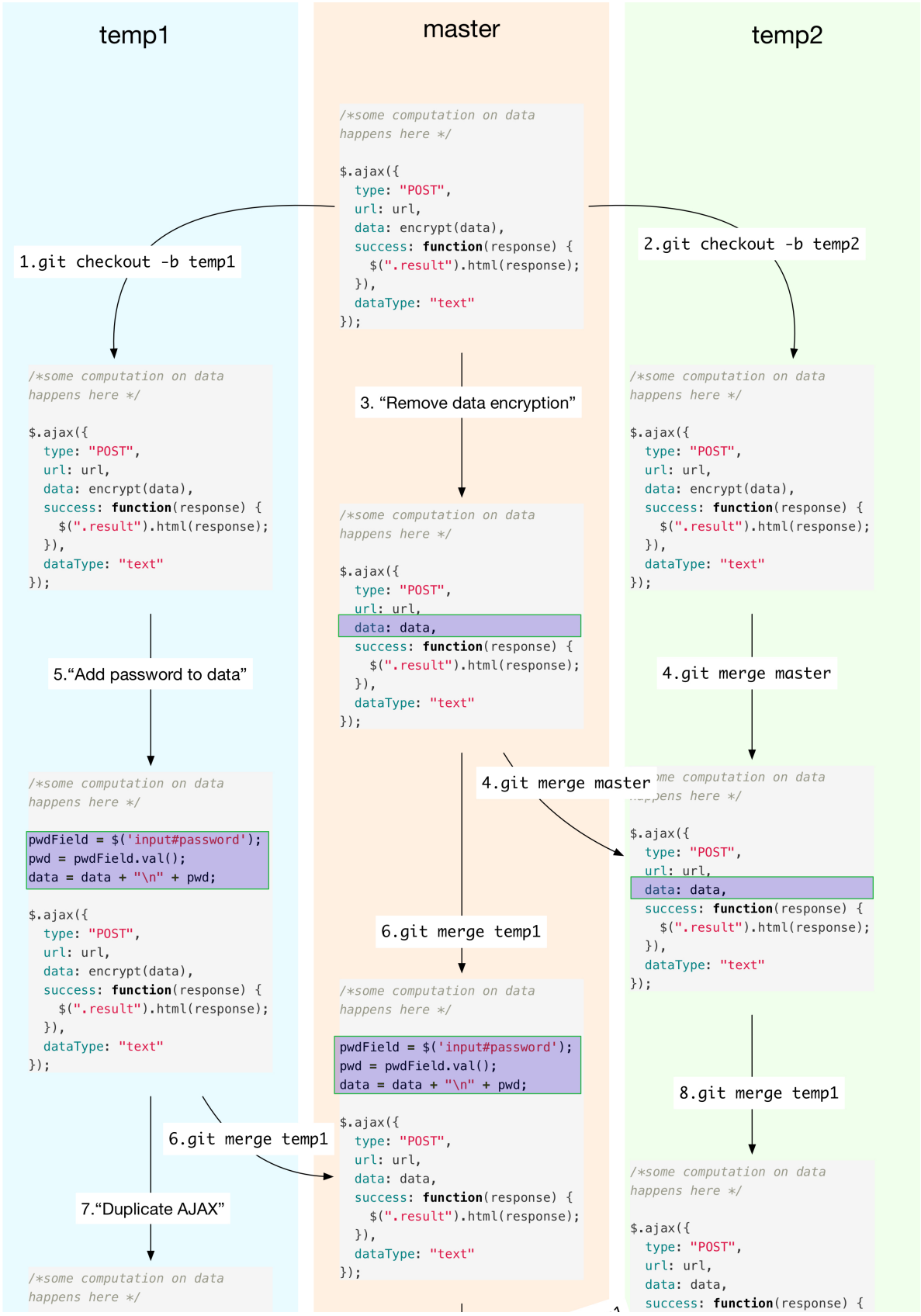
Now fork two branches, `temp1` and `temp2`, from master:

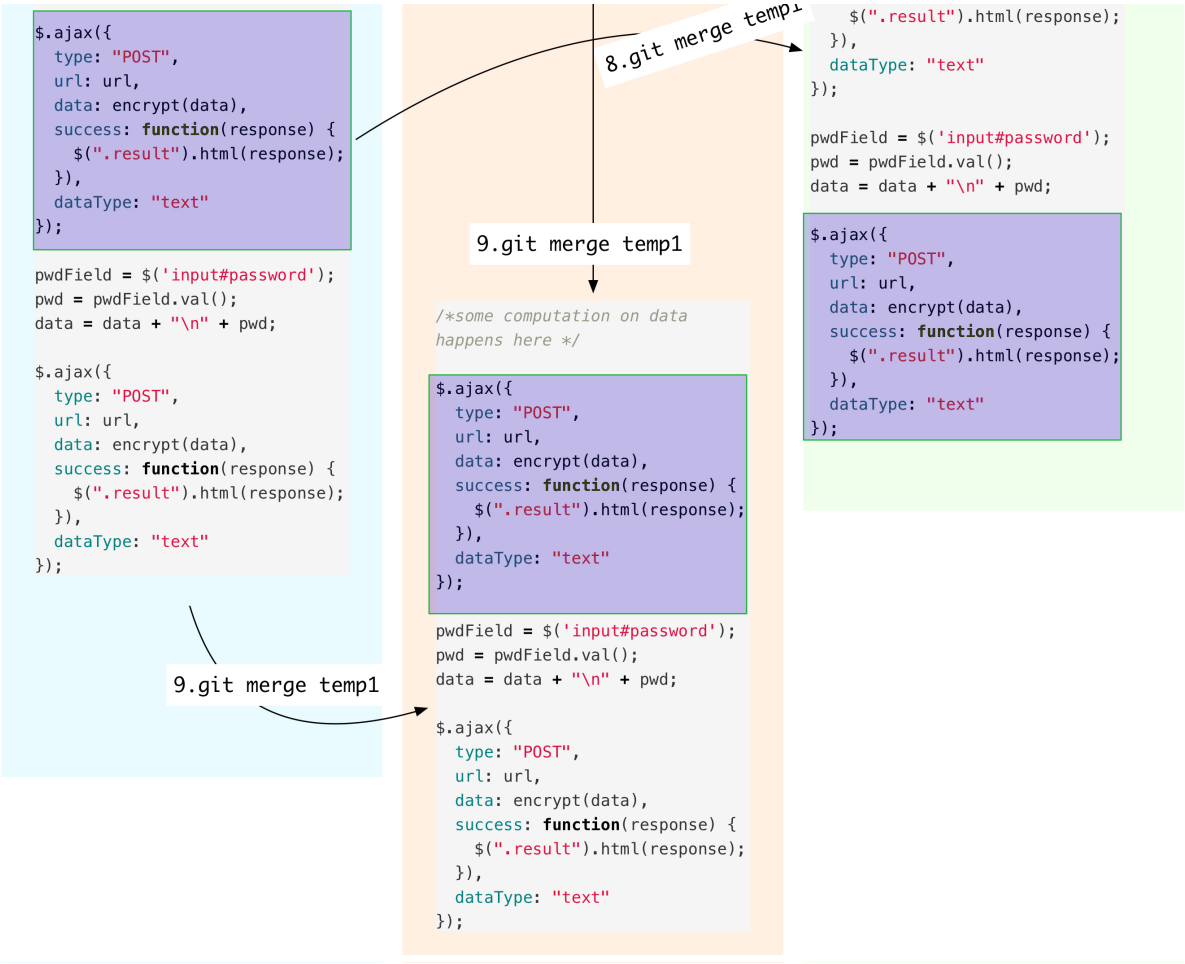
```
git checkout -b temp1; git checkout master
git checkout -b temp2; git checkout master
```

With three branches in place, let us manifest the version control graph shown in the below figure. Vertices in the graph are distinct versions. The diff of each version w.r.t its parent is highlighted. Edges leading to a version are labeled with the Git actions that led to the version. In case of a `git commit`, only the commit message is shown (in quotes). The actions are numbered, and each action is explained in greater detail below the figure. Each of

the three branches is assigned a different color background.

Now take a look at the version graph, and follow the explanation below the figure to understand it.





Actions 1 and 2 fork branches `temp1` and `temp2` as described previously. Actions 3-9 do the following:

- Action 3: On the master branch, we might decide to remove encryption as `data` contains nothing sensitive.
- Action 4: Your colleague Alice starts development on `temp2` by fast-forwarding it to current master (your latest version).
- Action 5: Independently on `temp1` branch, your other colleague Bob decides to add sensitive information (password) to `data` since it is anyway sent encrypted.
- Action 6: You pull the latest changes from Bob. Git automerges, and says everything is fine. You don't do anything.
- Action 7: On `temp1`, Bob may decide to commit a version that

sends the data twice, for whatever reason.

- Action 8: Alice pulls Bob's latest version from `temp1` onto `temp2`. She decides to review the code and sees two AJAX POSTS - first without data encryption and second with encryption. Since password is only sent the second time, she finds nothing wrong with the code, hence signs it off.
- Action 9: Now you pull Bob's latest version from `temp1`. You want to review the code, but learn that Alice has already signed off her code on `temp2` which has the same history of user commits as yours (see below). Relying on Alice's judgment, you sign off your code and deploy in production.
- Your code now sends passwords unencrypted although Alice's doesn't.

  You can see the this example on Github with few minor changes: I used branch `main` instead of master, and `sha256` instead of `encrypt`.

  The final commit histories of `main` and `temp2` are shown below. Observe that both branches have same set of user-generated commits (`3e3256`, `31001b`, `73a645`, and `8004f4`). The merge commits are all result of Git's automerge.

```
$git branch
  main
  master
  temp1
* temp2
$git log
commit 291329350e5ede0163ebdf9cb31ab0ad207ebb18
```

```
(HEAD -> temp2)
Merge: 31001b0 8004f40
Author: GitUser <gituser@example.com>
Date:   Mon Nov 25 07:25:45 2019 -0500

    Merge branch 'temp1' into temp2

commit 8004f40b718538d53458f2218b52f81c8c7e43a1
(temp1)
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 20:06:16 2019 -0500

    two ajaxes now

commit 73a645e9803b74dd9eac212ec706eb01fa328c5e
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 20:03:01 2019 -0500

    pwd added

commit 31001b08380cad566d83b14ec1adecbb2836e399
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 19:52:49 2019 -0500

    removed sha256

commit 3e325647d435895b8b1f526fbde9bd9208a555e7
(master)
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 19:50:52 2019 -0500
```

```
    adding foo.js

$git checkout main
Switched to branch 'main'
$git log
commit a52b2517b747d7804fe02ae5bb7425ea57b5908f
(HEAD -> main)
Merge: b2c3403 8004f40
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 20:06:29 2019 -0500

    Merge branch 'temp1' into main

commit 8004f40b718538d53458f2218b52f81c8c7e43a1
(temp1)
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 20:06:16 2019 -0500

    two ajaxes now

commit b2c3403b4254bc01553871d06526c438c53f3952
Merge: 31001b0 73a645e
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 20:03:23 2019 -0500

    Merge branch 'temp1' into main

commit 73a645e9803b74dd9eac212ec706eb01fa328c5e
Author: GitUser <gituser@example.com>
```

```
Date:   Sun Nov 24 20:03:01 2019 -0500

    pwd added

commit 31001b08380cad566d83b14ec1adecbb2836e399
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 19:52:49 2019 -0500

    removed sha256

commit 3e325647d435895b8b1f526fbde9bd9208a555e7
(master)
Author: GitUser <gituser@example.com>
Date:   Sun Nov 24 19:50:52 2019 -0500

    adding foo.js
```

Example 2

In the previous example, branches `main` and `temp2` obtained the same set of user commits, but with different *number* of pulls/merges. `main` pulled from `temp1` in two steps – first merging the intermediate version, and then merging the final version, whereas `temp2` pulled only once – the final version. The inconsistency shows that the granularity of merges matter. I will now describe another example, which demonstrates that the merge result also depends on the *order* of merging branches. That is, two branches pull the same set of user commits, but still end up with different versions because they pull the commits in different orders. The example also involves a scenario where automerge

succeeds, but result doesn't agree with our intuition.

Similar to the previous example, let's start with a file `foo.js` containing Javascript/JQuery pseudo-code:

```
/*some computation on data */

$.ajax({
  type: "POST",
  data: encrypt(data),
  url: url,
  success: function(response) {
    $(".result").html(response);
  }),
  dataType: "text"
});
```

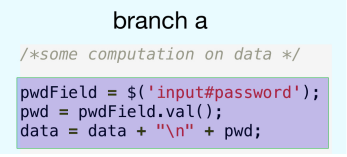
Let's commit it to master:

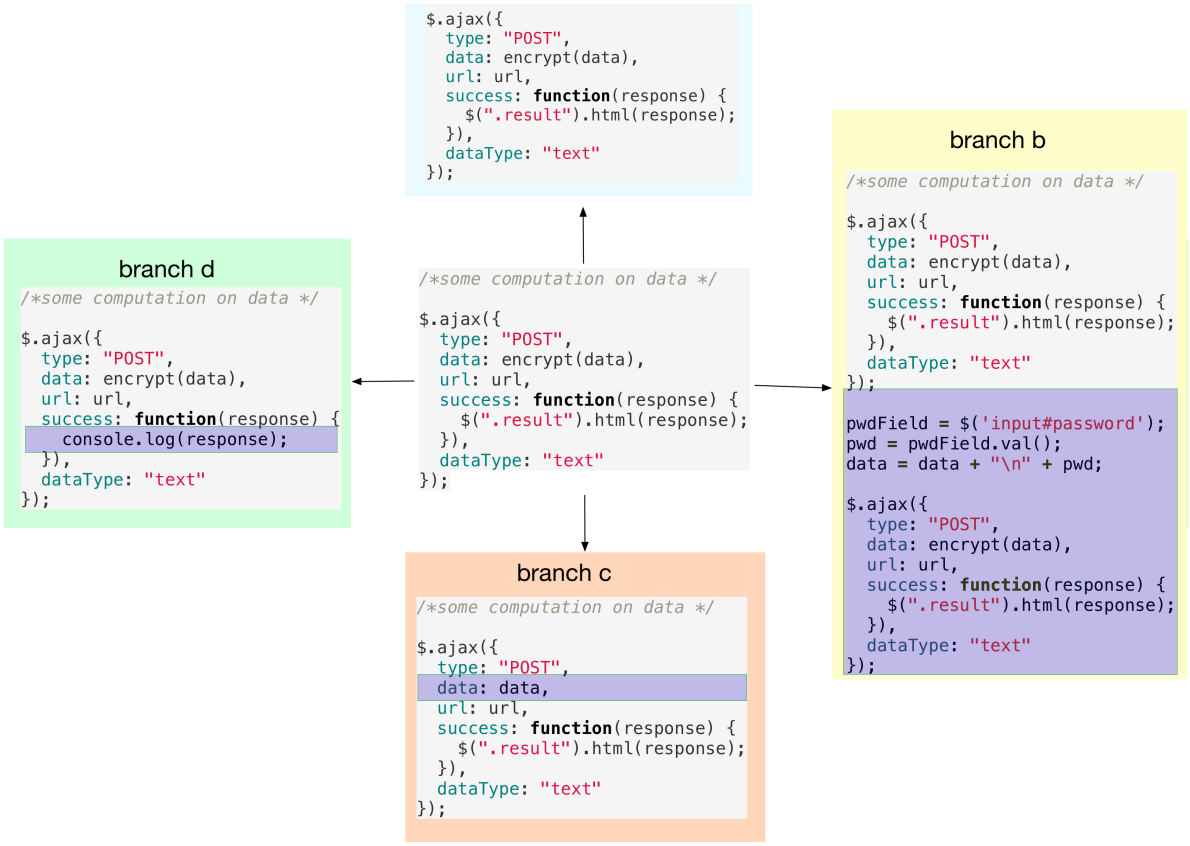
```
git init; git add foo.js; git commit -m "foo.js added"
```

Fork four branches, `a`, `b`, `c`, and `d`:

```
git checkout -b a; git checkout master
git checkout -b b; git checkout master
git checkout -b c; git checkout master
git checkout -b d; git checkout master
```

On each of the four branches, we make distinct changes to `foo.js` and commit. The four new commits are visualized in the figure below.





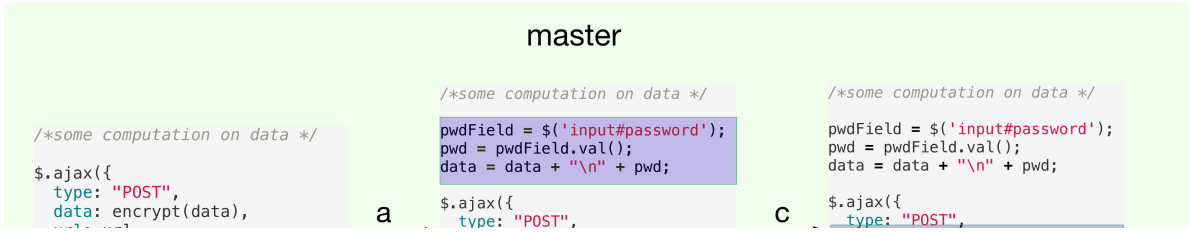
Let us now fork one more branch, `temp`, from master:

```
git checkout master; git checkout –b temp
```

We will now merge branches a, b, c, and d into master and `temp` in different orders and show that the resultant versions are different.

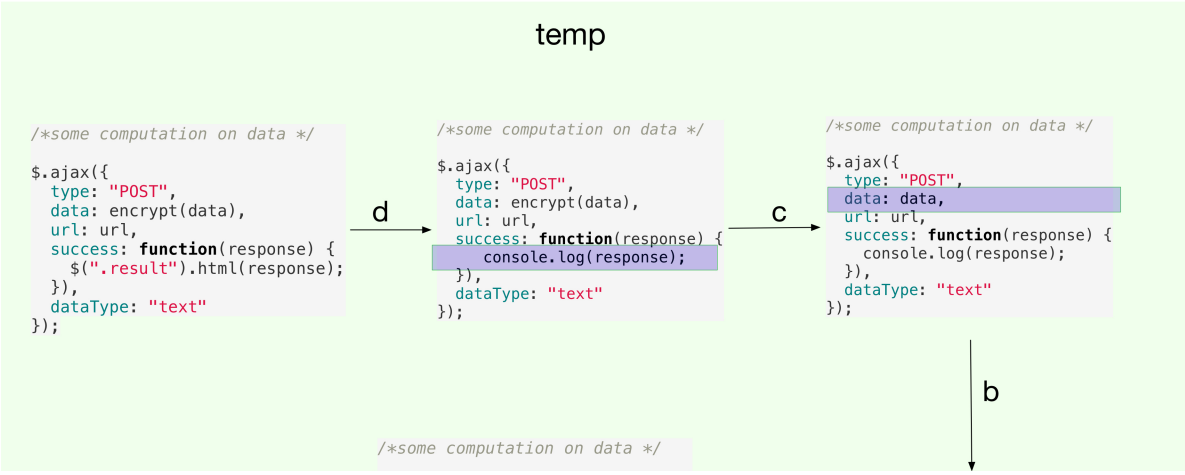
- On master, the merge order is a → c → b → d
- On `temp`, the merge order is d → c → b → a

Merges on master branch are visualized in the following figure. Each labeled edge represents a merge from the corresponding branch (branch heads are shown in the previous figure). As usual, the diff of each version w.r.t its previous version is highlighted.



As an aside, consider the merge from branch b. I would have expected the merge result to be a sequence of encrypted AJAX, followed by `data + pwd` logic, and finally unencrypted AJAX. A merge conflict would have been fine too! But the actual result has `data + pwd` logic twice interspersed by AJAX calls with unencrypted and encrypted data (resp.). This is puzzling.

Let us now focus on the `temp` branch. The merges on `temp` are visualized below:



Here again, the result of last merge (from a) is not what I expected. Given that the contents of a are contained inside the the merging `temp` version in the same order, I expected the merge to be the same as the previous version on `temp`. The actual result replicates `data + pwd` logic twice, and I don't understand why.

Leaving aside the concerns of intuitiveness, one can clearly see that that master and `temp` have different head versions even as both pulled the exact same versions albeit in different order. This shows that order in which merges are done does matter, which is a bit disconcerting.

Conclusion

The examples above demonstrate that Git merge could lead to inconsistent and unintuitive results. People who understand Git's merge algorithm can perhaps foresee such behaviors and work their way around them, however that's not a satisfactory justification for a well-designed system must have predictable behavior based on its interface, not its internals.