

Introduction to the Programming Assignments

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October 22, 2008

The Speaker

- Philipp Kupferschmied
- in charge of tutorials and programming assignments
- contact
 - pkupfer@ira.uka.de
 - Wed, 15:30–17:00h
Bdg. 50.34, R.163

Longish Roadmap

- 1 Motivation
 - Overview
 - Bonus
- 2 OS/161
 - Overview
 - Requirements & Tips
 - Linux
- 3 Mercurial
 - Purpose
 - Concept
 - Commands
 - Remote
- 4 SSH
 - Passwordless Remote Login
- 5 GDB
 - Debugging Applications
 - Hooking GDB up with System/161

System Architecture Course Structure

- 1 lecture
 - broad overview
 - abstract examples
- 2 tutorials
 - in-depth examination
 - isolated aspects
- 3 programming assignments
 - implement algorithms in OS
 - experience component interaction

Tutorials

- every week
 - Wednesday, Thursday, and Friday
 - started today ...
- online registration required
- attend the registered tutorial only
 - capacity of the rooms is quite limited
 - except on public holidays
- learn to describe and reason about abstract ideas
- discuss solutions to prepublished questions
- prepare and participate!
 - questions online on Friday
 - solutions online 1 or 2 weeks afterwards

Programming Assignments

- 4 programming assignments
 - ① setup the system
 - ② synchronization
 - ③ system calls and address spaces
 - ④ virtual memory subsystem
 - page-tables
 - page replacement strategies
 - swapping
- OS/161 as starting point
 - 20,000 LOC
- 3 assessable parts per assignment
 - ① code reading
 - ② analysis and design
 - ③ implementation
- 3 or 4 work weeks per assignment

Participation and Rewards

- programming assignments are **voluntary**
- bonus on final exam available
 - up to 4 bonus points
 - first bonus point
 - $\geq 50\%$ of code reading **and**
 - $\geq 50\%$ of practical parts
- groups of 2 students only
 - use the forum to find a partner
 - register your group on-line (OS/161 Groups)
- register with one of your tutors
 - via email to os161@ira.uka.de
 - your email must contain:
 - your group id (*sapwX*)
 - name of both team members
 - desired tutor
- first assignment is already out

Preliminary Marks

- ① setup
 - 20 points code reading
 - 10 points implementation
- ② synchronization
 - 20 points code reading
 - 15 points implementation
- ③ syscalls and address spaces
 - 20 points code reading
 - 15 + 5 points implementation
- ④ virtual memory
 - 20 points code reading
 - 20 points implementation

Assignment Submission

- code reading parts via web-form
- implementation via email to os161@ira.uka.de

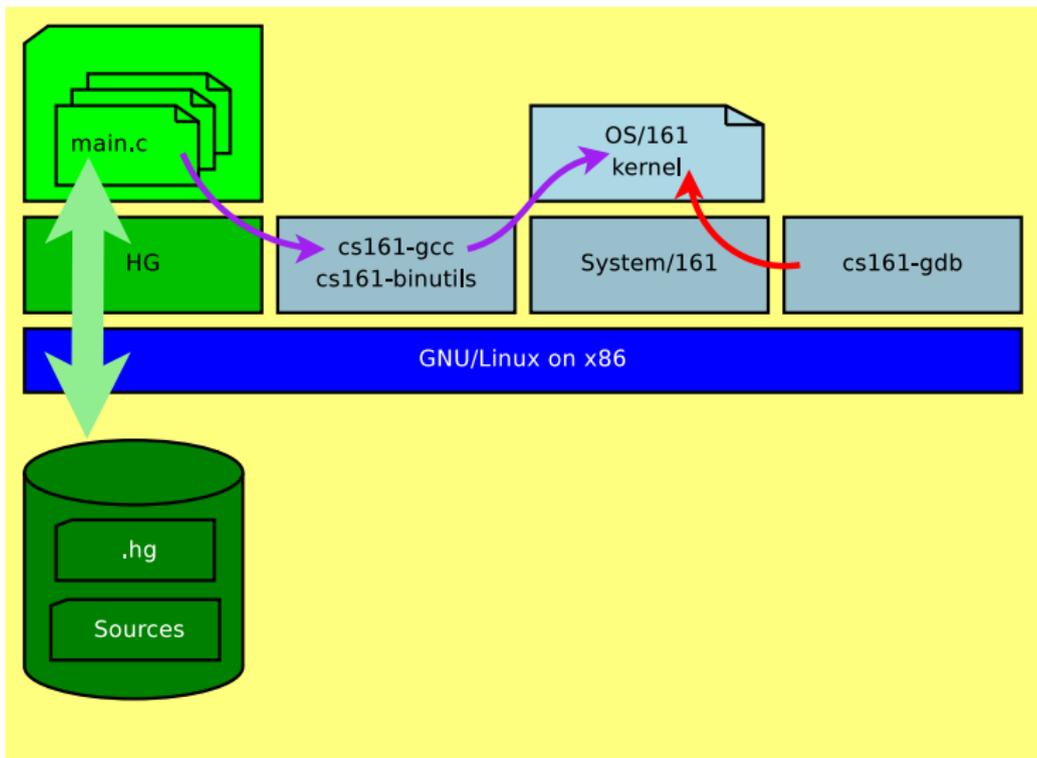
Preliminary Timeline

- programming assignment 0 is out since Monday
 - deadline for theoretical part: 7.11.2008
 - deadline for practical part: 14.11.2008
- programming assignment 1 will be out on 14.11.2008
 - deadline for theoretical part: 21.11.2008
 - deadline for practical part: 12.12.2008
- programming assignment 2 will be out on 12.12.2008
 - deadline for theoretical part: 19.12.2008
 - deadline for practical part: 16.01.2009
- programming assignment 3 will be out on 16.01.2009
 - deadline for theoretical part: 23.01.2009
 - deadline for practical part: 13.02.2009

OS/161 Software Family

- OS/161
 - rudimentary, functional OS
 - targets MIPS
 - (most) HW dependent parts done
 - stubs or holes at interesting places
- System/161
 - simulates MIPS processor and
 - simplified devices
 - GDB debugging hooks
- Cross-Compiler Toolchain
 - cs161-gcc, -as, -ld, ...
 - cs161-gdb
- Mercurial
 - manage the code
 - allow concurrent development
- SSH

Component Interaction



```
~/sysarch/root $ ./sys161 kernel
```

```
sys161: System/161 release 1.13, compiled Oct 21 2008 11:23:26
```

```
OS/161 base system version 1.10
```

```
Copyright (c) 2000, 2001, 2002, 2003
```

```
President and Fellows of Harvard College. All rights reserved.
```

```
Put-your-group-name-here's system version 0 (ASST0 #1)
```

```
Cpu is MIPS r2000/r3000
```

```
512k physical memory available
```

```
Device probe...
```

```
lamebus0 (system main bus)
```

```
emu0 at lamebus0
```

```
ltrace0 at lamebus0
```

```
⋮
```

```
lser0 at lamebus0
```

```
con0 at lser0
```

```
pseudorand0 (virtual)
```

```
OS/161 kernel [? for menu]: q
```

System Requirements

- primary platform: Linux on x86
 - e.g., ATIS machines
- reportedly works on *BSD, Mac OS X
 - requires development packages (build-essentials, gcc, binutils)
- Windows via cygwin
 - works, but unsupported
 - gcc, binutils, wget, tar, bzip2, make, bash, sed
 - probably more ...
 - use putty to work on i08fs1 instead?
- 500 MB hard disk space
 - while building cross-compilers
 - 100 MB afterwards
 - 50 MB on ATIS
 - cross-compilers already installed!
 - see `/opt/cs161/bin`

Proposed Filesystem Structure

- \$HOME/
 - sysarch/
 - sharedrepos/¹
 - bin/²
 - tools/²
 - root/
 - asst0-src/
 - ⋮
 - asst3-src/
 - (all downloaded archives).tbz2
 - simplifies clean-up half a year from now

¹only one of each team

²not on ATIS machines, see `/opt/cs161`

General Remarks (1/2)

- start early
 - read carefully
 - assignment
 - code
 - think
 - what do you need?
 - what is available? → read again
 - implement
- work continuously
 - avoid long breaks
- communicate with your partner
 - discuss problems
 - divide the implementation tasks

General Remarks (2/2)

- test early
 - not (only) 1h before deadline
- write dummy stubs
 - simple functionality
 - support early testing
 - but more work
- test again
 - changes may break test cases

Linux Basics (1/3)

- directories
 - mkdir -p `relative/path/name`
 - cd `relative/path/name`
 - cd ..
 - ls -l
- archives (tarballs)
 - .bz2: tar -xjf `archive.tbz2`
 - .gz: tar -xzf `archive.tgz`
- build process
 - ./configure [options]
 - make `target` or simply make
 - make install
 - not required for OS/161 sources

Linux Basics (2/3)

- environment
 - HOME: absolute path to your home
 - PATH: colon separated list of paths to search for executables
 - **must not** contain “.”
 - add /path/to/cs161-gcc
- inspecting environment variables
 - echo \$VAR
- defining environment variables
 - bash: export VAR="value"
 - other shells: see respective man page

Linux Basics (3/3)

- login shell standard environment
 - in `~/.bashrc` or `~/.profile` (or `~/.bash_login`):
`export PATH=/opt/cs161/bin:$HOME/sysarch/bin:$PATH`

Problem Statement

- two developers edit a single file
 - same file, the one who saves last prevails
 - distinct copies, must be merged sometime
- solutions
 - editor-specific file locking
 - policy
 - source code management systems

Purpose of Source Code Management

- allow concurrent development
 - no file locking
 - support merging of work
- track project history
 - who? when? what? how?
 - **why?**
- restore previous file revisions
 - after disk crash
 - drop development in a dead end
 - how was it done before?

Basic Notions of Mercurial

Mercurial distributed revision control tool

HG chemical symbol of mercury, “short name” of Mercurial

repository working directory + project history

revision retrievable state of a file

changeset collection of changes that lead to a new revision

tag symbolic name for a project state

working directory contains files on which development takes place

tip most recent changeset in repository

Mercurial Sample Session

```
philipp@host:~/hg-demo$ ls -la
total 12
drwxr-xr-x  3 philipp philipp 4096 2008-09-18 17:38 .
drwxr-xr-x 53 philipp philipp 4096 2008-09-18 17:43 ..
drwxr-xr-x  2 philipp philipp 4096 2008-09-18 17:38 sources
```

Mercurial Sample Session

```
philipp@host:~/hg-demo$ cd sources
philipp@host:~/hg-demo/sources$ ls -la
total 12
drwxr-xr-x 2 philipp philipp 4096 2008-09-18 17:38 .
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:38 ..
-rw-r--r-- 1 philipp philipp  104 2008-09-18 17:38 main.c
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg init
philipp@host:~/hg-demo/sources$ ls -la
total 16
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:44 .
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:38 ..
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:44 .hg
-rw-r--r-- 1 philipp philipp 104 2008-09-18 17:38 main.c
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg add  
adding main.c
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg commit -m "Initial commit"
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg log
changeset: 0:0391671a98ef
tag:      tip
user:     Philipp Kupferschmied <pk@ibds.uka.de>
date:     Thu Sep 18 17:45:52 2008 +0200
summary:  Initial commit
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ vim main.c
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg diff
diff -r 0391671a98ef main.c
--- a/main.c      Thu Sep 18 17:45:52 2008 +0200
+++ b/main.c      Thu Sep 18 17:47:31 2008 +0200
@@ -2,7 +2,8 @@
```

```
int main( int argc, char **argv )
{
- printf( "Hallo Welt!\n" );
+ //printf( "Hallo Welt!\n" );
+ printf( "Hello World!\n" );

return 0;
}
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg commit -m "Changed output language"
philipp@host:~/hg-demo/sources$ hg log
changeset: 1:a32fd2a82371
tag: tip
user: Philipp Kupferschmied <pk@ibds.uka.de>
date: Thu Sep 18 17:48:16 2008 +0200
summary: Changed output language

changeset: 0:0391671a98ef
user: Philipp Kupferschmied <pk@ibds.uka.de>
date: Thu Sep 18 17:45:52 2008 +0200
summary: Initial commit
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ cd ..
philipp@host:~/hg-demo$ ls -la
total 12
drwxr-xr-x  3 philipp philipp 4096 2008-09-18 17:38 .
drwxr-xr-x 53 philipp philipp 4096 2008-09-18 17:48 ..
drwxr-xr-x  3 philipp philipp 4096 2008-09-18 17:48 sources
philipp@host:~/hg-demo$ hg clone sources sources2
updating working directory
1 files updated, 0 files merged, 0 files removed, 0 files unresolved
philipp@host:~/hg-demo$ ls -la
total 16
drwxr-xr-x  4 philipp philipp 4096 2008-09-18 17:49 .
drwxr-xr-x 53 philipp philipp 4096 2008-09-18 17:48 ..
drwxr-xr-x  3 philipp philipp 4096 2008-09-18 17:48 sources
drwxr-xr-x  3 philipp philipp 4096 2008-09-18 17:49 sources2
```

Mercurial Sample Session

```
philipp@host:~/hg-demo$ cd sources2
philipp@host:~/hg-demo/sources2$ hg log
changeset: 1:a32fd2a82371
tag: tip
user: Philipp Kupferschmied <pk@ibds.uka.de>
date: Thu Sep 18 17:48:16 2008 +0200
summary: Changed output language

changeset: 0:0391671a98ef
user: Philipp Kupferschmied <pk@ibds.uka.de>
date: Thu Sep 18 17:45:52 2008 +0200
summary: Initial commit
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources2$ echo > foo.c  
philipp@host:~/hg-demo/sources2$ hg add  
adding foo.c
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources2$ hg commit -m "Added foo.c"
```

```
philipp@host:~/hg-demo/sources2$ hg log
```

```
changeset: 2:06d64ee049a9
```

```
tag: tip
```

```
user: Philipp Kupferschmied <pk@ibds.uka.de>
```

```
date: Thu Sep 18 17:51:11 2008 +0200
```

```
summary: Added foo.c
```

```
changeset: 1:a32fd2a82371
```

```
user: Philipp Kupferschmied <pk@ibds.uka.de>
```

```
date: Thu Sep 18 17:48:16 2008 +0200
```

```
summary: Changed output language
```

```
changeset: 0:0391671a98ef
```

```
user: Philipp Kupferschmied <pk@ibds.uka.de>
```

```
date: Thu Sep 18 17:45:52 2008 +0200
```

```
summary: Initial commit
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources2$ cd ../sources
philipp@host:~/hg-demo/sources$ ls -la
total 16
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:48 .
drwxr-xr-x 4 philipp philipp 4096 2008-09-18 17:49 ..
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:48 .hg
-rw-r--r-- 1 philipp philipp 138 2008-09-18 17:47 main.c

philipp@host:~/hg-demo/sources$ hg log
changeset: 1:a32fd2a82371
tag:      tip
user:     Philipp Kupferschmied <pk@ibds.uka.de>
date:     Thu Sep 18 17:48:16 2008 +0200
summary:  Changed output language

changeset: 0:0391671a98ef
user:     Philipp Kupferschmied <pk@ibds.uka.de>
date:     Thu Sep 18 17:45:52 2008 +0200
summary:  Initial commit
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ cd ../sources2
philipp@host:~/hg-demo/sources2$ hg push ../sources
pushing to ../sources
searching for changes
adding changesets
adding manifests
adding file changes
added 1 changesets with 1 changes to 1 files
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources2$ cd ../sources
philipp@host:~/hg-demo/sources$ ls -la
total 16
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:48 .
drwxr-xr-x 4 philipp philipp 4096 2008-09-18 17:49 ..
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:52 .hg
-rw-r--r-- 1 philipp philipp  138 2008-09-18 17:47 main.c
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg log
changeset: 2:06d64ee049a9
tag:       tip
user:      Philipp Kupferschmied <pk@ibds.uka.de>
date:      Thu Sep 18 17:51:11 2008 +0200
summary:   Added foo.c

changeset: 1:a32fd2a82371
user:      Philipp Kupferschmied <pk@ibds.uka.de>
date:      Thu Sep 18 17:48:16 2008 +0200
summary:   Changed output language

changeset: 0:0391671a98ef
user:      Philipp Kupferschmied <pk@ibds.uka.de>
date:      Thu Sep 18 17:45:52 2008 +0200
summary:   Initial commit
```

Mercurial Sample Session

```
philipp@host:~/hg-demo/sources$ hg update
```

```
1 files updated, 0 files merged, 0 files removed, 0 files unresolved
```

```
philipp@host:~/hg-demo/sources$ ls -la
```

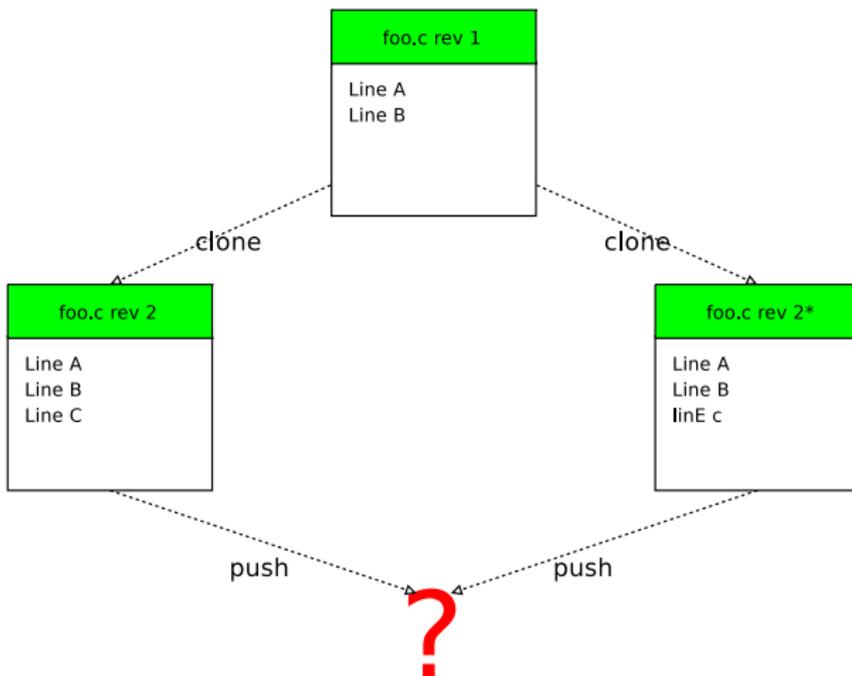
```
total 20
```

```
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:53 .  
drwxr-xr-x 4 philipp philipp 4096 2008-09-18 17:49 ..  
-rw-r--r-- 1 philipp philipp    1 2008-09-18 17:53 foo.c  
drwxr-xr-x 3 philipp philipp 4096 2008-09-18 17:53 .hg  
-rw-r--r-- 1 philipp philipp  138 2008-09-18 17:47 main.c
```

Our Scenario

- set up folder accessible by both team members
 - hosted on one member's ATIS account
- folder contains a Mercurial repository per programming assignment
- both team members
 - clone the repository
 - work/commit on the local copy
 - push local changes to shared repository
 - pull remote changes from shared repository
- detailed instructions can be found on assignment 0

Merge Conflicts



When Pushing of Changes Fails

- Mercurial error: *abort: push creates new remote heads!*
- What to do?
 - pull remote changes via *hg pull*
 - merge conflicts using *hg merge*

Output of *hg merge*

```
merging foo.c
warning: conflicts during merge.
merging foo.c failed!
0 files updated, 0 files merged, 0 files
removed, 1 files unresolved
```

foo.c

```
Line A
Line B
<<<<<<< local
Line C
=====
linE c
>>>>>>> other
```

Frequently Used Mercurial Commands

- hg init
 - creates new repository in given directory
- hg add [files]
 - schedules files for addition to the repository
- hg remove [files]
 - schedules files for removal from the repository
- hg commit [files]
 - commits the changes as new HEAD to the repository
 - requests short comment on changes
- hg update *revision*
 - updates the working directory to the specified revision (or tip if no number is given)

Using Multiple Repositories

- hg clone *src dst*
 - creates a copy of repository *src* in directory *dst*
- hg push *dest*
 - pushes changes from local repository to *dest*
- hg pull *src*
 - pulls changes from repository at *src*

Reviewing Your Changes

- `hg diff [files]`
 - show differences between
 - working copy and
 - corresponding repository revision (**not** tip revision)

Naming Milestones

- `hg tag tagname`
 - gives the current revision a name (tag) with name *tagname*

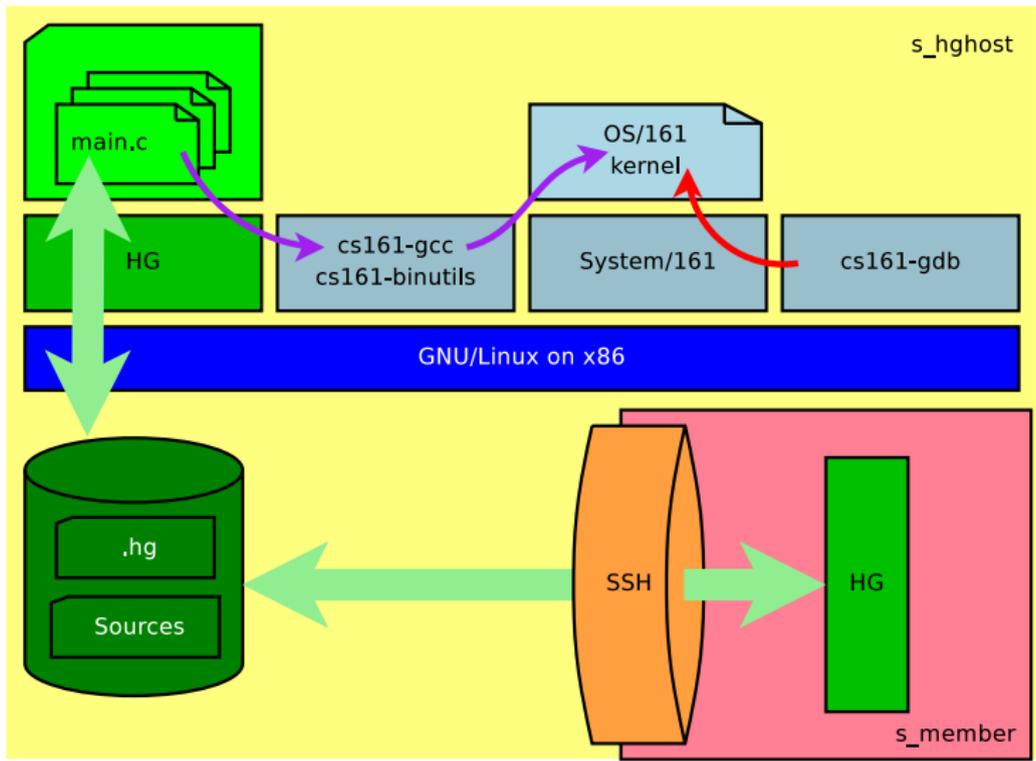
Some Hints

- commit frequently
 - use tags
 - only commit compiling code
- write meaningful commit messages
 - the first line of a commit message should contain a summary of your changes
 - use additional lines for more precise explanations
 - avoid meaningless messages like “made it work” or “bugfix”
 - there is no need to mention the files you modified, that’s recorded anyway
- feel free to work with multiple, local repositories
- additional documentation is available on the Mercurial website, a good starting point is
<http://www.selenic.com/mercurial/wiki/index.cgi/UnderstandingMercurial>

Accessibility

- Mercurial solves many problems
 - record project history
 - distributed development
 - time machine
- but
 - there has to be at least one repository used for “merging” the work of all group members
 - give write access to one repository?
 - not feasible in ATIS
 - no real groups
 - do **not** make your \$HOME group/world writable!

ATIS Scenario



Remote Mercurial Repositories

- set up SSH to allow logins w/o password
- restrict access to Mercurial repositories
- our suggestion
 - one member *s_hghost* creates repositories that are accessible for other group member *s_member*
 - local changes are pushed to “global” repository from time to time

Public Key Authentication

- `mkdir -p ~/.ssh`
 - `cd ~/.ssh`
 - `ssh-keygen -t dsa -P "" -f sysarch_s_member`
 - `cat >> config`
 - Host `sysarch_hg`
 - Hostname `i08fs1.ira.uka.de`
 - User `s_hghost`
 - IdentityFile `~/.ssh/sysarch_s_member`
- [Ctrl] + [d]

Key Binding

Tell SSH to log in to `i08fs1.ira.uka.de` as user `"s_hghost"` when requested to log in to `"sysarch_hg"`, authenticate via key pair `"~/.ssh/sysarch_s_member{.pub}"`.

Granting Restricted Access To Your Account

- as user `s_hghost` do
 - `mkdir -p ~/.ssh`
 - `cd ~/.ssh`
 - add to `authorized_keys` lines such as
command="cd /home/stud/s_hghost/sysarch/sharedrepos &&
/home/stud/s_hghost/.ssh/hg-ssh *",no-port-forwarding,
no-X11-forwarding,no-agent-forwarding,no-pty
 - command to no-pty must be one line
 - there must be no newline after "no-pty"
 - append s_member's public key to `authorized_keys`

Authorizing Keys

Whoever logs in to your account using the pasted key executes "hg-ssh", pretending to be `s_hghost`. With this configuration, s_member can only invoke the "hg-ssh" script, which allows access to the repositories in `~/sysarch/sharedrepos`.

GDB Command Overview

- `gdb myapp`
 - press [Ctrl] + [c] to enter the debugger

`b` set breakpoint

`bt,up,down` backtrace, inspect call-stack

`p sym` print symbol, `sym` may be any C cast

`s` execute line of code

`c` continue execution

`l` list source code at current location

`q` leave GDB

Debugging OS/161

Vain Attempts

- gdb kernel
 - cannot execute MIPS binary on x86
- cs161-gdb kernel
 - cannot execute MIPS binary on x86
- gdb ./sys161 kernel
- cs161-gdb ./sys161 kernel
 - debug System/161!?!?
- ./sys161 cs161-gdb kernel
 - cs161-gdb is not a MIPS binary

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- gdb ./sys161 kernel
- cs161-gdb ./sys161 kernel
 - debug System/161!?!?
- ./sys161 cs161-gdb kernel
 - cs161-gdb is not a MIPS binary

Debugging OS/161

Correct Solution

- ./sys161 -w kernel
 - start System/161
 - immediately wait for debugger to connect
 - or press [Ctrl] + [g] to wait for debugger
- cs161-gdb kernel
 - start debugger (in different shell!)
 - communicate with System/161 via sockets

Configuring cs161-gdb: .gdbinit

- add to `~/sysarch/root/.gdbinit`:
 - target remote unix:./sockets/gdb
 - talk to System/161 via named socket
 - dir `../asst0-src/kern/compile/ASST0`
 - use object files in this directory
 - **update** this for future assignments!
 - set print array on
 - set print pretty on
 - beautify output
 - b panic
 - break when panic() is called

Hint

Strictly speaking, only the first line is required ...

That's all, folks!

Thanks for your attention.

Good luck!

... and may the forum be with you ...