[Handout for L6P2]
How to Avoid a Big Bang: Integrating Software Components

Integration

Timing and frequency: 'Late and one time' vs 'early and frequent'

Integrating parts written by different team members is inevitable in multi-person projects. It is also one of the most troublesome tasks and it rarely goes smoothly.

In terms of timing and frequency, there are two general approaches to integration:

1. *Late and one time*: In an extreme case of this approach, developers wait till all components are completed and integrate all finished components just before the release. This approach is not recommended because integration often causes many component incompatibilities (due to previous miscommunications and misunderstandings) to surface which can lead to delivery delays: Late integration -> incompatibilities found -> major rework required -> cannot meet the delivery date.

2. *Early and frequent*: The other approach is to integrate early and evolve in parallel in small steps, re-integrating frequently. For example, we can write a working skeleton[6] first (i.e. it compiles and runs but does not produce any useful output). This can be done by one developer, possibly the one in charge of integration. After that, all developers can flesh out the skeleton in parallel, adding one feature at a time. After each feature is done, we can integrate the new code to the main system.

Whether we use frequent integration or we wait till the end to integrate, we still have to decide the order in which we integrate components. There are several approaches to doing this, as explained next.

The order of integration: Big bang vs incremental

Big-bang integration

In the *big-bang integration* approach, we integrate all components at the same time. This approach is not recommended since it will surface too many problems at the same time which could make debugging and bug-fixing more complex than necessary. The other three more 'incremental' approaches explained next are more suitable for non-trivial integration efforts.

Incremental integration

These are the approaches to integrate incrementally.

[6] Some call it a '*walking* skeleton'

- *Top-down* integration : In *top-down integration*, we integrate higher-level components before we bring in the lower-level components. One advantage of this approach is that we can discover higher-level problems early. One disadvantage is that this requires us to use dummy or skeletal components (i.e. stubs) in place of lower level components until the real lower-level components are integrated to the system. Otherwise, higher-level components cannot function as they depend on lower level ones.
- *Bottom-up* integration : This is the reverse of top-down integration. Advantages and disadvantages are simply the reverse of those of the top-down approach.
- *Sandwich* integration: This is a mix of the top-down and the bottom-up approaches. The idea is to do both top-down and bottom-up so that we meet in the middle.

Revision control (team)

In a previous handout we briefly mentioned the use of Revision control systems (RCS) for managing revisions of your own files. RCS are even more useful to manage revisions when you are working as a team[7].

When using an RCS in a team setting, in addition to the local repository on your machine, you also need a remote repository ('remote repo' for short) that other team members can access remotely.

There are two models we can follow when using an RCS in a team setting: the centralized model and the distributed model.

1. **Centralized RCS** (CRCS for short): In this model, there is a central remote repo shared by the team. Team members download ('pull') and upload ('push') changes between their own local repositories and the central repository. Older RCS tools such as CVS and SVN support only this model. Note that these older RCS do not support the notion of a local repo. Instead, they force users to do all the versioning with the remote repo. This situation is illustrated in Figure 12.

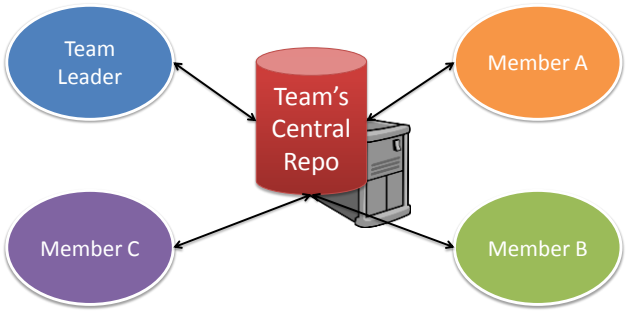


Figure 12. The centralized RCS approach without any local repos (e.g., CVS, SVN)

[7] Some parts of this section, including the three diagrams, were adapted from tutor Steve Teo's work.

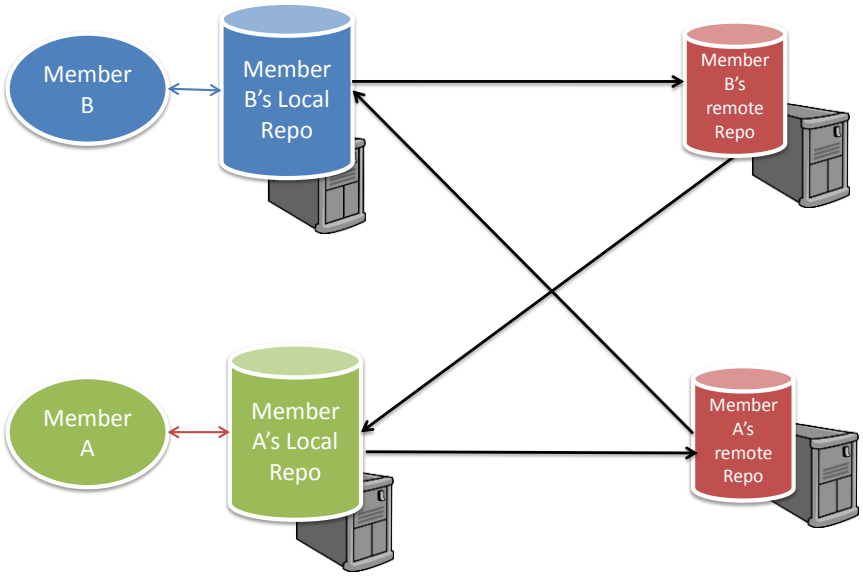


Figure 13. The decentralized RCS approach

2. **Distributed RCS** (DRCS for short, also known as *Decentralized* RCS): In this model, there can be multiple remote repos and pulling and pushing can be done among them in arbitrary ways. The workflow can vary differently from team to team. For example, every team member can have his/her own remote repository in addition to their own local repository, as shown in Figure 13. Mercurial, Git, and Bazaar are some prominent RCS tools that support distributed RCS.

Branching and merging are two terms that are often used in team-based RCS usage. Conceptually, branching is the process of evolving multiple versions of the software in parallel. For example, one team member can create a new branch and add an experimental feature to it while the rest of the team keep working on the *trunk*. 'Trunk' refers to the main line of development while 'branches' are other variants of the software being developed in parallel. A branch can contain many revisions. Once the experimental feature is stable, that branch can be *merged* to the main trunk. Branching and merging is illustrated in Figure 14.

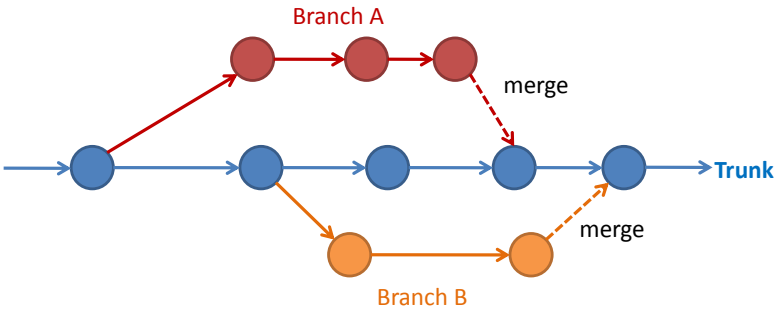
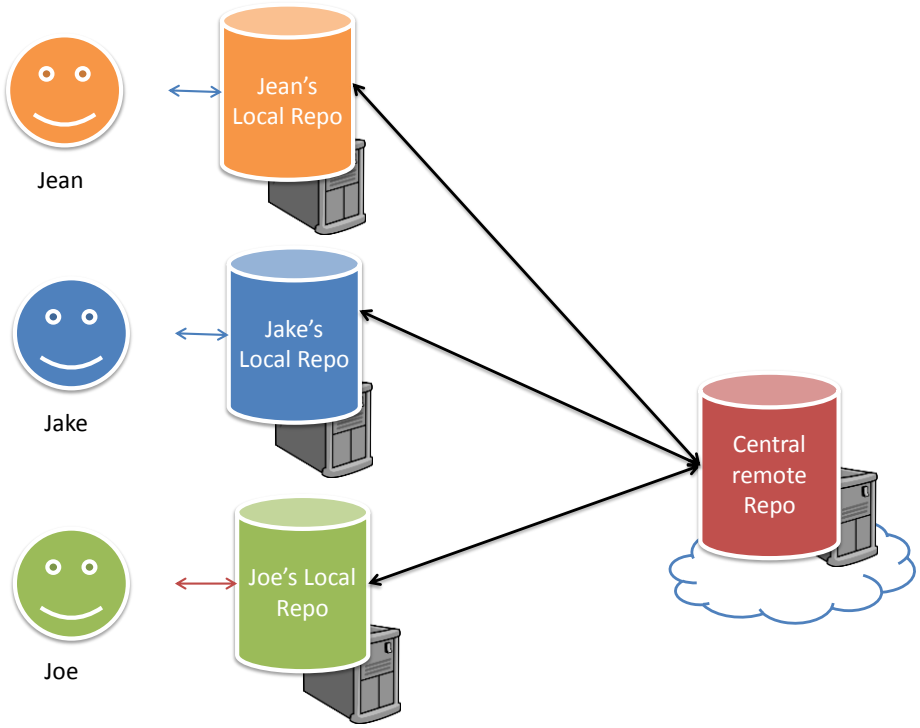


Figure 14. Branching and merging

When using the DRCS approach, there are multiple repositories (local and remote) each one containing different parallel versions. They are also called *clones*.

For simplicity, it is also possible to use DRCS in centralized fashion, as shown below, before moving to more decentralized workflows.

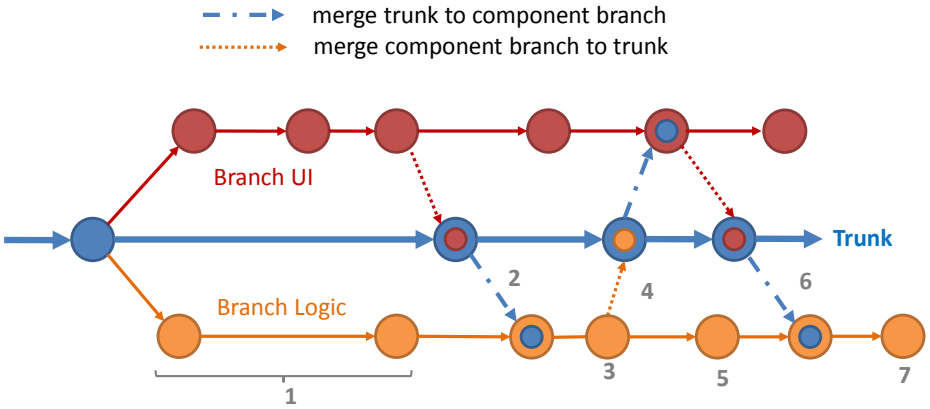


Here is an example sequence of actions when using a DVCS in centralized fashion.

1. Joe writes the first bit of code for the project. Inits a local repo, and commits the code.
2. Joe creates an account in a remote repo service (e.g. Google Code) and pushes his code to the remote repo. Joe's code is now in the remote repo.
3. Jake runs the clone command. As a result, Jake gets a local repo with Joe's code in it.
4. Jean too clones the repo and gets Joes code.
5. Jake writes some more code. Commits to the local repo. Pushes it to the remote repo.
6. Joe pulls from the remote repo. As a result, Jake's changes are downloaded to Joe's local repo.
7. Joe runs the update command. As a result, his working copy gets updated with Jakes additions.

[Steps 5,6,7] can be repeated to share one person's code with the rest of the team.

The above approach is recommended for beginners because it is simple. After you are somewhat familiar with using remote repos, you can switch to a more flexible workflow. There are many DVCS workflows around. Given below is one example. This workflow can be characterized by 'one branch per component'.



In this workflow, we have several branches, one for each major component (it can also be 'one for each developer'). The default branch (otherwise known as the 'trunk') contains the stable code. The tip of the trunk represents the latest working version of the product. The component branches evolve in parallel. Their tip need not be stable. A component branch can merge from trunk whenever there is new code in the trunk. A component branch can merge to the trunk whenever it has stable code it wants to contribute to the trunk.

Here is an example sequence of actions in this workflow. Let us assume Joe is in charge of the Logic branch. Item numbers correspond to the numbers shown in the revision tree diagram above.

1. Joe adds a new method to the Logic component. He commits to the Logic branch several times during this work.
2. Joe thinks he is ready to share this new method with others. He pulls the trunk from the remote repo to see if there are new changesets in the trunk. Joe sees some new changesets in the trunk he just pulled. He merges the trunk to his branch.
3. He runs the test cases and finds the code that came from the trunk has broken some tests in his branch. He fixes them and does another commit. At this point, his branch contains the latest code from the trunk and the new method he wrote. The code is stable.
4. He merges his branch with default and pushes the latest trunk to the remote repo.
5. Joe continues the branch. This time, he fixes a bug in the logic component that was reported recently by Jean. He commits the fix.
6. Before he could push the fix to the trunk, Jean (who is working on the UI branch) contributes some code to the trunk. Joe merges the trunk to his branch to get the new code.
7. Joe realizes his fix no longer works because of the code pushed by Jean. He continues to fix the bug with further commits.

Build automation

In a non-trivial project, building a product from source code can be a complex multi-step process. For example, it can include steps such as pull code from the revision control system, compile, link, run automated tests, automatically update release documents (e.g. build number), package into a distributable, push to repo, deploy to a server, delete temporary files created during building/testing, email developers of the new build, and so on. Furthermore, this build process can be done 'on demand', it can be scheduled (e.g. every day at midnight) or it can be triggered by various events (e.g. triggered by a code push to the revision control system).

Some of these build steps such as compile, link and package are already automated in most modern IDEs. For example, when you press the 'build' button in your IDE, several steps happen automatically. Some IDEs even allow you to customize this build process into some extent.

However, most big projects use specialized build tools to automate complex build processes. GNU *Make* (http://www.gnu.org/software/make/) is one such powerful build tool that has been used since long ago and still popular among practitioners. To quote its home page,

> *Make is a tool which controls the generation of executables and other non-source files of a program from the program's source files. Make gets its knowledge of how to build your program from a file called the makefile, which lists each of the non-source files and how to compute it from other files. When you write a program, you should write a makefile for it, so that it is possible to use Make to build and install the program.*

As you can see from the above description, all build instructions are written in a script file called *makefile*. Such a makefile is especially useful when you distribute your software as source code for expect users to build the product by themselves.

Apache Ant (http://ant.apache.org/) is a similar build tool popular in the Java world. Makefiles uses its own syntax while Ant 'buildfiles' are formatted as xml.

Sample Makefile (extract)

```
edit : main.o kbd.o command.o display.o \
            insert.o search.o files.o utils.o
             cc -o edit main.o kbd.o command.o display.o \
                        insert.o search.o files.o utils.o

main.o : main.c defs.h
         cc -c main.c
kbd.o : kbd.c defs.h command.h
         cc -c kbd.c
command.o : command.c defs.h command.h
         cc -c command.c
display.o : display.c defs.h buffer.h
         cc -c display.c
insert.o : insert.c defs.h buffer.h
         cc -c insert.c
clean :
         rm edit main.o kbd.o command.o display.o \
            insert.o search.o files.o utils.o
```

Sample Ant file (extract)

```
<target name="myTarget" depends="myTarget.check" if="myTarget.run">
    <echo>Files foo.txt and bar.txt are present.</echo>
</target>

<target name="myTarget.check">
    <condition property="myTarget.run">
        <and>
            <available file="foo.txt"/>
            <available file="bar.txt"/>
        </and>
    </condition>
</target>
```

An extreme application of build automation is called *continuous integration* (CI) in which integration, building, and testing happens automatically after each code change. There are build tools e.g. CruiseControl (http://cruisecontrol.sourceforge.net/) that specifically cater for continuous integration.

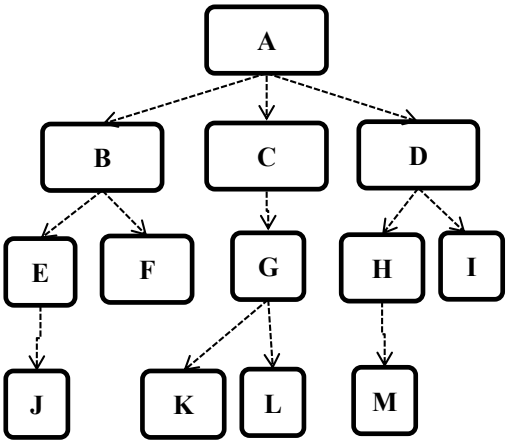
Worked examples

[Q1]

Consider the architecture given below. Give which components will be integrated with other components in which order if we were using the following integration strategies.

(a) big-bang
(b) top-down
(c) bottom-up
(d) sandwich

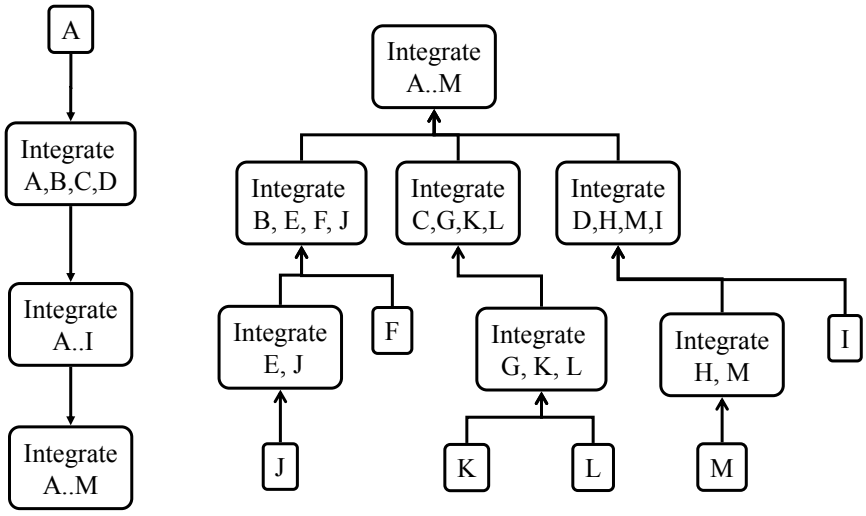
Note that dashed arrows show dependencies (e.g. A depend on B, C, D and therefore, higher-level than B, C and D).



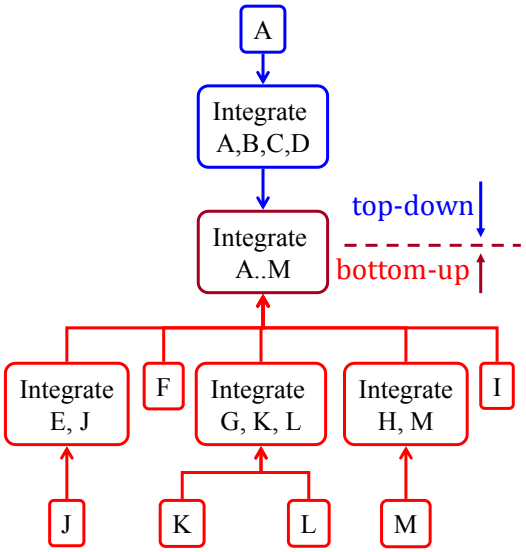
[A1]

(a) Big-bang approach: integrate A-M in one shot.

(b) Top-down approach and (c) bottom-up approach [side by side comparison]



(d) Sandwich approach



[Q2]
Give two arguments in support and two arguments against the following statement.

Because there is no external client, it is OK to use big bang integration for CS2103 course project

[A2]
Arguments for:

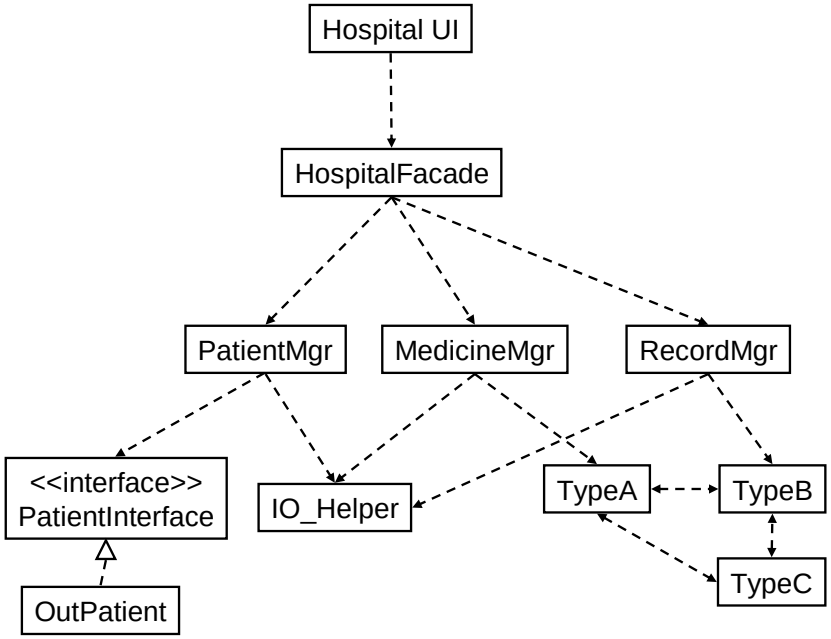
- It is relatively simple; even big-bang can succeed.
- Project duration is short; there is not enough time to integrate in steps.
- The system is non-critical, non-production (demo only); the cost of integration issues is relatively small.

Arguments against:

- Inexperienced developers; big-bang more likely to fail
- Too many problems may be discovered too late. Submission deadline (fixed) can be missed.
- Team members have not worked together before; increases the probability of integration problems.

[Q3]
Suggest an integration strategy for the system represented by following diagram. You need not follow a strict top-down, bottom-up, sandwich, or big bang approach. Dashed arrows represent dependencies between classes.
Also take into account the following facts in your test strategy.

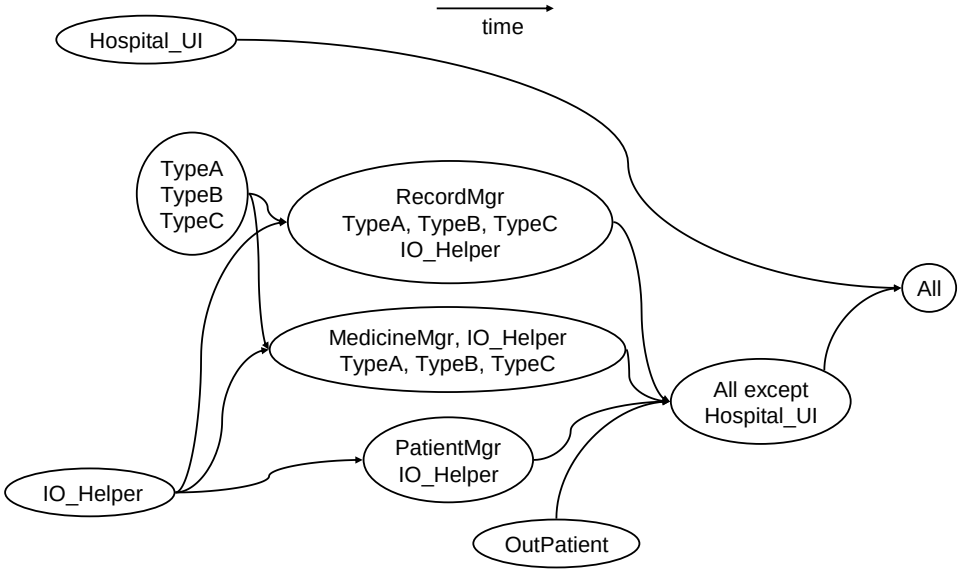
- **HospitalUI** will be developed early, so as to get customer feedback early.
- **HospitalFacade** shields the UI from complexities of the application layer. It simply redirects the method calls received to the appropriate classes below
- **IO_Helper** is to be reused from an earlier project, with minor modifications
- Development of **OutPatient** component has been outsourced, and the delivery is not expected until the 2nd half of the project.



[A3]
There can be many acceptable answers to this question. But any good strategy should consider at least some of the below.

- Since **HospitalUI** will be developed early, it's OK to integrate it early, using stubs, rather than wait for the rest of the system to finish. (i.e. a top-down integration is suitable for **HospitalUI**)
- Because **HospitalFacade** is unlikely to have lot of business logic. Instead of using a stub to integrate HospitalUI, we can use Therefore it may not be worth to write stubs to test it (i.e. a bottom-up integration is better for **HospitalFacade**)
- Since **IO_Helper** is to be reused from an earlier project, we can finish it early. This is especially suitable since there are many classes that use it. Therefore **IO_Helper** can be integrated with the dependent classes in bottom-up fashion.
- Since **OutPatient** class may be delayed, we may have to integrate **PatientMgr** using a stub.
- **TypeA**, **TypeB**, and **TypeC** seem to be tightly coupled. It may be a good idea to test them together.

Given below is one possible integration test strategy. Relative positioning also indicates a rough timeline.



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