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An easy way to run FEniCS is to use our prebuilt, high-performance Docker images. This documentation explains how to get quickly started with using FEniCS in Docker, as well as how to take advantage of more advanced features of Docker.
CHAPTER 1

Quickstart

To get started, follow these two steps:

1. Install Docker for your platform by following these instructions. Windows users must continue to use the Docker Toolbox, not Docker for Windows, if they wish to use the FEniCS Docker script described below.

2. Install the FEniCS Docker script:

   ```bash
   curl -s https://get.fenicsproject.org | bash
   ```

   If using the Docker Toolbox (macOS versions < 10.10 or Windows versions < 10), make sure you run this and other commands inside the Docker Quickstart Terminal.

   **Note:** Not working? Try the Troubleshooting section.

Once both Docker and the FEniCS Docker script have been installed, you can easily start a FEniCS session by running the following command:

```bash
fenicsproject run
```

The FEniCS Docker script can also be used to create persistent sessions (fenicsproject create myproject followed by fenicsproject run myproject) or to run different versions of FEniCS (fenicsproject run dev).

For all fenicsproject commands, the contents of the current directory will be shared into the project at ~/shared.

**Note:** Only folders under C:\Users on Windows and /Users on macOS can be shared into a project. On Linux there are no restrictions.
**Warning:** We *strongly* advise against sharing your entire home directory into a project, i.e. running `fenicsproject create` in `C:\Users\<username>` or `/Users/<username>`. Make a logical folder for each project, e.g. `/Users/<username>/myproject`.

To see more options, run the following command:

```
fenicsproject help
```

The above instructions will get you quickly up and running with FEniCS in Docker. We recommend continuing to the *Introduction* if you want to learn more about using the `docker` command for greater control over running FEniCS in a container.
Note: Want to get up and running quickly? Try the fenicsproject script in Quickstart.

Docker allows FEniCS and its dependencies to be packaged into a standard format for identical deployment almost anywhere. Docker containers are lightweight and are based on open standards that run on all major Linux distributions, macOS and Microsoft Windows platforms. For more information, visit https://www.docker.com/what-docker.

2.1 Installing Docker

Install Docker by following these instructions.

If using the Docker Toolbox (macOS versions < 10.10 or Windows versions < 10), make sure you run all commands inside the Docker Quickstart Terminal.

2.2 Running FEniCS in Docker

Under macOS or Windows, start a Docker Quickstart Terminal.

For Linux, use a standard terminal. You may need to prepend sudo to the commands below. In addition, if you are executing docker via fenicsproject script, you must prepend it with sudo -E. This flag allows sudo to see the enviromental variables, such as $FENICS_SRC_DIR. To allow sudo-less use, refer to the installation instructions for your distribution to add your user to the docker group.

First check that Docker is working:

```
docker run hello-world
```

You should see a message saying that your Docker installation is working correctly.
Note: Not working? Check out the Troubleshooting section.

To pull the quay.io/fenicsproject/stable image:

```bash
docker pull quay.io/fenicsproject/stable:latest
```

To start FEniCS, run:

```bash
docker run -ti quay.io/fenicsproject/stable:latest
```

You will be presented with a prompt where you can run FEniCS:

```bash
fenics@0521831b5f28:~$ fenics
```

fenics is your username inside the container and the number 0521831b5f28 is the CONTAINER ID that Docker has assigned. This ID is unique to your computer and this container and will be different to the one above.

The DOLFIN poisson.py example can be run using:

```bash
cd ~/demo/documented/poisson/python
python3 demo_poisson.py
```

The results will be outputted to the file poisson.pvd in the same directory. How to open this file with a visualisation tool is covered in the next section.

2.3 Sharing files from the host into the container

Most users want to continue using the text editor, version control and other tools already installed on their computers, and just use the Docker container to run FEniCS.

To share files between the host system and the container, use:

```bash
docker run -ti -v $(pwd):/home/fenics/shared quay.io/fenicsproject/stable
```

Note: Users running Linux distributions with SELinux enabled (Redhat, CentOS, Fedora, and others) will need to add the :z option to all subsequent host volume mounts `-v`, e.g.:

```bash
docker run -ti -v $(pwd):/home/fenics/shared:z quay.io/fenicsproject/stable
```

Note: Permissions issues on Linux? Check out the Troubleshooting section.

This command will run a new container with the current working directory `$ (pwd)` shared with the container at the path `/home/fenics/shared` from inside the container.

The syntax for the argument `-v is `/path/on/host::/path/in/container`. Note that all paths are absolute paths.

Now, you can edit your code on the host and run the following inside the container:

```bash
cd $HOME/shared
python3 my_code.py
```
In this case, all files in `my-work-directory` will be shared into the container. Any files you place in the directory `/home/fenics/shared` in the container will be available on the host system at the current working directory `$(pwd)`, and vice versa. We recommend keeping the source code and generated results for your projects in this shared directory, easily accessible on the host machine.

Any files placed in any other directory than `/home/fenics/shared` in the container will remain in the container and are not accessible on the host.

### 2.4 Naming a container

Every container can be given a name so it can be easily referred to in the future by passing the `--name` flag to the `docker run` command, e.g.:

```bash
docker run -ti -v $(pwd):/home/fenics/shared --name fenics-container quay.io/fenicsproject/stable
```

The container can be stopped and started:

```bash
docker stop fenics-container
docker start fenics-container
docker exec -ti -u fenics fenics-container /bin/bash -l
```

To see the name and other information of every container you have ever created:

```bash
docker ps -a
```

To see the information of only running containers:

```bash
docker ps
```

For more details on ways of working with Docker and FEniCS, check out *Suggested workflows*. 
Available FEniCS images

Please see the Bitbucket repository for a full list.
Docker is an extremely powerful and flexible system for running containers. However, with that flexibility comes a steep learning curve that may raise difficulties for new users. In this section we cover some common workflows that you might find useful.

Advanced users may find the Docker Cheat Sheet useful for quick reference.

### 4.1 Separate container for each user project

We would like to have a separate container for each user project. Say we have two projects located at $HOME/project-1 and $HOME/project-2 on the host. We want *project-1* to use the *dev* image with the development version of FEniCS, and *project-2* to use the *stable* image with the stable version of FEniCS. Also we would like to easily know which container corresponds to which project.

Then we can run in one terminal:

```
    cd $HOME/project-1
docker run -ti --name project-1 -v $(pwd):/home/fenics/shared quay.io/fenicsproject/dev
```

and in another terminal:

```
    cd $HOME/project-2
docker run -ti --name project-2 -v $(pwd):/home/fenics/shared quay.io/fenicsproject/stable
```

Notice the `--name` argument, this allows us to assign an easy-to-remember name to our container, rather than the CONTAINER ID. We now have two containers with two different versions of FEniCS running.

### 4.2 Multiple shells running in one container

You can get a list of all running containers by running the command:
docker ps

On my system I have the following output:

<table>
<thead>
<tr>
<th>CONTAINER ID</th>
<th>IMAGE</th>
<th>COMMAND</th>
<th>CREATED</th>
<th>STATUS</th>
<th>PORTS</th>
<th>NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ed8960fcf652</td>
<td>quay.io/fenicsproject/dev</td>
<td>&quot;sudo /sbin/my_init -&quot;</td>
<td>3 seconds ago</td>
<td>Up 2 seconds</td>
<td></td>
<td>project-1</td>
</tr>
</tbody>
</table>

We would like to have another bash container running inside the container project-1. We can execute a new process in the container using the `docker exec` command:

docker exec -ti -u fenics project-1 /bin/bash -l

The `-l` is important and ensures that your environment in the container is setup correctly for FEniCS to run. You could also enter into an `ipython3` prompt instantly using:

docker exec -ti -u fenics project-1 /bin/bash -l -c ipython3

The `-c` flag makes `bash` read the commands from the string.

### 4.3 Restart an exited container

Start a container in the normal way:

docker run -ti --name new-project -v $(pwd):/home/fenics/shared quay.io/fenicsproject/dev

Now `exit` the bash shell in the container:

exit

You will be returned to the shell on the host system. By default, when you `exit` the running process the container is stopped, but not deleted. All of the data associated with the container `new-project` remains on your system. This means we can restart this container right where we left it.

We can see a list of all running and stopped containers using the command:

docker ps -a

On my system I have the following output:

<table>
<thead>
<tr>
<th>CONTAINER ID</th>
<th>IMAGE</th>
<th>COMMAND</th>
<th>CREATED</th>
<th>STATUS</th>
<th>PORTS</th>
<th>NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>143043b0f9fd</td>
<td>quay.io/fenicsproject/dev</td>
<td>&quot;sudo /sbin/my_init -&quot;</td>
<td>9 seconds ago</td>
<td>Exited (0)</td>
<td>1 seconds ago</td>
<td></td>
</tr>
</tbody>
</table>

You may need to scroll the above code box to the right to see the `NAMES` field where you will see the recently exited container `new-project`.

To start the container `new-project` again simply run the command:

docker start new-project

We can make a new shell in the container using the command:
Conversely, you can stop a running container using the command:

docker stop new-project

4.4 Run FEniCS in a Docker container like an application

You don’t have to run FEniCS by starting a shell in Docker and running python3 to execute your FEniCS scripts. It is also possible to execute any executable directly in the container from the docker run command.

Say we have a python file my-code.py in the current working directory on the host and that we want to run python3 on it directly within a one-shot FEniCS container. We can do this with the following command:

```
docker run --rm -v $(pwd):/home/fenics/shared -w /home/fenics/shared quay.io/fenicsproject/stable "python3 my-code.py"
```

Let’s break this complex run command down flag-by-flag:

- **--rm** means that Docker will remove the container immediately after exiting the container. Old and unused containers won’t clutter up your machine.
- **-v $(pwd):/home/fenics/shared** shares the current working directory $(pwd) into the container at /home/fenics/shared just as before.
- **-w** sets the current working directory in the container to our shared directory /home/fenics/shared.
- **"python3 my-code.py"** is the command passed to the Docker container. The container will immediately execute this command in the working directory.

In my my-code.py I have the following simple Python/FEniCS code:

```python
from dolfin import *
print("Running FEniCS...")
mesh = UnitSquareMesh(10, 10)
V = FunctionSpace(mesh, "P", 1)
u = interpolate(Constant(1.0), V)
with XDMFFile("f.xdmf") as f:
    f.write(u)
```

Running the docker run command above then gives me the output:

```
Running FEniCS...
Calling FFC just-in-time (JIT) compiler, this may take some time.
```

and the files f.xdmf and f.h5 written back onto the host system in the current working directory.

In practice, there are two (easily fixable!) issues with the above approach; firstly, on each call to docker run we get a completely fresh container, meaning that the Instant cache of compiled objects needs to be regenerated everytime, and secondly the above command is rather cumbersome to type out.

The first issue can be solved with the concept of data volume containers. Interested users can refer to the official Docker documentation here. In short, we will create a persistent Docker volume that is just used to store the compiled Instant object cache across individual run-s:

```
docker volume create --name instant-cache
```
We can then mount the persistent `instant-cache` image inside a *one-shot* container using the following command:

```bash
docker run --rm -v instant-cache:/home/fenics/.instant -v $(pwd):/home/fenics/shared -v /home/fenics/shared quay.io/fenicsproject/stable "python3 my-code.py"
```

The argument `-v instant-cache:/home/fenics/.instant` mounts the data volume `instant-cache` container into the *one-shot* container we use to execute our Python code. If you run the command twice, you will notice on the second time that we do not need to just-in-time compile the Instant object that our Python script requires, because the cache is now stored inside the Docker volume.

The second issue, that the above is cumbersome to write out, can be solved simply using a shell script. You might want to try putting the following code:

```bash
#!/bin/bash
docker volume create --name instant-cache > /dev/null 2>&1
docker run --rm -v instant-cache:/home/fenics/.instant -v $(pwd):/home/fenics/shared -v /home/fenics/shared quay.io/fenicsproject/stable "$@"
```

into a file `fenics` somewhere in your `${PATH}` and making it executable with `chmod +x fenics`. Then you can simply run:

```
fenics "python3 my-code.py"
```

You could use the ideas in the above script to write your own custom launcher for FEniCS.

### 4.5 Compile a development version of FEniCS

The image `quay.io/fenicsproject/dev-env` makes it very easy to compile a development version of FEniCS, or start contributing to the development of FEniCS. We cover the latter in *FEniCS development using Docker*.

Let's run the `dev-env` image and share the current working directory into the container at `/home/fenics/build`:

```
docker run -ti -v $(pwd):/home/fenics/build quay.io/fenicsproject/dev-env
```

You might be surprised how quick it was to download the image `dev-env`. This is because the image `stable` is actually built on top of the image `dev-env`. Docker can quickly work out that we have already downloaded all of the necessary *layers* already when getting the `stable` image, and start the `dev-env` container almost instantly.

This environment contains everything we need to compile the latest version of FEniCS from the *master* branch. We provide a helper script `fenics-update` that will take care of pulling the source from git, compiling them, and installing them in the right locations. Using `fenics-update` is optional, you can pull and build FEniCS in anyway you wish inside the container.

For more advanced usage, see *FEniCS development using Docker*.

### 4.6 Reproduce my results

Whether you are using the `stable` image, or have compiled a particular revision of FEniCS inside a `dev-env` container, you might want to make sure that you can always get back to that specific version at some later date so you can reproduce your results. Docker makes that easy.

First the simple case: we want to save a particular version of the `stable` image that will be used for all runs of code in paper-1. We can do this using the `tag` directive:
docker tag quay.io/fenicsproject/stable:latest my-name/fenics-stable:paper-1

Now, even if you decide to pull a newer version of FEniCS stable image:

docker pull quay.io/fenicsproject/stable:latest

The tag my-name/fenicsproject:paper-1 will always point to the version of FEniCS we have tagged, so when we do:

docker run -ti my-name/fenics-stable:paper-1

we will get the right version.

In the case we have compiled our own version of FEniCS for paper-2 in a dev-env image, the steps are slightly more involved. Start with:

docker run -ti quay.io/fenicsproject/dev-env

and in the new container:

fenics-update

After the compile has finished, exit the container:

exit

Now, back on the host, we must commit the container. This freezes the modifications to the filesystem we made when we compiled FEniCS. Make a note from your terminal of the unique hash in the bash prompt of the container when it was running e.g. fenics@88794e9fddcf5:$ and then run, e.g.:

docker commit 88794

Docker will return a new hash, e.g.:

sha256:e82475ade54e046e950a7e25c234a9d7d3e77f3ba19062729810a241a50f8c8a9

which we can then tag as before:

docker tag e824 my-name/fenics-dev:paper-2

Note that Docker can auto-complete hashes if you only provide the first few letters, making typing less cumbersome!

### 4.7 Share my container with a colleague

There are two main ways of doing this. The simplest is just to save your container in a tar file and send it to your colleague via your preferred file transfer method. First off exit your container and commit it:

exit
docker commit 88794

Docker will return a new hash, e.g.:

sha256:e82475ade54e046e950a7e25c234a9d7d3e77f3ba19062729810a241a50f8c8a9

Now we can save to a tar file with:
docker save e82475 > my-fenics-environment.tar

Send the file my-fenics-environment.tar to your colleague, and she can load it into Docker using:

docker load < my-fenics-environment.tar

and wait for the import to finish. Your colleague can then start the image using:

docker run -ti e82475

Of course, your colleague can also tag the image for easy reference in the future.

The other option is to push your image up to a cloud repository like Dockerhub, or our preferred provider, quay.io. Both of these services will store images for you and allow others to pull them, just like our images.

First get an account on Dockerhub or quay.io.

In the case that you have chosen quay.io you need to login using docker login and the URL of the quay.io repository:

docker login https://quay.io/v2/

In the case you have chosen Dockerhub, you can login without specifying a URL as Dockerhub is the default repository:

docker login

Then, you can push your image to the remote repository using docker tag and docker push:

docker tag e82475 quay.io/my-user/test-repo:latest
docker push quay.io/my-user/test-repo:latest

quay.io is the remote repository I want to push to, my-user is my username on quay.io and test-repo is the name of the repository I want to create. Dockerhub users can leave off the quay.io/ prefix as Dockerhub is the default remote repository.

Once the upload is complete anyone can pull your image from the repository:

docker pull quay.io/my-user/test-repo

and run it:

docker run -ti quay.io/my-user/test-repo

4.8 Create a custom image for my project

We probably haven’t included every Python module, every application and every small utility that you need for your project. However, we have done all the work of compiling and maintaining FEniCS.

You can build off of our work by learning to write your own Dockerfile that inherits FROM one of our pre-built images. We won’t go into all of the details of how to do this here, but can point you in the right direction. For full details, take a look at the official Docker tutorials and manual pages.

Let’s say that we need to run scipy alongside FEniCS in Python scripts within a container. Because our image is built to be as lean as possible, we don’t include scipy by default. However, you can add it easily.
Begin by making an empty folder, for example `my-docker-image/` and create a file called `Dockerfile` inside of it:

```bash
mkdir my-docker-image
cd my-docker-image
touch Dockerfile
```

Then open up `Dockerfile` in your favourite text editor and add in the following text:

```bash
FROM quay.io/fenicsproject/stable:latest
USER root
RUN apt-get -qq update && \
    apt-get -y upgrade && \
    apt-get -y install python3-scipy && \
    apt-get clean && \
    rm -rf /var/lib/apt/lists/* /tmp/* /var/tmp/*
USER root
```

Let's go through each directive one-by-one. The `FROM` directive instructions Docker to build the new image using `quay.io/fenicsproject/stable:latest` image as a base. The `USER` directive instructions Docker to run all subsequent commands as the user `root` in the container. This method is preferred to using `sudo` in the `Dockerfile`. Then, we `RUN` a few shell commands that update the `apt-get` cache and install `scipy`. Note that we clean up and delete the `apt-get` cache after using it. This reduces the space requirements of the final image. Finally, we switch back to the `USER root`. The reasons for switching back to the user `root` are outside the scope of this tutorial.

Save `Dockerfile` and exit back to the terminal, and then run:

```bash
docker build .
```

Docker will build the container using the instructions in the `Dockerfile`. After the build is complete Docker will output a hash, e.g.:

```
Successfully built 10c39a18651f
```

that you can `tag` your container for future use:

```bash
docker tag 10c39 quay.io/my-user/my-docker-image
```

We can now run the container in the usual way:

```bash
docker run -ti quay.io/my-user/my-docker-image
```

Now, inside the container, you should be able to use `scipy` and `dolfin`:

```bash
python3 -c "import scipy; import dolfin"
```

Congratulations, you've built your first Docker container!

This is just the beginning of what you can do to customise and build on our containers. In general, if you can install it in Ubuntu, you can install it in our container. For ideas, you can take a look at the source code of our `Dockerfiles` here and at the official Docker tutorials and manual pages.
4.9 Use graphical applications on Linux hosts

This allows X11 applications (e.g. matplotlib plot windows) to be displayed on Linux host systems. To enable this, first run `xhost +` and then append `-e DISPLAY=$DISPLAY -v /tmp/.X11-unix:/tmp/.X11-unix` to the Docker `run` command. For example, you can run the stable version with:

```bash
xhost +
docker run -ti -e DISPLAY=$DISPLAY \
  -v /tmp/.X11-unix:/tmp/.X11-unix \
  quay.io/fenicsproject/stable
```

After exiting docker, execute `xhost -` on the host to restore X settings.
Running Jupyter notebooks

Jupyter notebooks allow you to create and share documents that contain live code, equations and visualisations. For more information check out https://jupyter.org.

It only takes two commands to get a Jupyter notebook up and running with a FEniCS environment installed.

**Note:** The `fenicsproject notebook myproject` command automates the tasks outlined below. See Quick-start for instructions.

### 5.1 Docker for Mac, Docker for Windows and Linux users

First of all we run a new Docker container with the `jupyter-notebook` command specified and the default port 8888 exposed on localhost:

```
docker run --name notebook -w /home/fenics -v $(pwd)/home/fenics/shared -d -p 127.0.0.1:8888:8888 quay.io/fenicsproject/stable 'jupyter-notebook --ip=0.0.0.0'
```

The notebook will be available at http://localhost:8888 in your webbrowser. See Finding out the access token for the next step.

### 5.2 Docker Toolbox for Windows and Mac users

First of all we run a new Docker container with the `jupyter-notebook` command specified and the default port 8888 exposed on the IP of the virtual machine where docker is running:

```
docker run --name notebook -w /home/fenics -v $(pwd)/home/fenics/shared -d -p $(docker-machine ip $(docker-machine active)):8888:8888 quay.io/fenicsproject/stable 'jupyter-notebook --ip=0.0.0.0'
```

To find out the IP of the virtual machine:
The notebook will be available at http://<ip-of-virtual-machine>:8888 in your web browser. See Finding out the access token for the next step.

5.3 Finding out the access token

Jupyter creates a unique access token (password) to ensure that only you can access the notebook. To find out this access token run the following command on the host:

docker logs 3b4c7bcee5de

where the hash is your container ID (see docker ps).

Near the bottom of the output you should see something like:

Copy/paste this URL into your browser when you connect for the first time, to login with a token:
http://0.0.0.0:8888/?
→token=b8d00059b0a71a94edd67d03d8ebecaa09d8c28eb7e7a0a9

In this case, the token is b8d00059b0a71a94edd67d03d8ebecaa09d8c28eb7e7a0a9. Copy your token to the clipboard. Paste the token into the password field.

5.4 Plotting

Basic two and three-dimensional plotting are available from within the Jupyter notebook. To see an example of what’s possible check out this notebook.

Note: Safari and Firefox are currently recommended for 3D plotting. Chrome has an intermittent issue where plots may not render.

For matplotlib plotting (2D), open up a new Jupyter notebook, and in the first cell type:

%matplotlib inline

Execute (Shift-Enter) the cell. In the next cell, we will load in the code from the DOLFIN Python Poisson demo:

%load ~/demo/documented/poisson/python/demo_poisson.py

Execute (Shift-Enter) the cell. In the same cell, the code from the demo_poisson.py file will be shown. Click in the cell and execute (Shift-Enter) again. A plot of the solution variable u will appear.

For X3DOM plotting (3D), continuing from above, in a new cell type:

from IPython.display import HTML
HTML(X3DOM().html(u))

Execute (Shift-Enter) the cell. A 3D plot will appear that you can rotate and zoom using the mouse.
5.5 Further instructions

The current working directory $(pwd)$ will be available in the Jupyter notebook interface. You might want to give the container a name that you can easily remember. In this example I have simply chosen `notebook`.

**Note:** This setup is secure by default. Users on your local network cannot access the web interface, even if they know your IP address.

With the flag `-d` we have placed the container into daemon mode. It will continue to run in the background until we stop it:

```
docker stop notebook
```

To start it again just run:

```
docker start notebook
```

If you want to see the log output from the Jupyter notebook server type:

```
docker logs notebook
```
Running FEniCS in Docker may be faster than using a native build since our Docker images have been tuned for performance, even when running Docker using virtualisation technologies on Mac and Windows.

A range of FEniCS performance tests using containers can be found in

CHAPTER 7

FEniCS development using Docker

The FEniCS Docker images provide a convenient environment for FEniCS development since the images provide all FEniCS dependencies. Follow the instructions below to create an environment that let’s you pull, push, edit and build FEniCS using Docker.

7.1 Development quickstart

On the host:

```bash
curl -s https://get.fenicsproject.org | bash
export FENICS_SRC_DIR=$HOME/dev/fenics
mkdir -p $FENICS_SRC_DIR
cd $FENICS_SRC_DIR
for p in fiat instant dijitso ufl ffc dolfin mshr; do git clone git@bitbucket.org:fenics-project/$p.git; done
fenicsproject pull dev-env
fenicsproject create my-dev-env dev-env
fenicsproject start my-dev-env
```

Inside the container:

```
fenics-build
```

The workflow is to edit the code and interact with the git repositories on the host with your favourite tools, and then build and run FEniCS inside the container.

7.2 Install the fenicsproject script

```bash
curl -s https://get.fenicsproject.org | bash
```
While it is possible to use straight docker commands to launch a development container, the script makes things significantly easier. Read on for full details: Install the fenicsproject script.

### 7.3 Set up your FEniCS source tree

We will set up the FEniCS source tree on the host. This means you can use all of your usual development tools, like vim or emacs on the host, and just do the compilation and execution inside the container. You should also use git push and git pull on the host so that you can use your usual git SSH keys and setup.

We need to make a folder, e.g. $HOME/dev/fenics on the host system to hold the FEniCS source code:

```bash
export FENICS_SRC_DIR=$HOME/dev/fenics
mkdir -p $FENICS_SRC_DIR
```

You can make this setup permanent by setting the environment variable export FENICS_SRC_DIR=$HOME/dev/fenics in your $HOME/.profile or similar file. Feel free to choose another directory for your FEniCS sources.

### 7.4 Pull the FEniCS sources

```bash
cd $FENICS_SRC_DIR
git clone git@bitbucket.org:fenics-project/fiat.git
git clone git@bitbucket.org:fenics-project/instant.git
git clone git@bitbucket.org:fenics-project/dijitso.git
git clone git@bitbucket.org:fenics-project/ufl.git
git clone git@bitbucket.org:fenics-project/ffc.git
git clone git@bitbucket.org:fenics-project/dolfin.git
git clone git@bitbucket.org:fenics-project/mshr.git
```

Alternatively, the following short form can be used in place of the string of clones:

```bash
for p in fiat instant dijitso ufl ffc dolfin mshr; do git clone git@bitbucket.org:fenics-project/$p.git; done
```

Note that we pull the sources from outside the Docker container (which we have yet to create). This ensures that we pull using the ssh protocol (rather than the https protocol) and it ensures that you can interact with the repositories using your normal credentials (keys) on the host system. If you are using other repositories than the standard ones (in particular forks not owned by fenics-project), make suitable adjustments to the git clone commands above.

### 7.5 Create the Docker container

We will now setup the development container using the fenicsproject script.

```bash
fenicsproject pull dev-env
cd $FENICS_SRC_DIR
fenicsproject create my-dev-env dev-env
```

The first command pulls the latest FEniCS dev-env image containing all the dependencies you need for building FEniCS such as PETSc and MPI. This will happen automatically when you run the fenicsproject create command below, but if you have previously used the dev-env image, make sure to run the fenicsproject pull command to get the very latest version of the dev-env image.
The second command enters the FEniCS source directory. This is not strictly necessary for our purposes, but the `fenicsproject` script will complain if the `fenicsproject create` command is issued from the home directory. Feel free to enter some other directory which will then be shared to `$HOME/shared` inside the Docker container. The source directory will automatically be shared anyway at `$HOME/local/src`.

The third command creates a container named `my-dev-env` that you will be using for FEniCS development. You may of course choose another name for this container.

### 7.6 Start the FEniCS Docker container

```
fenicsproject start my-dev-env
```

This command will fire up the Docker container and we are ready to get going. The FEniCS source directory that we created previously will be shared into the directory `$HOME/local/src` inside the container.

### 7.7 Build FEniCS inside the Docker container

To build all of the FEniCS components from the source you have shared into the container, simply run the following command inside the container:

```
fenics-build
```

Both commands build all the sources residing in `$HOME/local/src` and install the results into `$HOME/local`. Once all components have been built, you may run FEniCS programs without changing any paths or setting any other environment variables. Everything is already setup correctly to point at the `$HOME/local` installation directory.

Note that there is also a command named `fenics-pull`. This will pull all the FEniCS sources into `$HOME/local/src` by entering each source directory and calling `git pull`. This means that the command will pull the sources for the default remote for the particular branch that each repository happens to be located at.

During development, you will likely need to rebuild and install a particular component repeatedly. For example, to re-build ffc:

```
fenics-build ffc
```
The image base defines the end-user experience for all containers, including creating the fenics user, setting default ENTRYPOINT and CMD variables, and setting the version of phusion/baseimage to use. All other images should ultimately inherit FROM this image.

The image dev-env-base includes the fenics.conf helper script, the fenics.env.conf environment variable script, and sets the version numbers of the packages to compile in the child images. All dev-env-{variant} should inherit FROM this image.
9.1 I can’t access the internet in the container

Docker images default to using the Google Domain Name Servers (DNS). Access to these may be blocked on some networks, resulting in no internet access in the container. In this case, you can set the address of the DNS using the Docker option `--dns`, e.g.:

`docker run --dns=4.4.4.4 -ti fenicsproject/dev-env:latest`

and replace 4.4.4.4 with the address of your local DNS.

For setting the DNS system-wide, see <https://docs.docker.com/engine/admin/systemd/> and <https://stackoverflow.com/questions/33784295/setting-dns-for-docker-daemon-using-systemd-drop-in/>.

9.2 I can’t share a folder into the container

*macOS*: By default, only files and directories under `/Users/` can be shared into a container using the `--v` flag.

*Windows*: By default, only files and directories under `C:\Users` can be shared into a container using the `--v` flag.

9.3 My file permissions are wrong on the host

**Note:** The `fenicsproject` script automates this step.

**Note:** This step is not necessary on macOS or Windows hosts.

Pass your host UID and GID to the container as environment variables, e.g.:
By default, the fenics user in the container has UID=1000 and GID=1000. When you create a file inside the container its ownership will be identical to that of the fenics user inside the container. The problem is that the UID and GID on the host may be different. This results in files that are not readable or writeable on the host. The above command modifies the UID and GID of the user fenics inside the container at runtime to match the current user on the host.

### 9.4 I’ve run out of space for new containers or images

Users using the Docker Toolbox on macOS and Windows are actually running the Docker containers inside a Virtual Machine. If you pull too many images from Dockerhub then you may fill up the virtual machine’s disk drive.

You can see how much space you have left using the following command:

```
docker-machine ssh $(docker-machine active) sudo df -h /dev/sda1
```

You should see something like this:

<table>
<thead>
<tr>
<th>Filesystem</th>
<th>Size</th>
<th>Used</th>
<th>Available</th>
<th>Use%</th>
<th>Mounted on</th>
</tr>
</thead>
<tbody>
<tr>
<td>/dev/sda1</td>
<td>75.8G</td>
<td>45.8G</td>
<td>26.2G</td>
<td>64%</td>
<td>/mnt/sda1</td>
</tr>
</tbody>
</table>

If the Use% column is greater than 90%, then you should follow the steps outlined below. Remember that files shared into the container from the host will not be deleted when you delete a container.

To cleanup, you first need to remove containers you are no longer using. To list all containers, type:

```
docker ps -a
```

You can then remove unwanted containers using:

```
docker rm <name>
```

where `<name>` is the name of the container shown in the output of `docker ps -a`. Note that containers typically do not take up much space, but the images they are based on can be hundreds of megabytes each.

Now, you can clean up unused or dangling images (images not associated with a container) by running:

```
docker rmi $(docker images -q --filter "dangling=true")
```

Note that if an image is associated with a container it cannot be deleted. So it is important to `rm` some containers first.

### 9.5 Still not working?

Support requests can be sent to the FEniCS Support mailing list (fenics-support@googlegroups.com).
Support requests can be sent to the FEniCS Support mailing list (fenics-support@googlegroups.com).

For development-related questions and suggestions, use the FEniCS Development mailing list (fenics-dev@googlegroups.com). Bugs can be registered on the Bitbucket Issue Tracker (https://bitbucket.org/fenics-project/docker/issues).
Background on the use of containers with FEniCS, including performance data, is available in

CHAPTER 12

Indices and tables

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