UDOCKER

LIP Computing

INCD

Jorge Gomes <jorge@lip.pt>

deep Hybrid DataCloud

Cofinanciado por:

COMPETE 2020

PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO

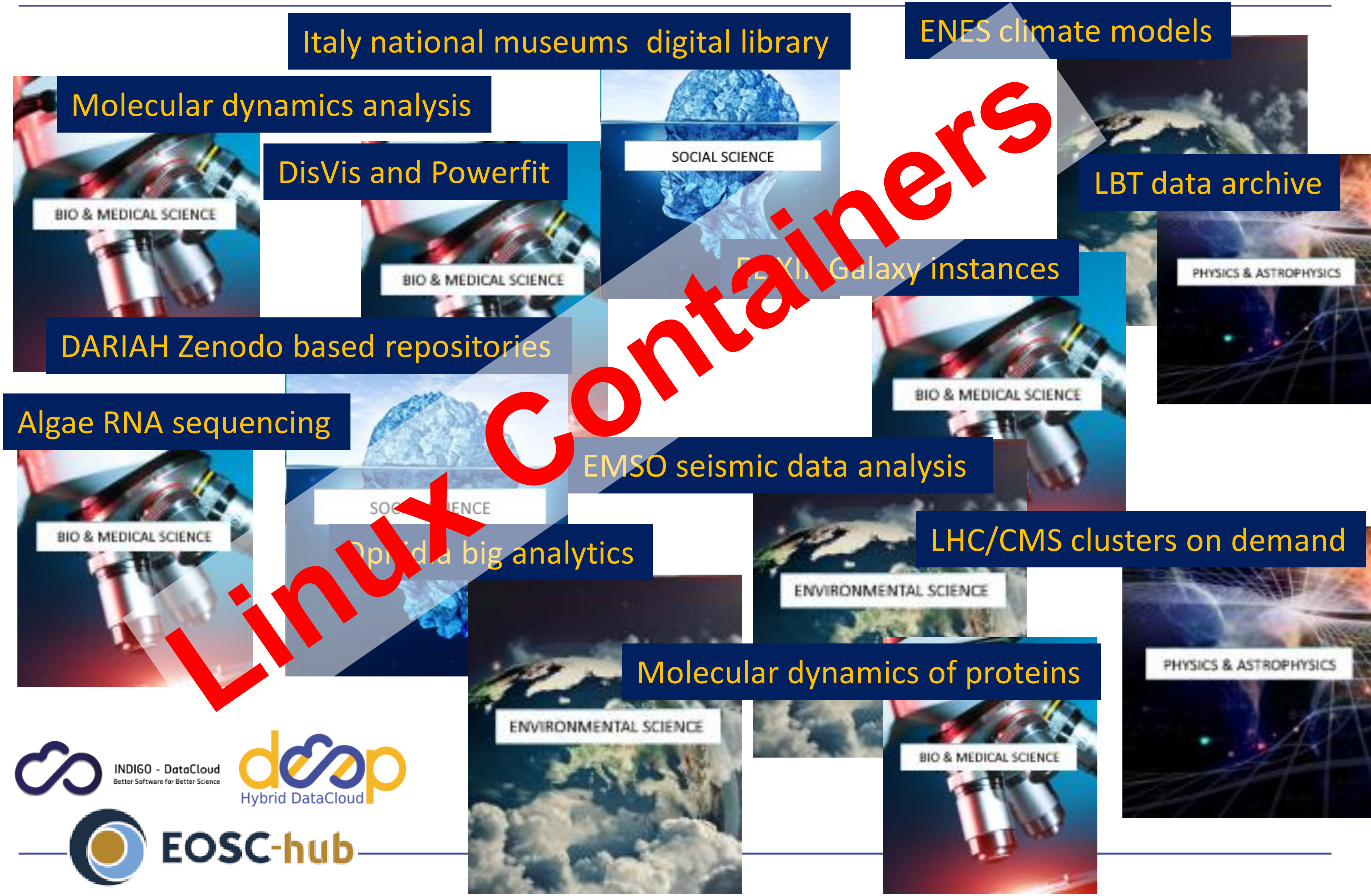
PORTUGAL 2020

UNIÃO EUROPEIA
Fundo Europeu
de Desenvolvimento Regional

Lisb@20²⁰

FCT Fundação para a Ciência e a Tecnologia

INDIGO-DataCloud



Italy national museums digital library

ENES climate models

Molecular dynamics analysis

DisVis and Powerfit

LBT data archive

ELIXIR Galaxy instances

DARIAH Zenodo based repositories

Algae RNA sequencing

EMSO seismic data analysis

LHC/CMS clusters on demand

Ophidia big analytics

Molecular dynamics of proteins

Linux Containers

INDIGO - DataCloud
Better Software for Better Science

UDOCKER

deep Hybrid DataCloud

EOSC-hub

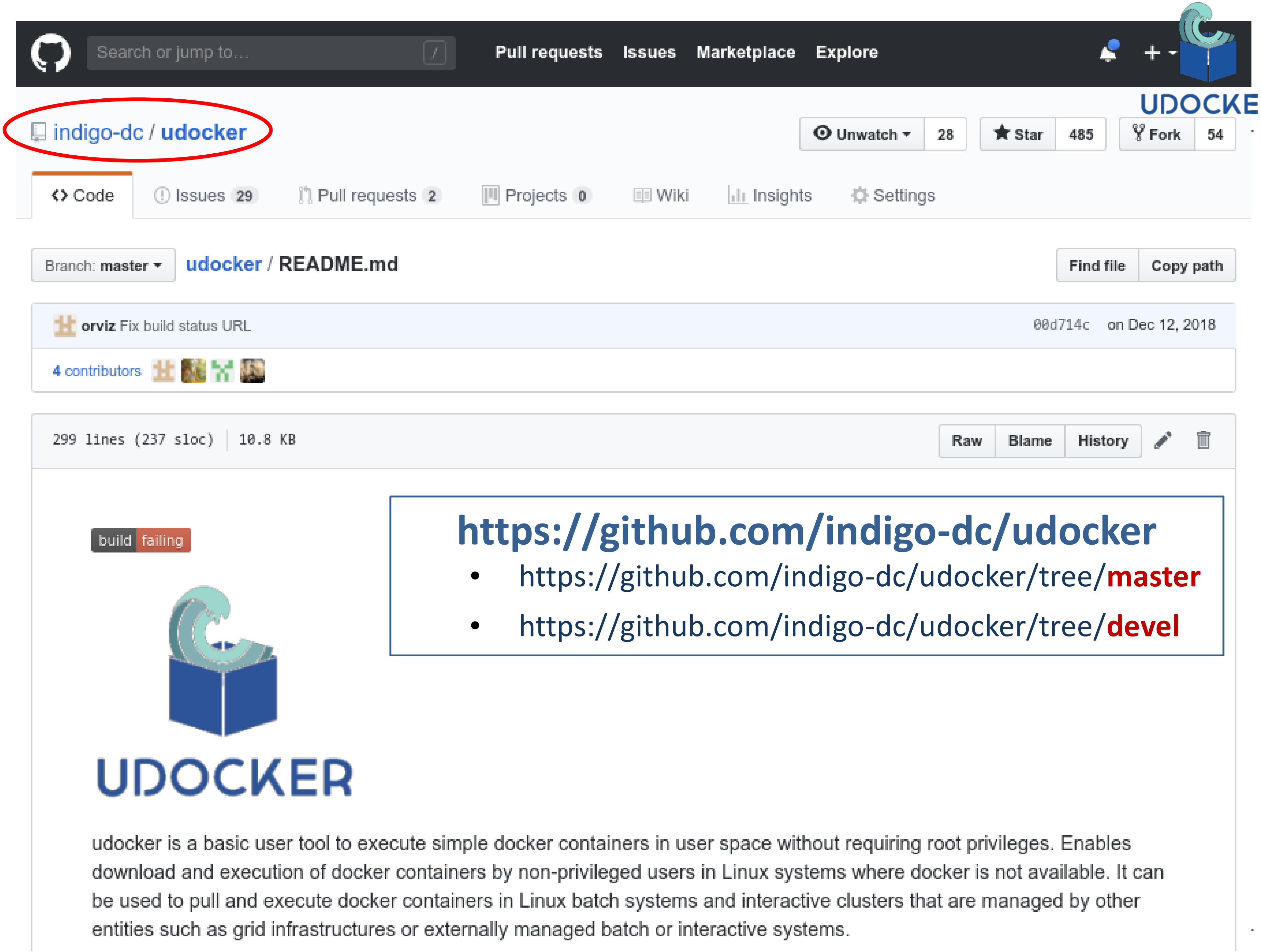
udocker motivations

- **Run applications encapsulated in docker containers:**
  - **without using docker**
  - **without using privileges**
  - **without system administrators intervention**
  - **without additional system software**

- **and run:**
  - **as a normal user**
  - **with the normal process controls and accounting**
  - **in interactive or batch systems**

- Empower end-users to run applications in containers

UDOCKER



indigo-dc / udocker

udocker / README.md

orviz Fix build status URL 00d714c on Dec 12, 2018

4 contributors

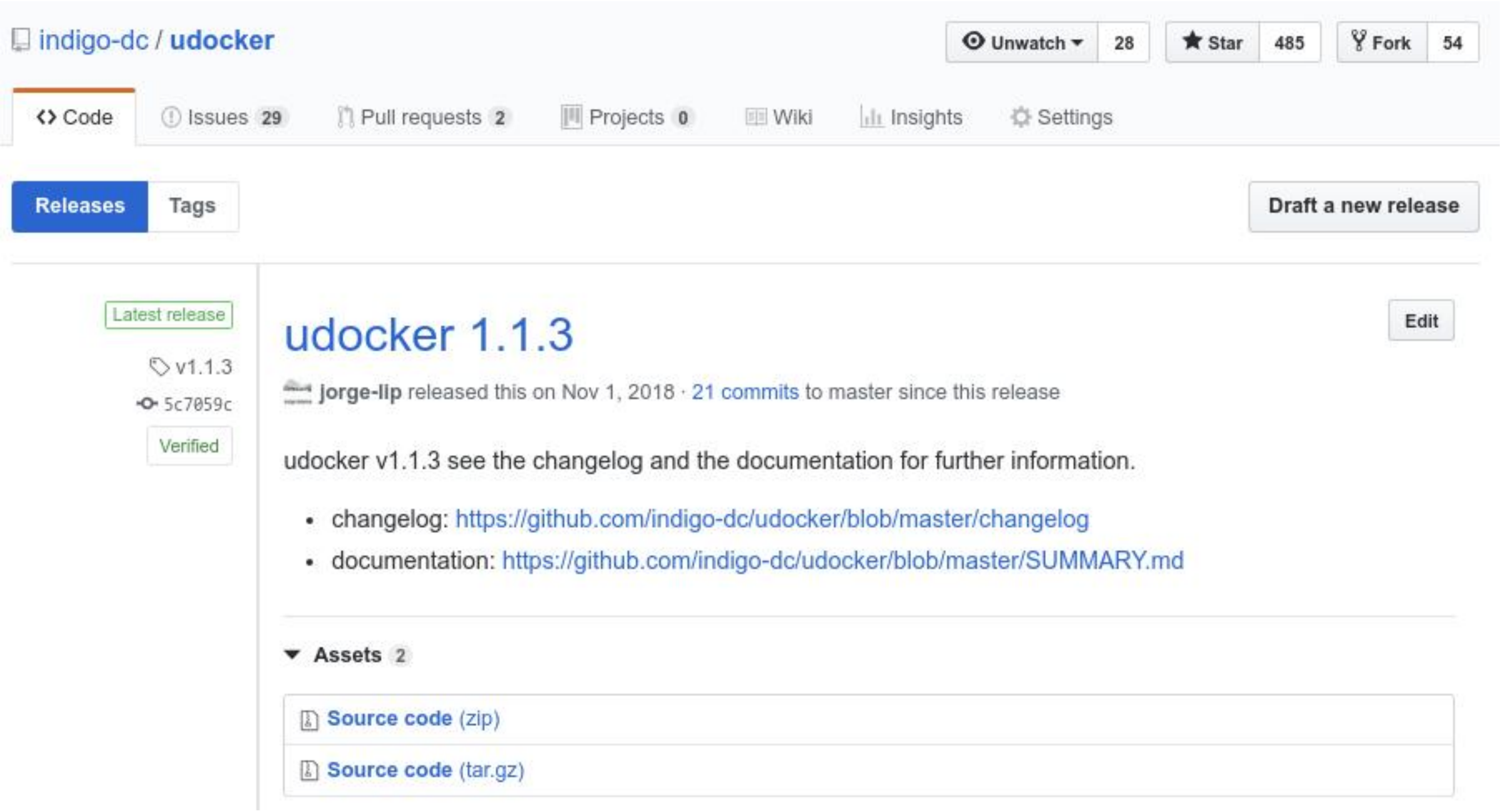
299 lines (237 sloc) 10.8 KB

https://github.com/indigo-dc/udocker

- https://github.com/indigo-dc/udocker/tree/**master**
- https://github.com/indigo-dc/udocker/tree/**devel**

udocker is a basic user tool to execute simple docker containers in user space without requiring root privileges. Enables download and execution of docker containers by non-privileged users in Linux systems where docker is not available. It can be used to pull and execute docker containers in Linux batch systems and interactive clusters that are managed by other entities such as grid infrastructures or externally managed batch or interactive systems.

Download release from github



udocker 1.1.3

jorge-lip released this on Nov 1, 2018 · 21 commits to master since this release

udocker v1.1.3 see the changelog and the documentation for further information.

- changelog: https://github.com/indigo-dc/udocker/blob/master/changelog
- documentation: https://github.com/indigo-dc/udocker/blob/master/SUMMARY.md

▾ Assets 2

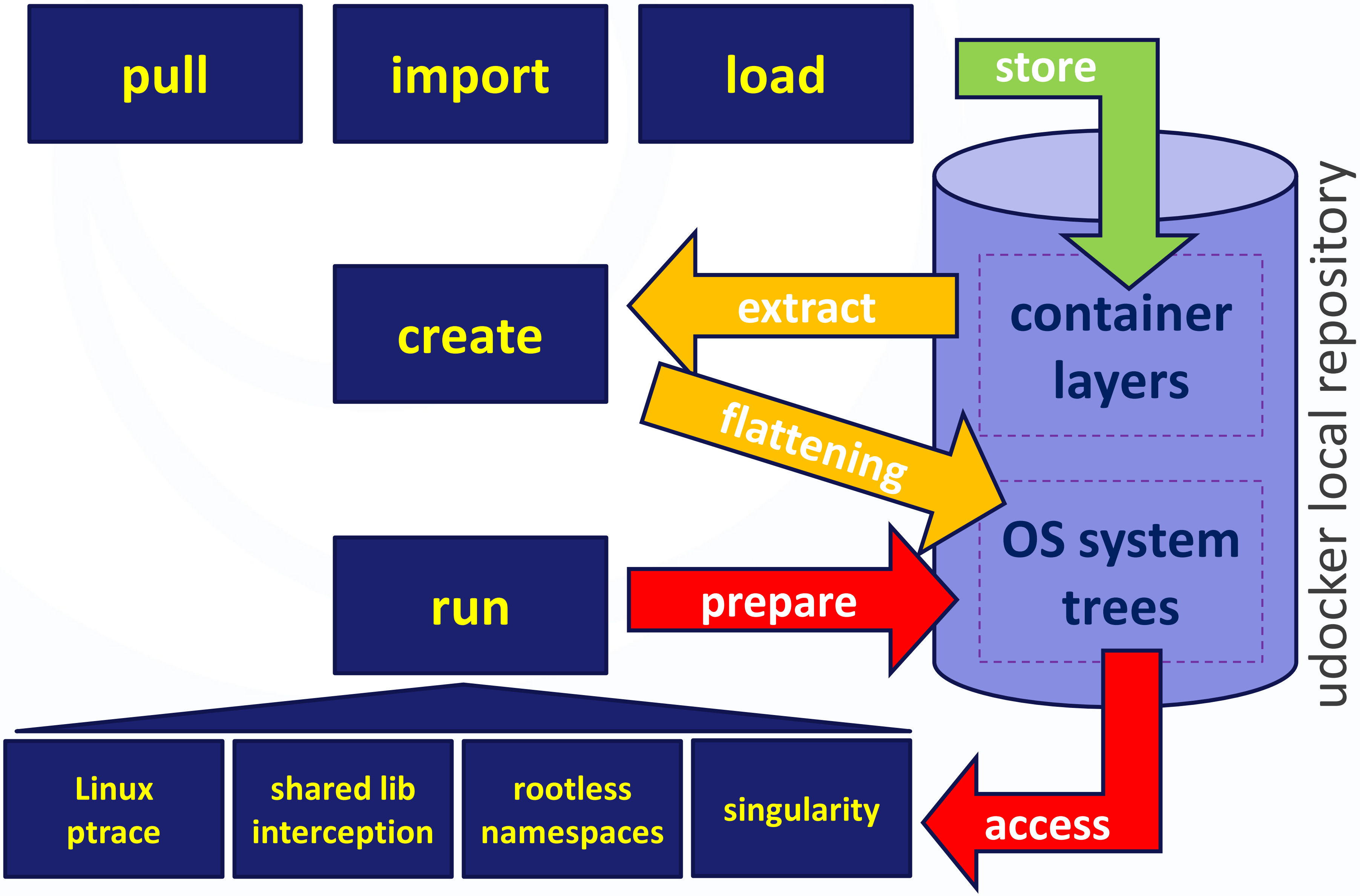
- Source code (zip)
- Source code (tar.gz)

Install from github

```
$   curl  https://raw.githubusercontent.com/indigo-
    dc/udocker/master/udocker.py > udocker


$   chmod  u+rx  udocker


$   ./udocker  install
```

or devel

Does not require compilation or system installation
Python plus tools delivered statically compiled



pull

import

load

store

create

extract

container layers

flattening

run

prepare

OS system trees

udocker local repository

access

Linux ptrace

shared lib interception

rootless namespaces

singularity

Pull images from repository

```
$ udocker pull ubuntu:14.04
```

Search for names and tags at:
https://hub.docker.com/

```
Downloading layer: sha256:bae382666908fd87a3a3646d7eb7176fa42226027d3256cac38ee0b79bdb0491
Downloading layer: sha256:f1ddd5e846a849fff877e4d61dc1002ca5d51de8521cced522e9503312b4c4e7
Downloading layer: sha256:90d12f864ab9d4cfe6475fc7ba508327c26d3d624344d6584a1fd860c3f0fefa
Downloading layer: sha256:a57ea72e31769e58f0c36db12d25683eba8fa14aaab0518729f28b3766b01112
Downloading layer: sha256:783a14252520746e3f7fee937b5f14ac1a84ef248ea0b1343d8b58b96df3fa9f
Downloading layer: sha256:a3ed95caeb02ffe68cdd9fd84406680ae93d633cb16422d00e8a7c22955b46d4
```

List local images

```
$ udocker images
```

```
REPOSITORY
msoffice:lastest                                   .
iscampos/openqcd:latest                            .
fedora:25                                          .
docker.io/susymastercode/mastercode:latest         .
ubuntu:14.04                                       .
ubuntu:16.10                                       .
ubuntu:latest                                      .
indigodatacloud/disvis:latest                      .
jorge/private:latest                               .
busybox:latest                                     .
jorge_fedora22_32bit:latest                        .
debian:oldstable                                   .
```

Create container from image

```
$  udocker  create  --name=ub14   ubuntu:14.04
```

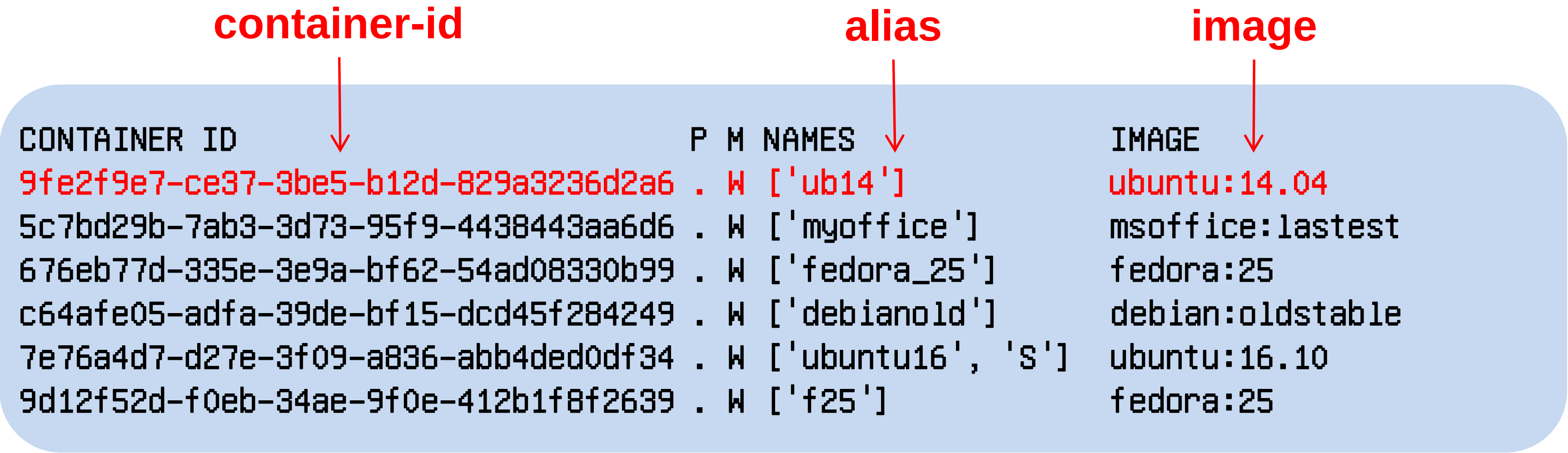
container-alias

```
9fe2f9e7-ce37-3be5-b12d-829a3236d2a6
```

container-id

List containers

```
$ udocker   ps
```



container-id

alias

image

```
CONTAINER ID                         P M NAMES              IMAGE
9fe2f9e7-ce37-3be5-b12d-829a3236d2a6 . W ['ub14']           ubuntu:14.04
5c7bd29b-7ab3-3d73-95f9-4438443aa6d6 . W ['myoffice']       msoffice:lastest
676eb77d-335e-3e9a-bf62-54ad08330b99 . W ['fedora_25']      fedora:25
c64afe05-adfa-39de-bf15-dcd45f284249 . W ['debianold']      debian:oldstable
7e76a4d7-d27e-3f09-a836-abb4ded0df34 . W ['ubuntu16', 'S']  ubuntu:16.10
9d12f52d-f0eb-34ae-9f0e-412b1f8f2639 . W ['f25']            fedora:25
```

Execute a created container

```
$ udocker  run  ub14
```

udocker respects container metadata, if the container has a default cmd to run it will be run otherwise starts a shell

```
 *****************************************************************************
 *                                                                           *
 *               STARTING 9fe2f9e7-ce37-3be5-b12d-829a3236d2a6               *
 *                                                                           *
 *****************************************************************************
 executing: bash
root@nbjorge:/# cat /etc/lsb-release
DISTRIB_ID=Ubuntu
DISTRIB_RELEASE=14.04
DISTRIB_CODENAME=trusty
DISTRIB_DESCRIPTION="Ubuntu 14.04.5 LTS"

root@nbjorge:/# apt-get  -o APT::Sandbox::User=root install firefox
```

root emulation

Execute container as yourself

```
$ udocker run  --user=jorge  -v /home/jorge  \
  -e HOME=/jorge/home  --workdir=/home/jorge  ub14
```

```
 Warning: non-existing user will be created

 ******************************************************************************
 *                                                                            *
 *               STARTING 9fe2f9e7-ce37-3be5-b12d-829a3236d2a6                *
 *                                                                            *
 ******************************************************************************
 executing: bash
jorge@nbjorge:~$ id
uid=1000(jorge) gid=1000(jorge) groups=1000(jorge),10(uucp)
jorge@nbjorge:~$ pwd
/home/jorge
jorge@nbjorge:~$
```

Shell scripts in the command line

```
$ udocker run --user=jorge --bindhome \
  --hostauth ub14  /bin/bash -c “id; pwd”
```

```
$ udocker run --user=jorge --bindhome \
  --hostauth ub14 /bin/bash <<EOF
id; pwd
EOF
```

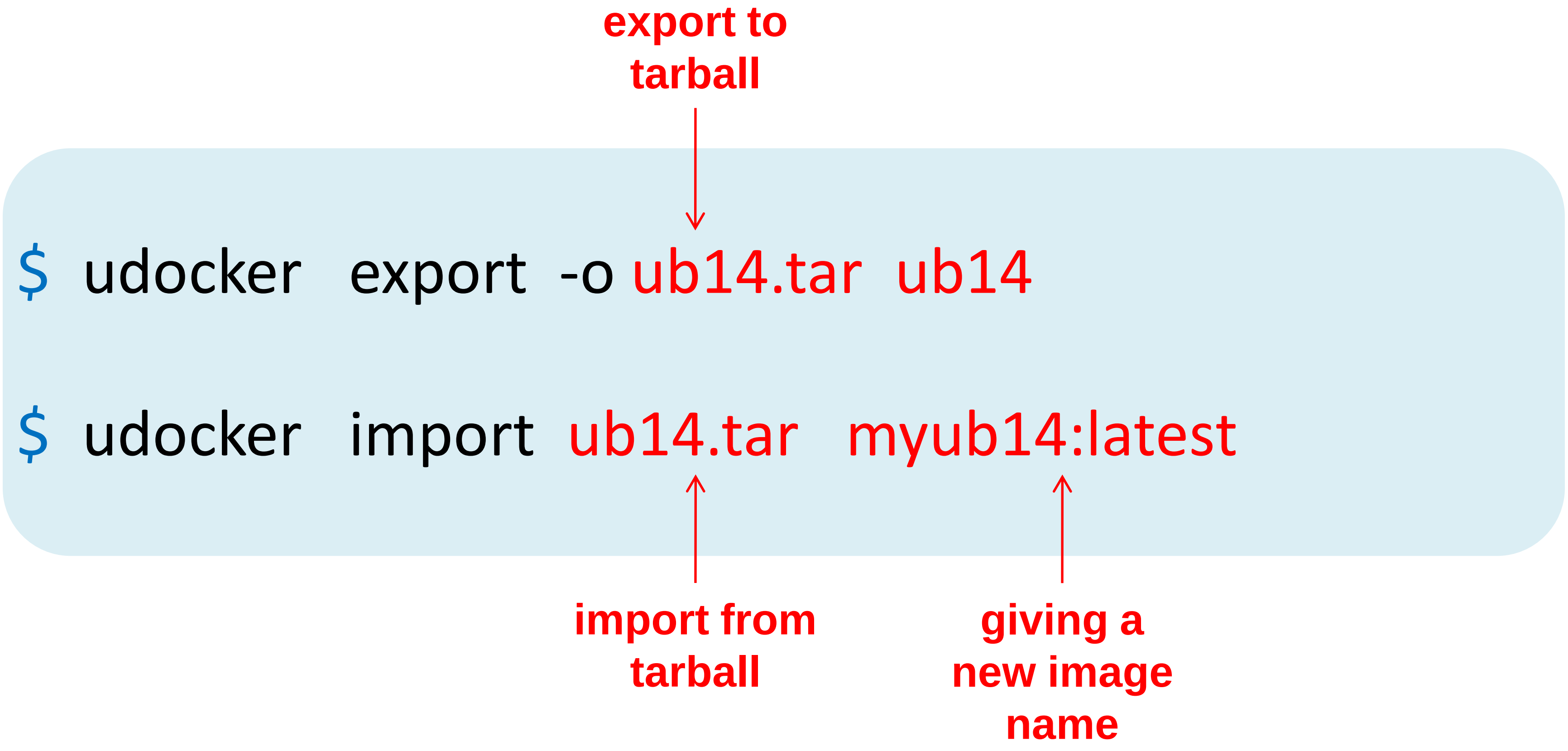
Duplicate a container

```
$ udocker  clone  --name=yy  ub14
```

cloned container-id

```
9fe2f9e7-ce37-3be5-b12d-829a3236d2a6
```

Export and import as tarballs as images



export to tarball

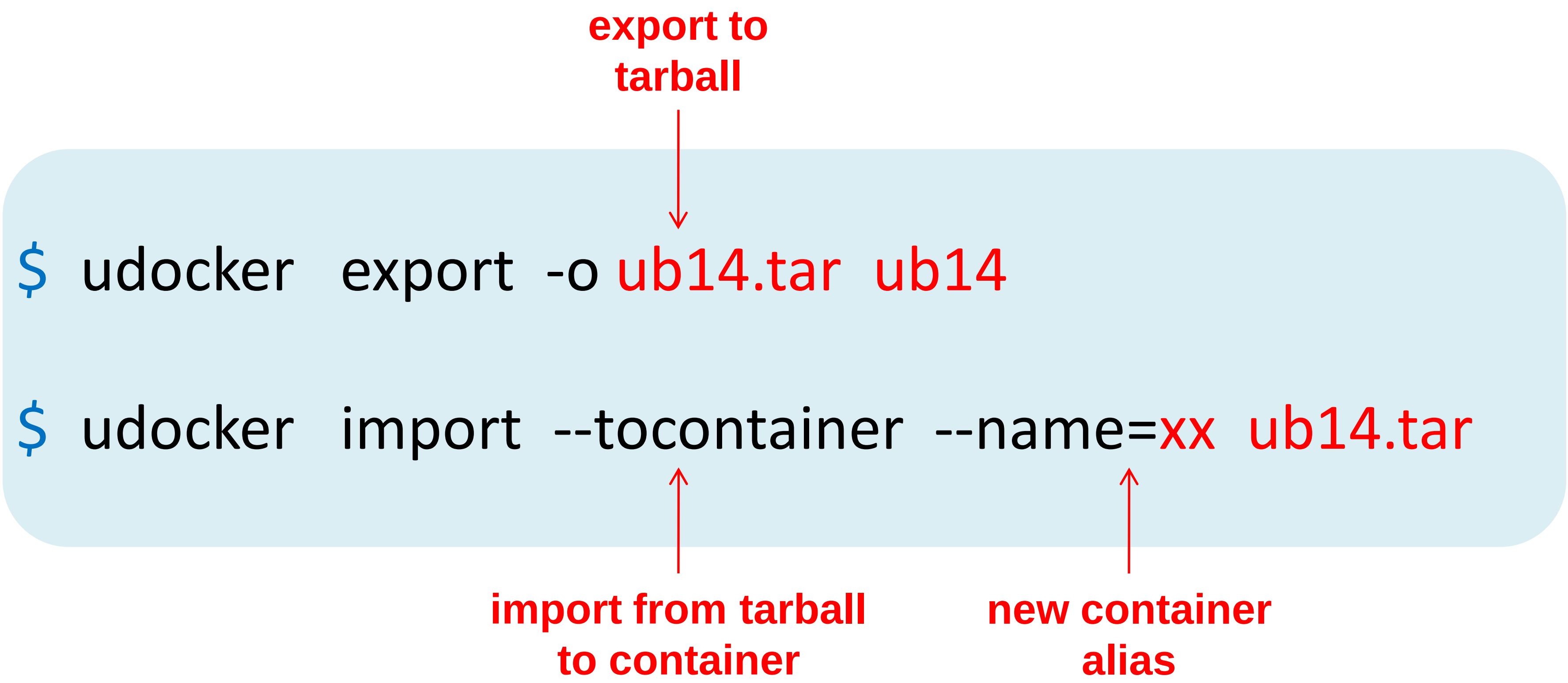
```
$ udocker   export  -o ub14.tar  ub14

$ udocker   import  ub14.tar   myub14:latest
```

import from tarball

giving a new image name

- Only the container files are exported, metadata is lost
- This is interoperable with docker

Export and import as container



export to tarball

```
$ udocker   export  -o ub14.tar  ub14

$ udocker   import  --tocontainer  --name=xx  ub14.tar
```

import from tarball to container

new container alias

- Only the container files are exported, metadata is lost
- Export is interoperable with docker
- Allows importing directly as container

Export and import as container

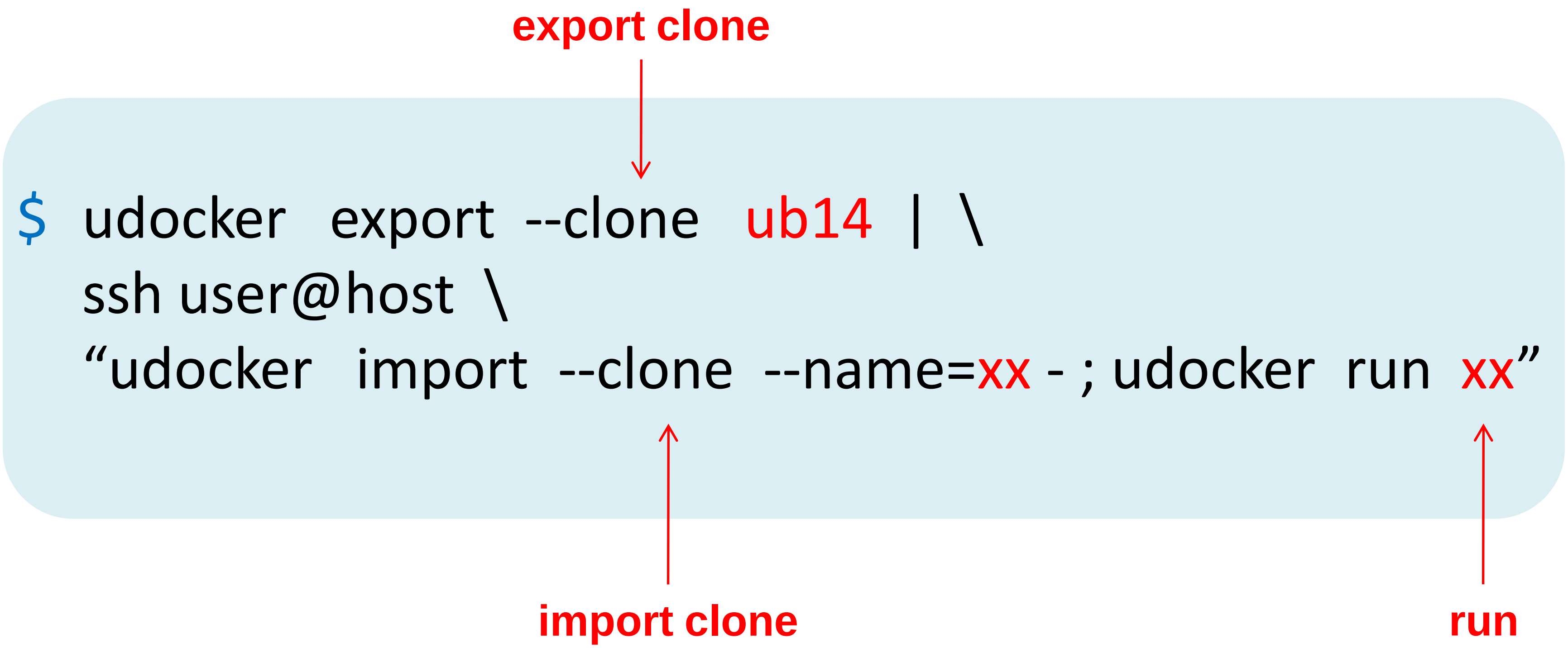
export clone

```
$  udocker   export  --clone  -o ub14.tar  ub14

$  udocker   import  --clone  --name=xx  ub14.tar
```

import clone

- Is imported as a container saving space and time
- Container metadata and execution mode are preserved
- This is NOT interoperable with docker

Export and import as container



export clone

```
$  udocker  export  --clone  ub14  |  \
   ssh user@host  \
   “udocker  import  --clone  --name=xx - ; udocker  run  xx”
```

import clone

run

- Export and import across nodes
- Piping stdout to stdin and minimizing I/O

Save and load images

save image with all layers and metadata

```
$ docker  save -o image.tar centos:centos6

$ udocker  load -i image.tar
```

load image with all layers and metadata

- Docker saves the image as a tarfile containing layers
- Udocker loads the image
- Can be used to transfer images without having to pull them

Save and load images

save image with all layers and metadata

```
$ docker  save  centos:centos6 | udocker  load
```

load image with all layers and metadata

- Save from docker and load with udocker
- Piping stdout to stdin

Remove containers and images

remove container by alias or id

```
$ udocker  rm  ub14
$ udocker  rm  9fe2f9e7-ce37-3be5-b12d-829a3236d2a6
```

remove image

```
$ udocker  rmi  ubuntu:14.04
```

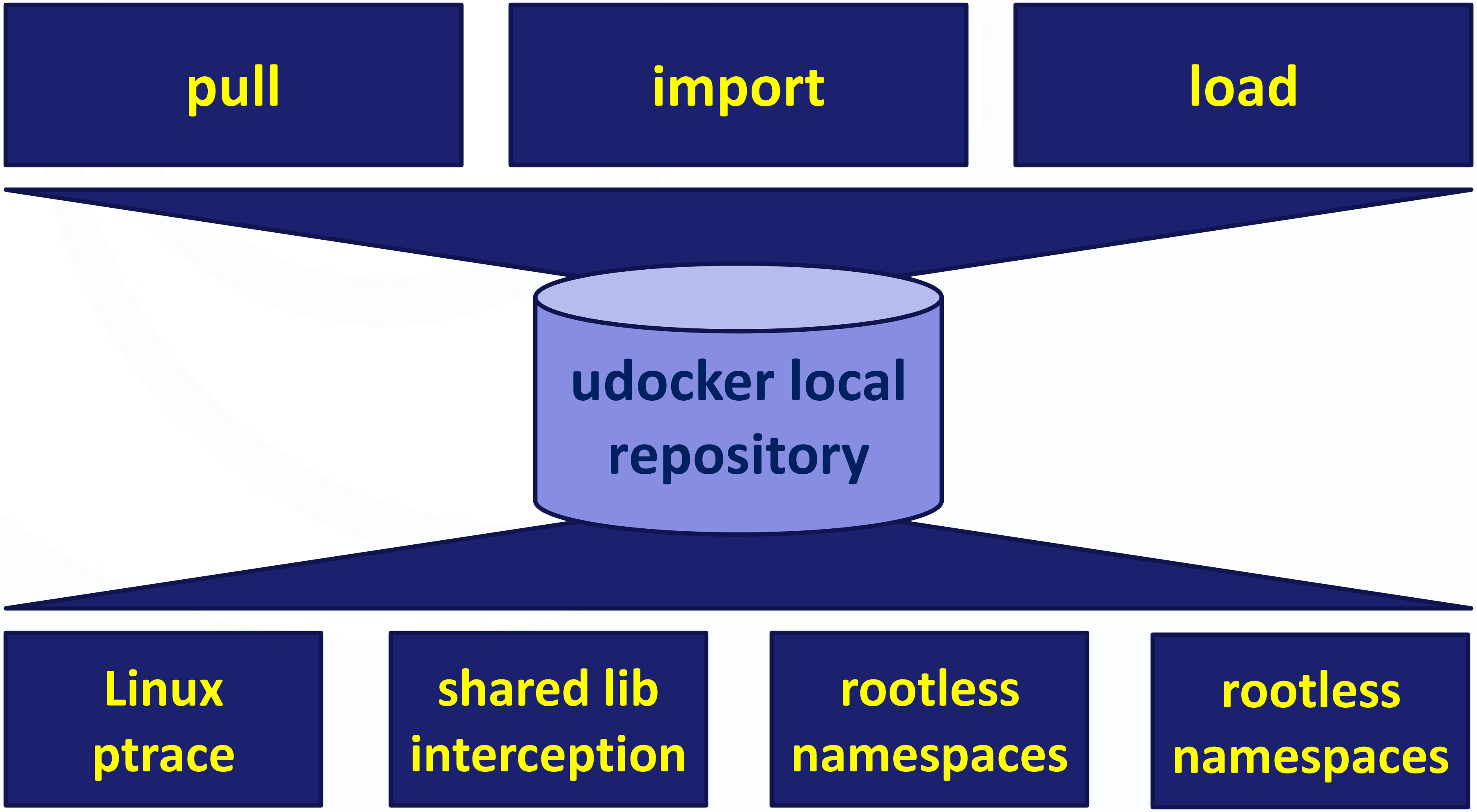
How does it work ...

udocker

- Integrates several tools

- Can run:
  - CentOS 6, CentOS 7, Fedora >= 23
  - Ubuntu 14.04, Ubuntu 16.04
  - Any distro that supports python 2.7

- Components:
  - Command line interface docker like ← Python
  - Pull of containers from Docker Hub ← Python
  - Local repository of images and containers ← Python
  - Execution of containers with modular engines ← several tools



pull

import

load

udocker local repository

Linux ptrace

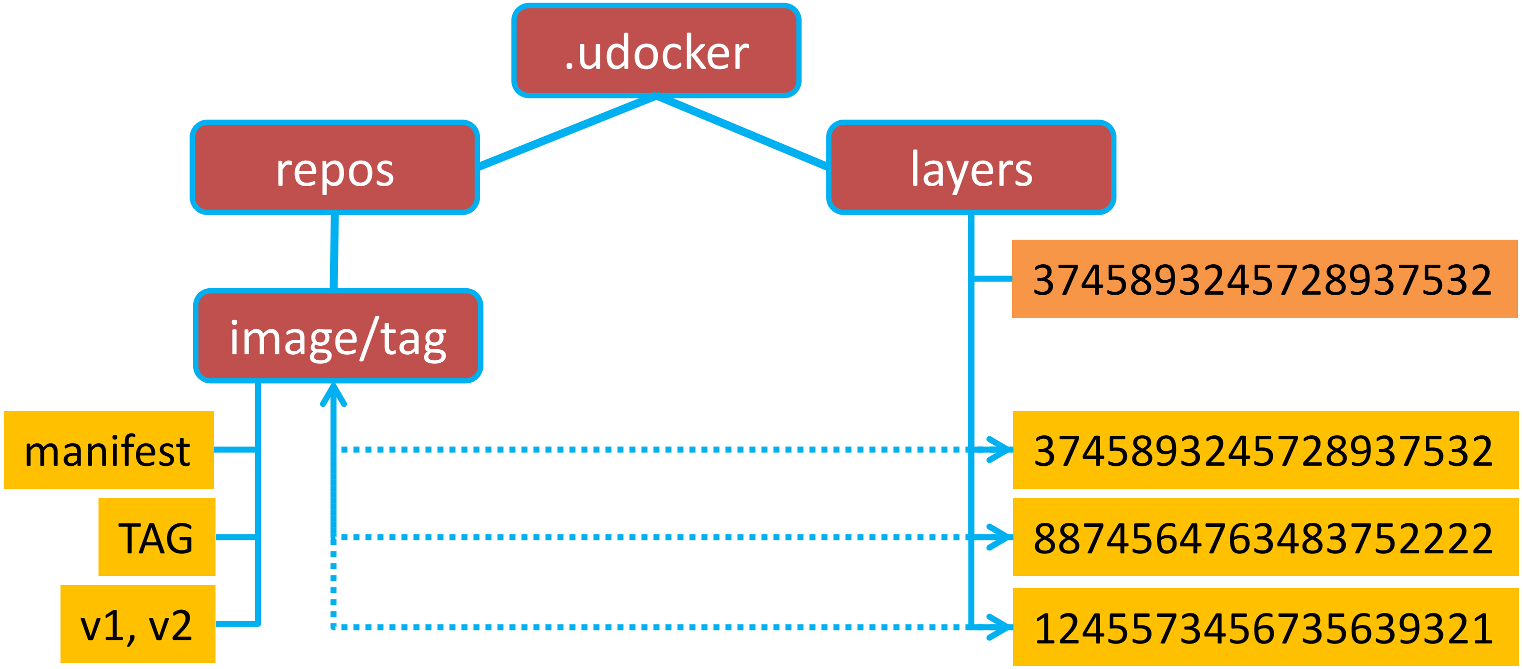
shared lib interception

rootless namespaces

rootless namespaces

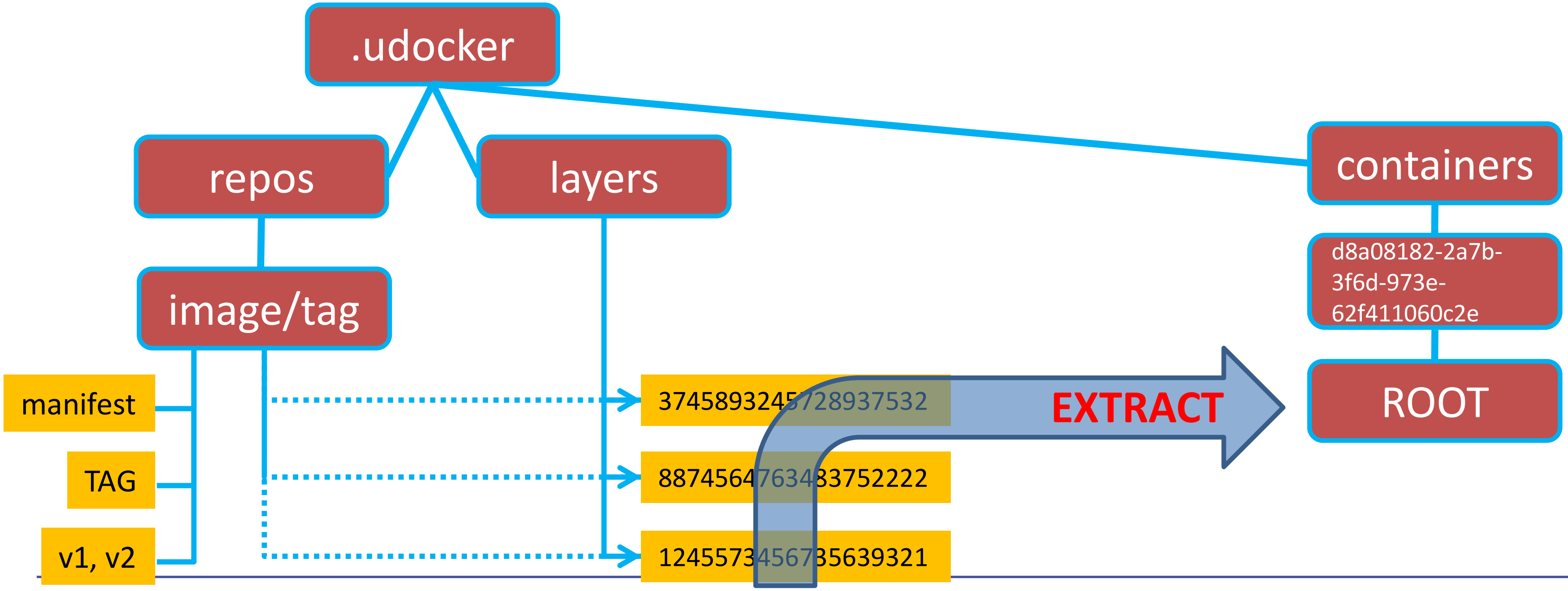
Images and layers

- Images
  - Layers and metadata are pulled with Docker Hub REST API
  - Image metadata is interpreted to identify the layers
  - Layers are stored in the use home directory under ~/.udocker/layers so that can be shared by multiple images



Extract layers to create container

- Containers
  - Are produced from the layers by flattening them
  - Each layer is extracted on top of the previous
  - Whiteouts are respected, protections are changed
  - The obtained directory trees are stored under ~/.udocker/containers in the user home directory

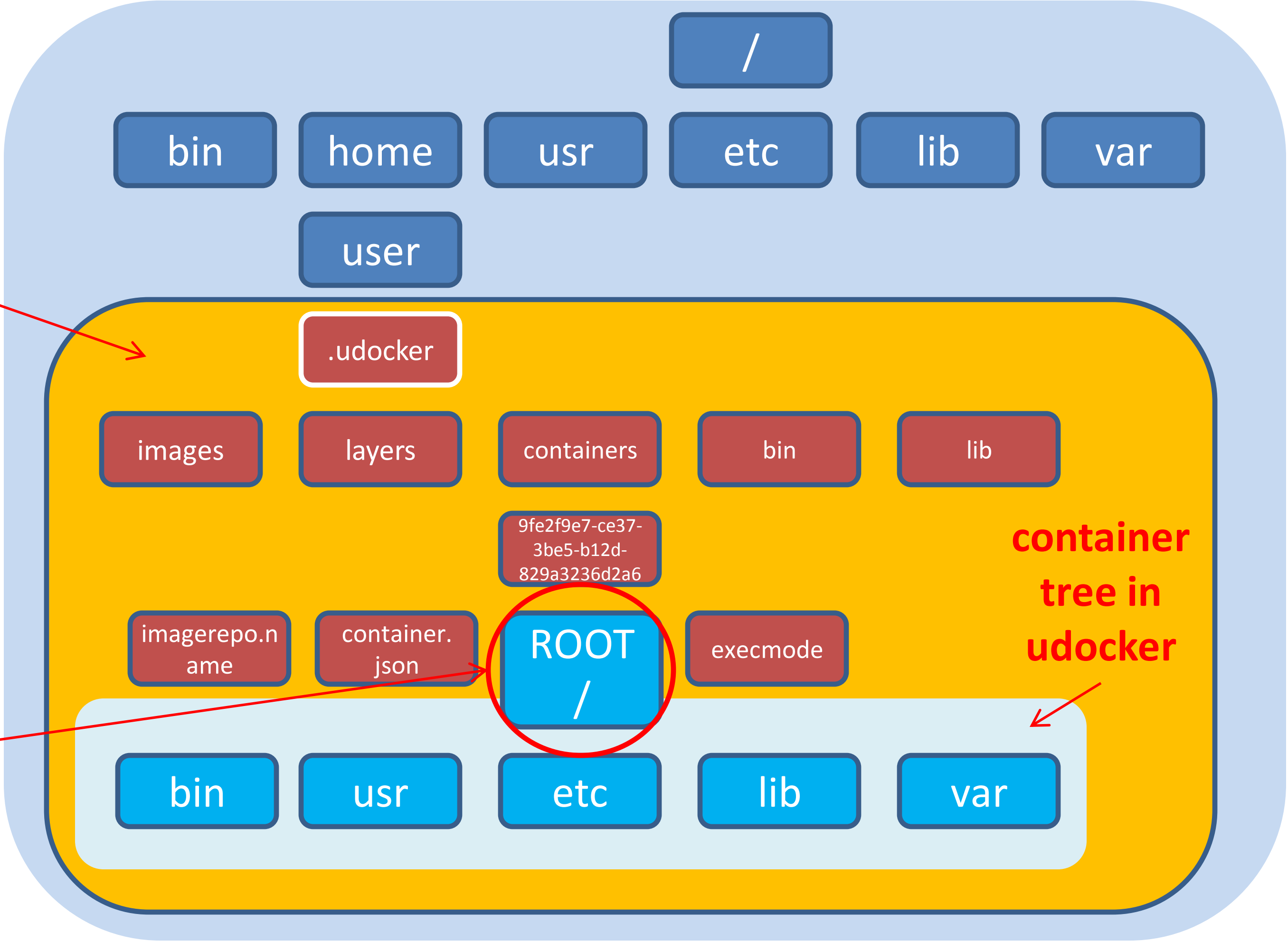


Container execution

- Execution
- chroot-like

udocker directory tree $HOME/.udocker

chroot to this directory becomes the new root for container processes



container tree in udocker

Execution methods

- udocker supports several techniques to achieve the equivalent to a chroot without using privileges
  - They are selected per container id via execution modes

Mode	Base	Description
P1	PRoot	PTRACE accelerated (with SECCOMP filtering) ← DEFAULT
P2	PRoot	PTRACE non-accelerated (without SECCOMP filtering)
R1	runC	rootless unprivileged using user namespaces
F1	Fakechroot	with loader as argument and LD_LIBRARY_PATH
F2	Fakechroot	with modified loader, loader as argument and LD_LIBRARY_PATH
F3	Fakechroot	modified loader and ELF headers of binaries + libs changed
F4	Fakechroot	modified loader and ELF headers dynamically changed
S1	Singularity	where locally installed using chroot or user namespaces

PRoot engine (P1 and P2)

- PRoot uses PTRACE to intercept system calls
- Pathnames are modified before the call
  - To expand container pathnames into host pathnames
- Pathnames are modified after the call
  - To shrink host pathnames to container pathnames

- The P1 mode uses PTRACE + SECCOMP filtering, to limit the interception to the set of calls that manipulate pathnames
  - We developed code to make it work on recent kernels
  - P1 is the udocker default mode
- The P2 mode uses only PTRACE ➔ therefore tracing all calls

- The impact of tracing depends on the system call frequency

runC engine (R1)

- runC is a tool to spawn containers according to the Open Containers Initiative (OCI) specification
  - In a very recent release 1.0 candidate 3, runC supports unprivileged namespaces using the user namespace
  - Unprivileged namespaces have many limitations but allow execution in a contained Docker like environment
  - Only run as root is supported
  - Available devices are limited

- We added conversion of Docker metadata to OCI
- udocker can produce an OCI spec and run the containers with runC transparently

Fakechroot engine

- Fakechroot is a library to provide chroot-like behaviour
- Uses the Linux loader LD_PRELOAD mechanism to:
  - intercept library calls that manipulate pathnames
  - change the pathnames similarly to PRoot
- It was conceived to support debootstrap in debian

- The OS in the host and in the chroot must be the same
  - as the loader inside the chroot will by default load libraries from the host system directories
  - the loaders are statically linked and the pathnames inside are absolute and non changeable

Fakechroot engine

- The loaders search for libraries:
  - If the pathname has a / they are directly loaded
  - If the pathname does not contain / (no directory specified) a search path or location can be obtained from:
    1. DT RPATH dynamic section attribute of the ELF executable
    2. LD LIBRARY PATH environment variable
    3. DT RUNPATH dynamic section attribute of the ELF executable
    4. cache file /etc/ld.so.cache
    5. default paths such as /lib64, /usr/lib64, /lib, /usr/lib
- The location of the loader itself is encoded in the executables ELF header

Fakechroot engine (F1)

- The loader is encoded in the ELF header of executable
  - is the executable that loads libraries and calls the actual executable
  - also act as library providing functions and symbols
- Is essential that executables in the container are run with the loader inside of the container instead of the host loader

- The mode F1 enforces the loader:
  - passes it as 1st argument in exec* and similar calls shifting argv
  - the loader starts first gets the executable pathname and its arguments from argv and launches it
  - Enforcement of locations is performed by filling in LD_LIBRARY_PATH with the library locations in the container and also extracted from the container ld.so.cache

Fakechroot engine (F2)

- The mode F2 changes the loader binary within the container:
  - A copy of the container loader is made
  - The loader binary is then edited by udocker
  - The loading from host locations /lib, /lib64 etc is disabled
  - The loading using the host ld.so.cache is disabled
  - LD_LIBRARY_PATH is renamed to LD_LIBRARY_REAL

- Upon execution
  - Invocation is performed as in mode F1
  - The LD_LIBRARY_REAL is filled with library locations from the container and its ld.so.cache
  - Changes made by the user to LD_LIBRARY_PATH are intercepted and pathnames adjusted to container locations and inserted in LD_LIBRARY_REAL

Fakechroot engine (F3 and F4)

- The mode F3 changes binaries both executables and libraries
  - The PatchELF tool was heavily modified to enable easier change of
    - Loader location in ELF headers of executables
    - Library path locations inside executables and libraries

- When modes F3 or F4 are selected the executables and libraries are edited
  - The loader location is change to point to the container
  - The libraries location if absolute are changed to point to container
  - The libraries search paths inside the binaries are changed to point to container locations

- The loader no longer needs to be passed as first argument
- The libraries are always fetched from container locations

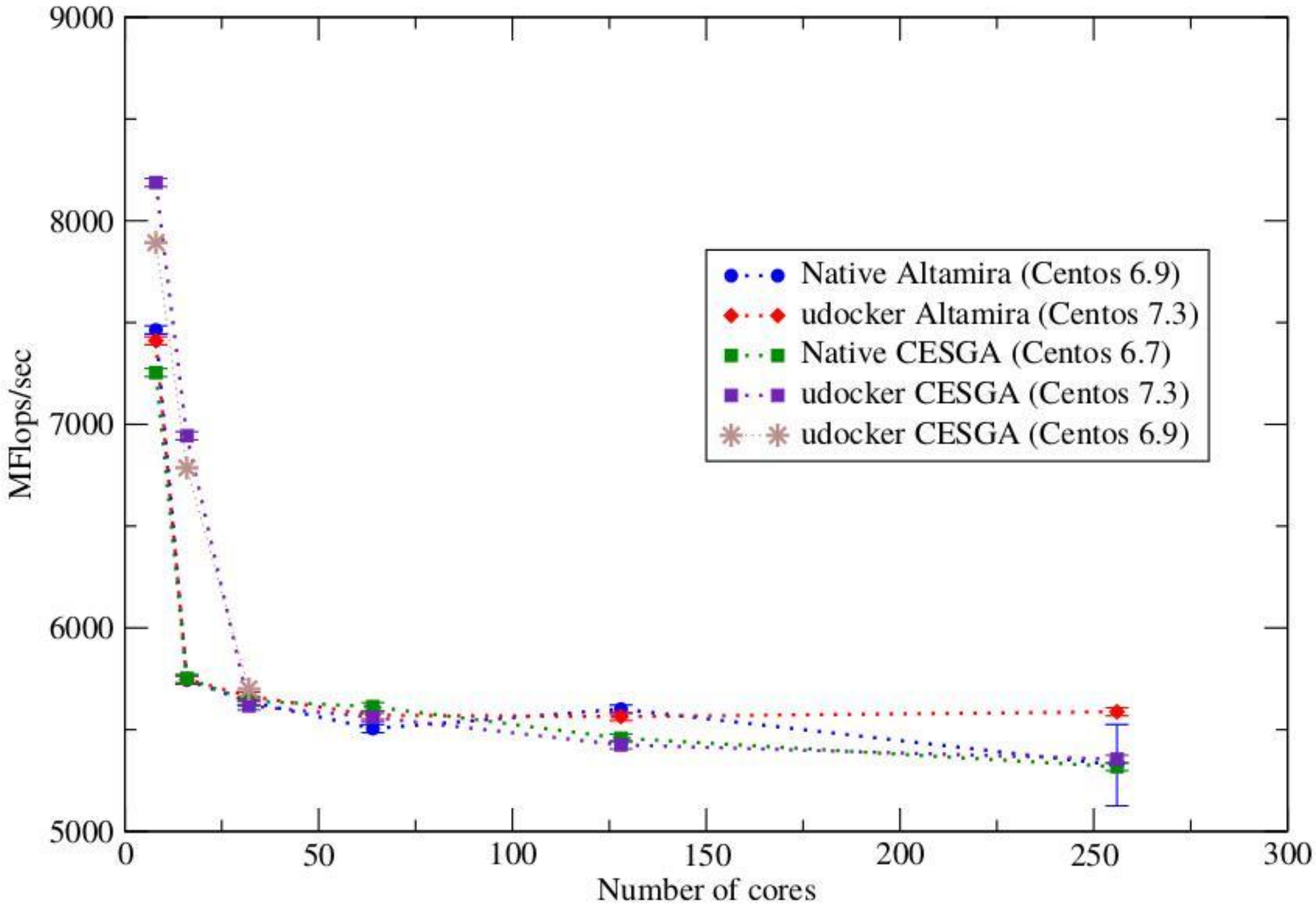
Fakechroot engine (F3 and F4)

- The LD_LIBRARY_REAL continues to be used in F3 and F4

- The mode F4 adds dynamic editing of executables and libraries
- This is useful with libraries or executables are added to the container or created as result of a compilation

- Containers in modes F3 and F4 cannot be transparently moved across different systems:
  - the absolute pathnames to the container locations will likely differ.
  - In this case convert first to another mode before transfer
  - or at arrival use: “setup --execmode=Fn --force”

udocker & Lattice QCD



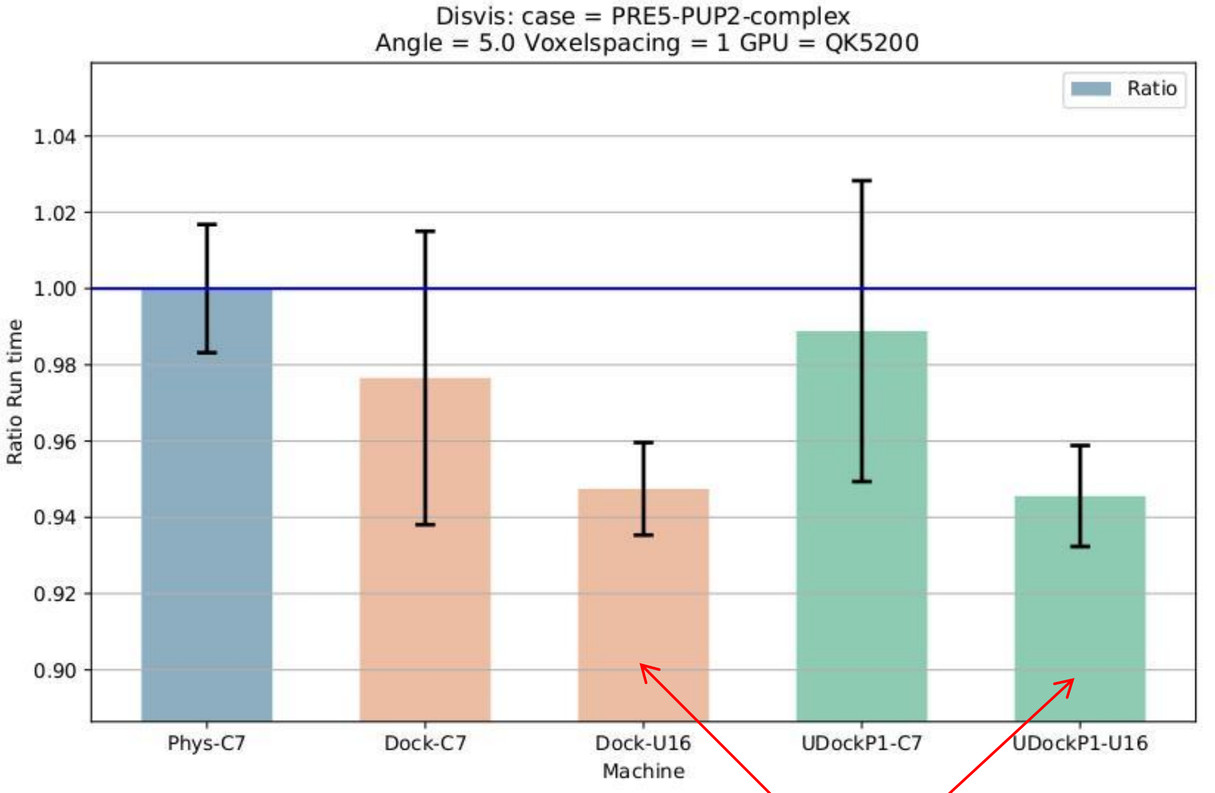
OpenQCD is a very advanced code to run lattice simulations

Scaling performance as a function of the cores for the computation of application of the Dirac operator to a spinor field.

Using OpenMPI

udocker in P1 mode

udocker & Biomolecular complexes



Better performance with Ubuntu 16 container

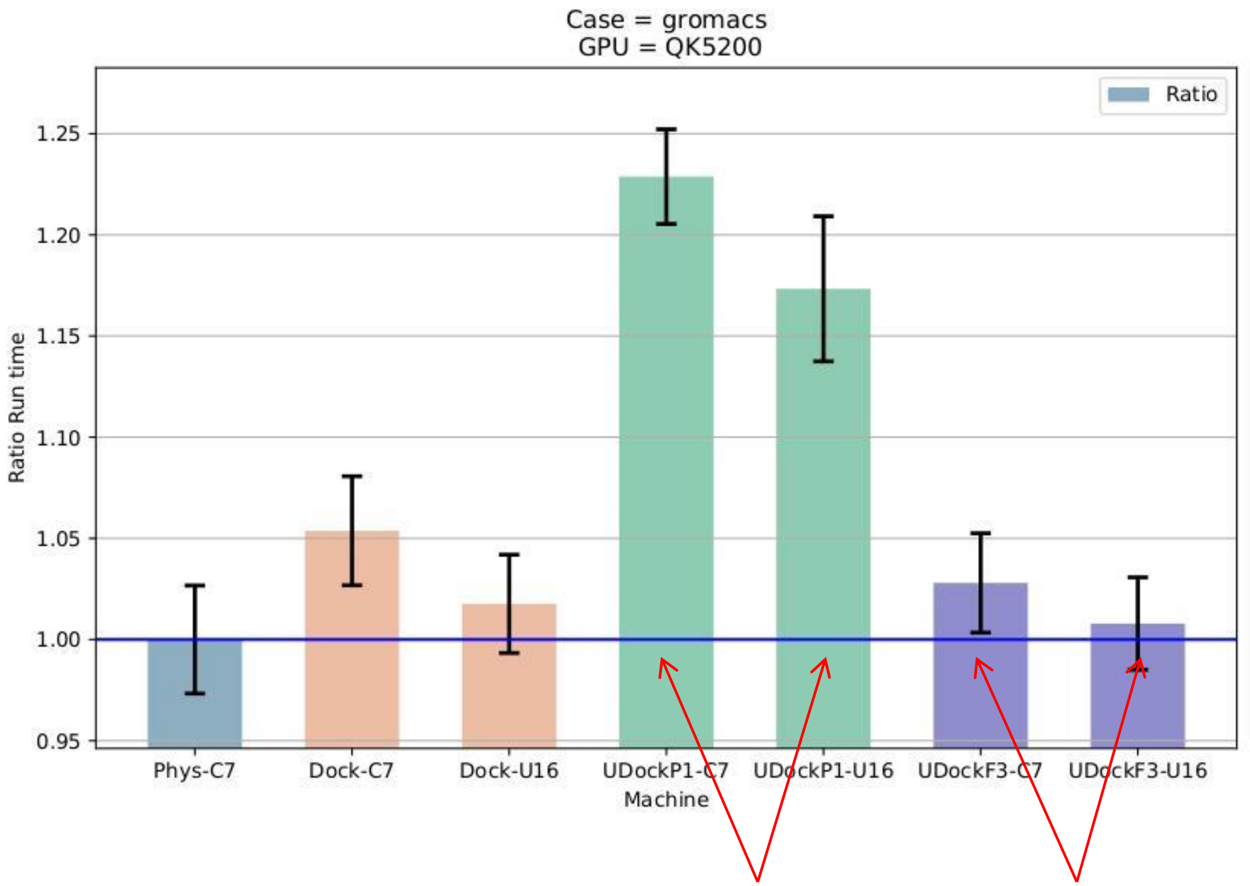
DisVis is being used in production with udocker

Performance with docker and udocker are the same and very similar to the host.

Using OpenCL and NVIDIA GPGPUs

udocker in P1 mode

udocker & Molecular dynamics



PTRACE **SHARED LIB CALL**

Gromacs is widely used both in biochemical and non-biochemical systems.

udocker P mode have lower performance udocker F mode same as Docker.

Using OpenCL and OpenMP

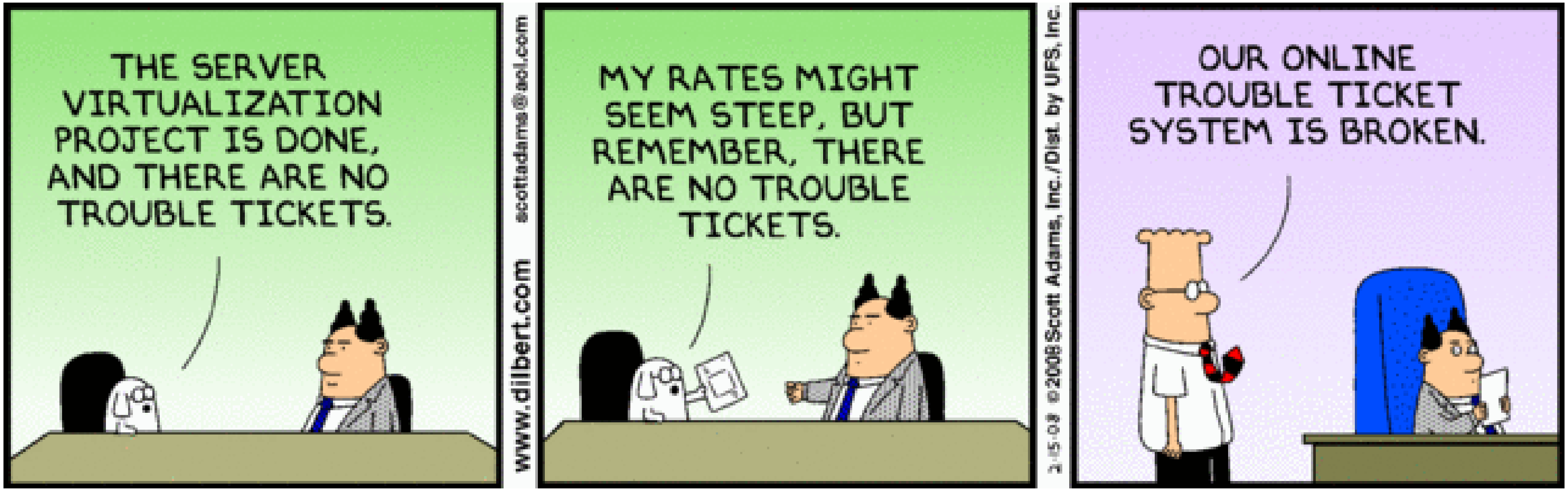
udocker in P1 mode
udocker in F3 mode

Upcoming

- Improving GPU driver integration
- Better support for MPI applications
- Porting to Python 3
- Better translation of “volume” directories
- Support for installation with pip
- Command line interface enhancements
- Improve root emulation

Thank you

https://github.com/indigo-dc/udocker


THE SERVER VIRTUALIZATION PROJECT IS DONE, AND THERE ARE NO TROUBLE TICKETS.
MY RATES MIGHT SEEM STEEP, BUT REMEMBER, THERE ARE NO TROUBLE TICKETS.
OUR ONLINE TROUBLE TICKET SYSTEM IS BROKEN.
scottadams@aol.com
www.dilbert.com
2-15-08 ©2008 Scott Adams, Inc./Dist. by UFS, Inc.