CS-2011, Machine Organization and Assembly Language, D-Term 2014

Setting up your Virtual Machine

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Project assignments in CS-2011 require you to debug low-level *C* and assembly code. Some of the tools used to support the projects (and some of the grading tools) are platform-dependent — meaning that they are not portable among Windows, Macintosh, and various versions of Linux. Therefore, in order to provide a uniform platform for all students in the course, a *virtual machine* was created.

This document describes how to set up your virtual machine on your personal computer using *VMware Player* or *VMware Fusion*. A number of other virtualization platforms are also available. If you are intent on using one of them, you are on your own for support. The *VMware* virtual disk image distributed to class may be used on or converted to other virtualization platforms, so that the resulting version of Linux is the same.

Students who need to use the Zoo Lab (Fuller A21) or another public computer lab should see the Professor and/or the Teaching Assistants for guidance in setting up a virtual machine for use there.

Virtual Machines

A *virtual machine* is an application program capable of simulating a computer system with enough fidelity and performance to mimic actual computer hardware. The virtual machine concept originated in the 1960s, and it has matured to the point where virtual machines are routinely used in a wide variety of commercial, academic, and organizational settings.

Two important terms in virtual machine technology are *host* and *guest*.

- The *host* is the hardware and operating system on which the virtual machine application runs — e.g., your own computer, a laboratory computer, or a departmental or corporate server. The host operating system is irrelevant, so long as it supports the virtual machine application. Sometimes the host system has no formal operating system of its own and, instead, runs the virtualization application directly on "bare hardware." In this case, the virtualization application is called a *hypervisor*.
- The *guest* is the simulated computer, which runs its own operating system and set of applications — e.g., a Linux guest running on top of a Windows or Mac-OS host.

The virtual machine application uses the host processor(s) to simulate the guest processor(s), and it uses files on the host system to simulate the disks and RAM of the guest system. It also connects some host resources directly to the guest system — e.g., the host's CD or DVD drive or a USB flash drive under user control.

Virtual machines are commonly used in operating system courses in order to provide opportunities to carry out project work inside of modern operating systems without doing damage to other systems or users. Other courses also use virtual machines to provide uniform project environments separate from students' own computer platforms.

For this course, we provide a small virtual machine with one processor, one gigabyte of virtual RAM, and *Ubuntu 12.04.3desktop* already installed.

VMware Player

The virtual machine for this course was prepared on *VMware Player*. *VMware Player* is free for personal use but requires a license for commercial use. It is a subset of a more comprehensive application, *VMware Workstation*, that provides additional facilities not needed in this course.

VMware Fusion is a similar product for the Mac, which a number of students used successfully in previous years. Discounts are available to WPI students.

Other virtualization platforms, such as *Virtual Box* and *Parallels* can also be used with the disk image of this virtual machine. An installation guide was written last year by one of the TAs and will be available on the course web-site.

Installing your virtual machine

There are three parts to setting up your virtual machine:–

- Copy the course version of the virtual machine to a hard drive on your host system;
- Edit or adjust the properties of your virtual machine as needed; and
- Boot the virtual machine for the first time, connect it to the network, and create an identity for yourself

Obviously, you may recreate your virtual machine often as you need to. In particular, if you really mess up, the easiest thing may be to throw it away and install another.

Download and install your virtual machine

Download and unzip the file from the following URL:–

http://www.cs.wpi.edu/~cs2011/d14/Resources/Mini-Ubuntu_12.04.3.zip

Note that this file is about 2.3 gigabytes. It will download fairly quickly on the WPI campus, but it could take a very long time to off-campus locations with slow network service.[1] Unzip this folder into a suitable place on your hard drive. Please remember that the unzipped files may eventually grow to about 20 gigabytes on your host machine with usage. The unzipped folder should look something like Figure 1 below:–

[1] If download speed is a problem for you, it is suggested that you download the zip file to a flash drive using a public computer on campus and then physically carry it to your computer off campus.

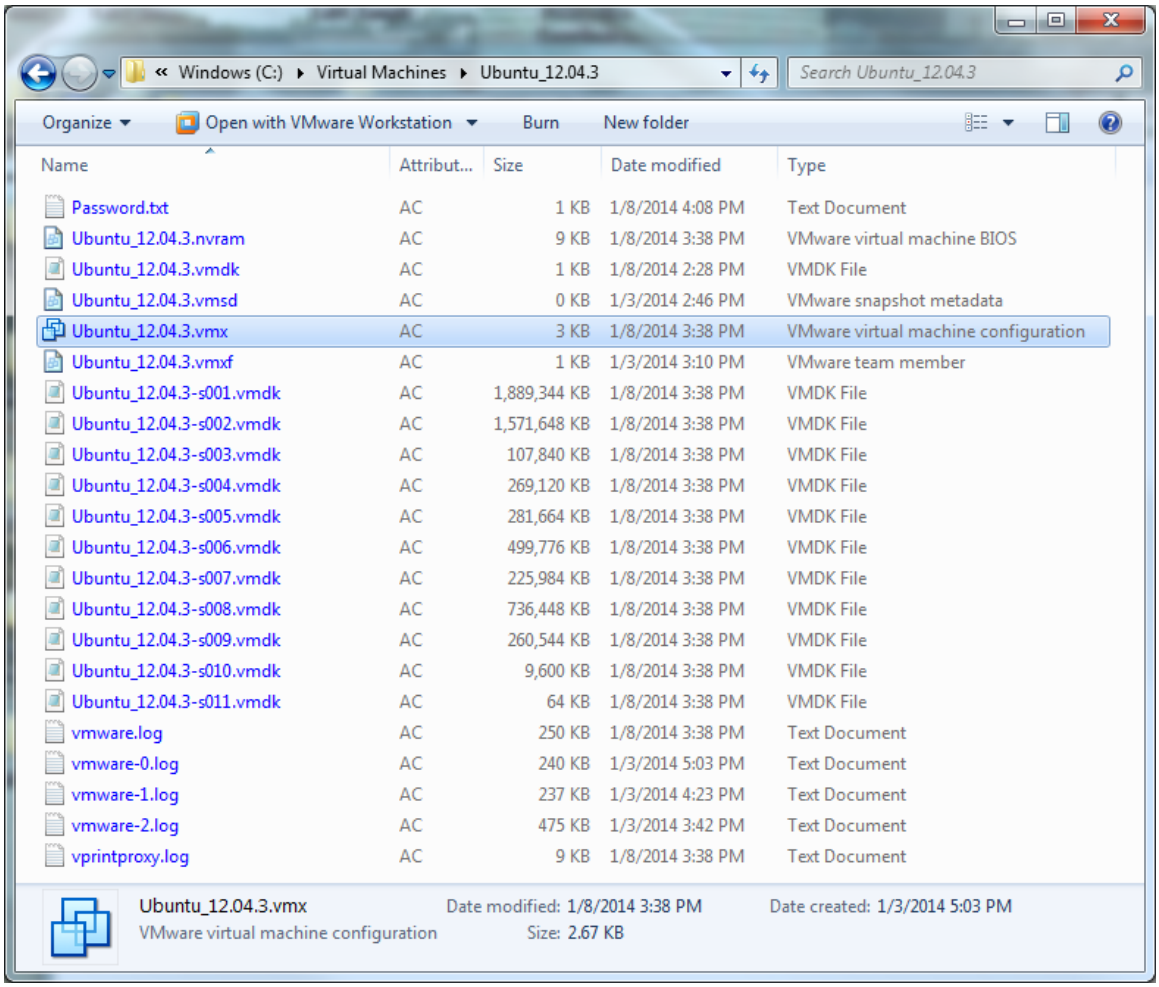

Figure 1

The most important file is the *VMware virtual machine configuration* file, which is highlighted in the figure. This is a text file describing all of the attributes of the virtual machine and its component files. You could open it in a text editor such as *Notepad* and examine its contents, but that should not normally be necessary. *VMware Player* and most other virtualization platforms provide tools for adjusting the settings.

Also included in this folder are a set of files with the extension *.vmdk*. Together, these simulate the hard drive of the guest system; each can grow to 2 gigabytes. Also note that when the guest system is running, several additional files are created, along with a lock folder to prevent the virtual machine from being opened more than once concurrently. None of these are included in the zipped folder but instead are created on the fly.

Before you can use your virtual machine, you need to acquire and install *VMware Player* or *VMware Fusion* (Macintosh). You can download and install *VMware Player* from here:–

https://my.vmware.com/web/vmware/free#desktop_end_user_computing/vmware_player/6_0

Adjusting the Properties of your Virtual Machine

Although it is possible (and easy) to change the number of processors, size of virtual RAM, and other properties of your virtual machine, it is not necessary for this course.

Starting your Virtual Machine for the first time

To start your virtual machine, open *VMware Player*, click on *Play Virtual Machine*. The virtual machine can also be opened and started by double-clicking on the *.vmx* file of Figure 1. If you are using another virtualization application, follow the instructions of that application to start your virtual machine.

The next thing you should see is the following dialog box:–

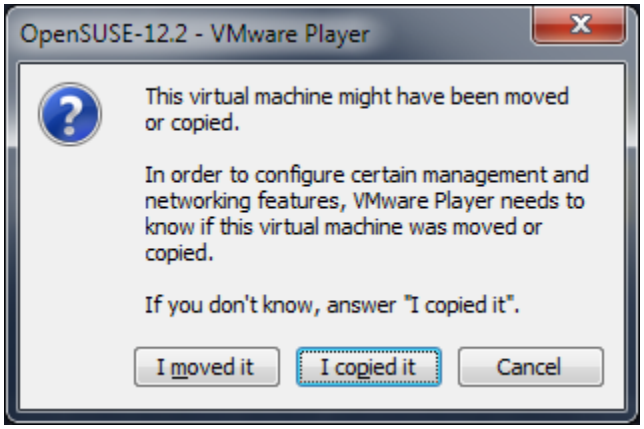

Figure 2

Be sure to select "I copied it." The reason is that *VMware* generates a network MAC address[2] from the path name of the *VMware virtual machine configuration* file. *VMware* uses this path name to figure out whether it is dealing with the same virtual machine or a copy. *Very, very bad things happen* when two or more computers get onto the same network with the same MAC address. By selecting "I copied it," *VMware* changes the MAC address to something different (and hopefully unique, at least within the scope of your network).[3]

Note: Later, if you open your virtual machine on a PC different from the one where you created it, you may get this message again. This time, select "I moved it" so that it keeps the same MAC address, thereby avoiding the need to reconfigure the network.

Next, you will see the boot sequence of the guest operating system, culminating in the logon screen shown in Figure 3 below. In *VMware Player*, this screen will occupy the entire application window. In other virtualization applications, it may occupy a panel of the window, or the entire window, depending upon your settings of the application.

If you should ever need to control the boot options explicitly, do so by clicking in the boot screen before a timeout expires, then using the arrow keys to select the operating system kernel that you want to boot.

Note: You transfer the input focus of the mouse and keyboard to the virtual machine by clicking in its window or typing *CTRL-G*. You can return the input focus to the host

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2 *MAC addresses* are the hardware addresses that Ethernet devices use to communicate with each other. *MAC* stands for "Media Access Code".

3 MAC addresses of network adapters are supposed to be globally unique, and each manufacturer (including *VMware*) is assigned a range of MAC addresses for its own products. Nevertheless, it is possible for network devices to masquerade as others by pretending to have MAC addresses other than their own. For example, cable modems do this often (in a controlled way).

desktop by typing *CTRL-ALT*. If the input focus is in the wrong place, the virtual machine won't hear you type and won't notice you moving the mouse.[4]

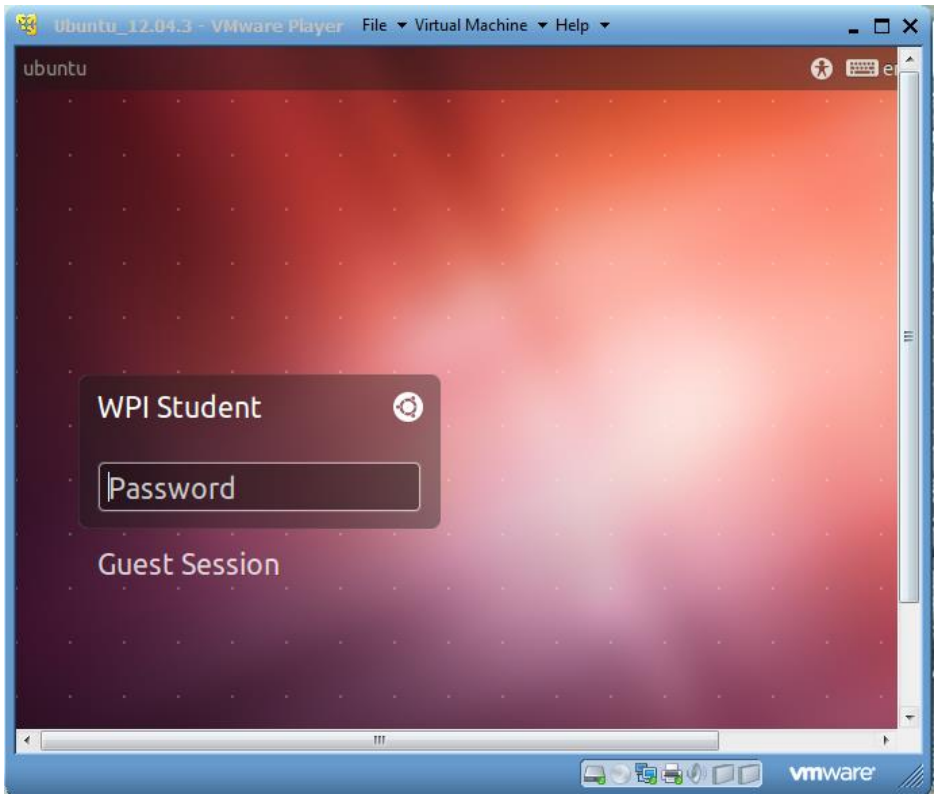

Figure 3

If you wish the guest operating system to take over the entire display (i.e., run in *full-screen mode*), press *CTL-ALT-Enter*. Later, if you wish to return it to a window of your *VMware Player* or *VMware Workstation*, press *CTL-ALT-Enter* again.

When you are running your virtual machine in full-screen mode, a fragment of a menu bar appears at the top of the screen, shown in Figure 4. This lets you access useful *VMware* commands at run time. The "thumb tack" at the left of the menu bar locks it in place or allows it to retract upward from view.

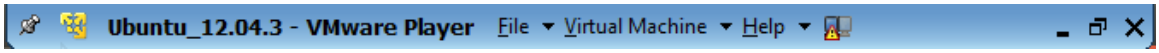

Figure 4

In this menu bar, the *Virtual Machine* pull-down menu contains various commands that allow you to change the settings of the virtual machines, connect host devices such as CD-DVD drives and USB devices to the virtual machine, etc. Also at the right of the menu bar are buttons to minimize, maximize, and close the guest. *VMware Fusion* provides similar menu bars with appropriate selections of commands.

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[4] Normally, when a popular guest operating system such as *Ubuntu* is running, you can simply click in a host or guest window to transfer the focus. However, during boot time and also with some experimental systems (including kernels that you build in this course), you may have to resort to *CTRL-G* and *CTRL-ALT*.

Logging in

The virtual machine is configured with a single user having the login ID *student*. Your password this term is "*D-term14*" (without the quotes). After you have logged in, you will be presented with the *Ubuntu* graphic desktop shown in Figure 5. This is the *Ubuntu* equivalent of the Windows or Macintosh desktop, and it is used much the same way. In particular, note the toolbar on the left side and the *Dash Home* icon at the upper left. These gives you access to applications, files, and other tools.

Hover your cursor over each of the icons in the toolbar on the left to see what they are. Note that *Eclipse CDT* (third from the bottom) is installed for your convenience.

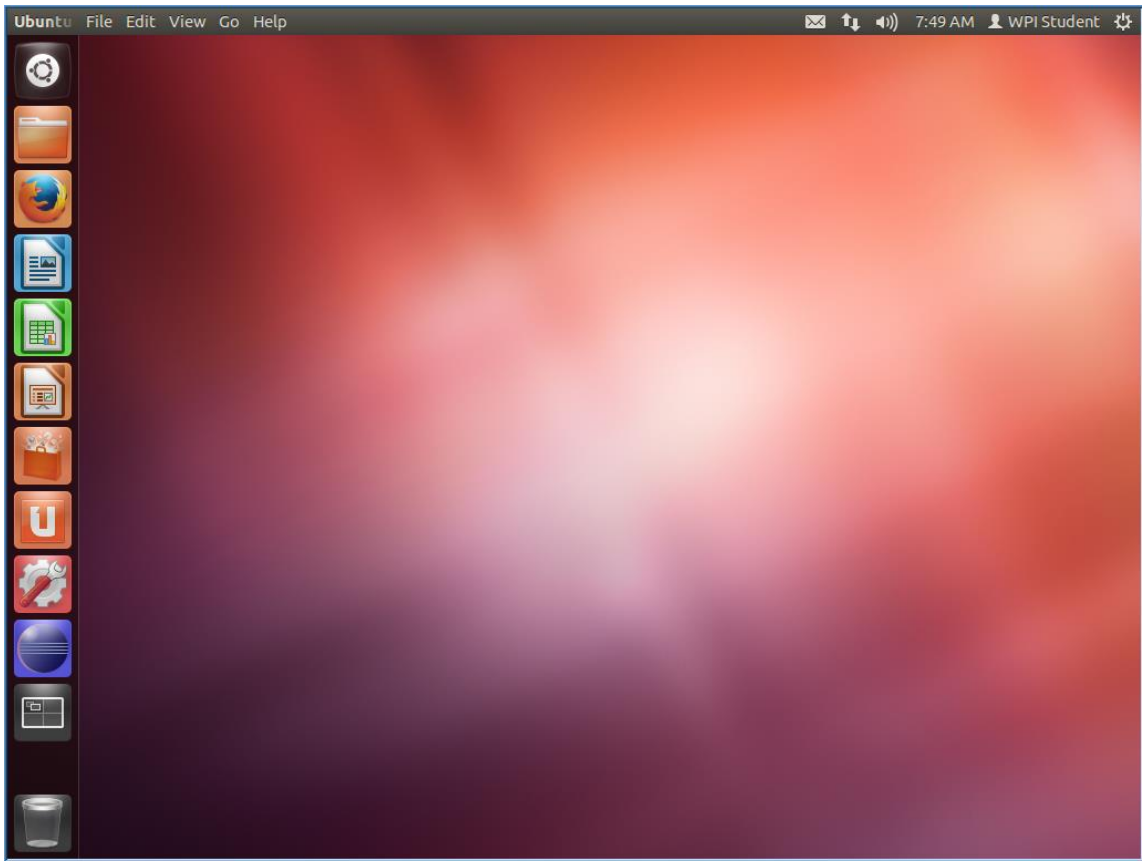

Figure 5

Changing the Display Size

It is a nuisance to try to work with a virtual display of the guest system that does not fit into a window or on the screen of the host system. Therefore, to change the default display size of the guest, invoke the *System Settings* tool by clicking on the  icon on the left of the desktop. Select *Displays* from the options, and set the display size to be convenient for your host work environment.

Open a Command Shell

To open a window containing a Linux command shell, simply type *CTRL-ALT-T* in the *Ubuntu* desktop. This brings up the application *gnome-terminal*, which offers all of the usual fea-

tures of a command shell or command prompt window. In particular, if you click anywhere in a terminal window and then move your cursor to the very top of the desktop, you will see the menu bar for the *gnome-terminal* application.

Note: The menu bar for any application in the Ubuntu desktop can be accessed the same way — by clicking in the application window and then moving the cursor to the top of the display.

Creating a user identity for yourself

It is helpful to create a user identity for yourself and to get rid of the *student* identity built into your virtual machine. (If you are part of a team, create an identity for each team member.)

To create a user identity, click on the words "WPI Student" in the upper right corner of the display (see Figure 5). This will bring up a small, pull-down menu; select the last item called "User Accounts." This will bring up the *User Accounts* tool shown in Figure 6.

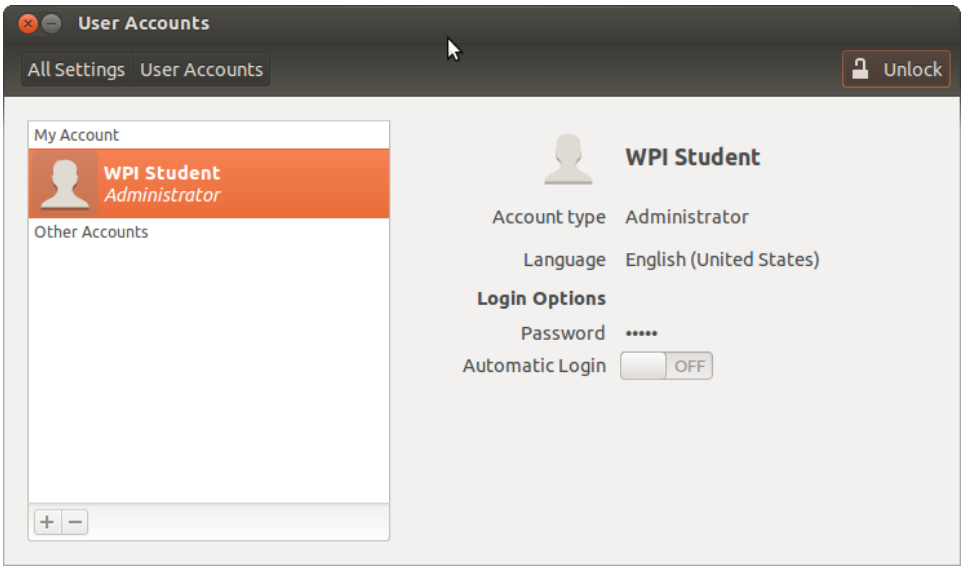

Figure 6

In order to create or edit the list of authorized users, you need to "unlock" the tool by clicking on the *Unlock* icon in the upper right of the window. This will ask you for your password; *type the same password* (e.g., "D-term14" without the quotes) *with which you logged in*. Click the plus sign at the bottom left of the list to bring up the new account dialog, shown below in Figure 7.

Type in the full name(s) and user name(s) of the user(s) that you wish to add. Be sure to set the account types to *Administrator* (note that the default is *Standard*). *Administrator* means that the new user(s) will have the ability to use the **sudo** command to access privileged facilities. Next, return to the *User accounts* tool (i.e., Figure 6) and for each user, click to the right of "Password" and enter a new password. Finally, log out as *student*, log in as your new user identity, and use the *User accounts* tool to disable or delete the *student* account.

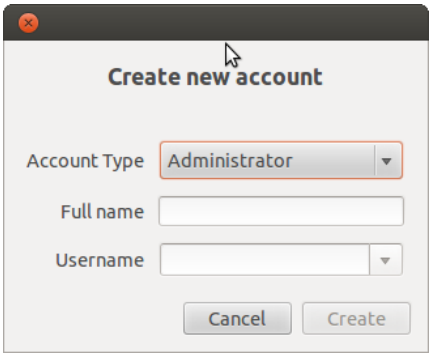

Figure 7

Administrator Privileges and Installing Software

From time to time, your actions may require "administrator" privileges. As a user with the *Administrator* account type, you can gain these privileges on a case-by-case basis by providing your own password. If you invoke the action from the graphical user interface, a dialog box will appear asking for your password. If you invoke the action in a command line of a command shell, you must prefix the command with the word **`sudo`** (meaning S*uper* U*ser* D*o*).

Note: In modern versions of Linux, you rarely, if ever, need to log in as *root*. The **`sudo`** command and the password dialog box will generally suit your needs. This avoids accidents that are typical in most system development environments.

Software may be installed using the *Ubuntu Software Center*, accessible via the  icon in the toolbar on the left, or it may be installed using the **`apt-get`** command from a shell. Administrator privileges are required in either case.

Note: While you may install any software you like onto your virtual machine, it is best not to update the operating system or system software during this course. The reason is that course assignments are based on a particular version of *Ubuntu*, and upgrading may cause changes that render your projects incompatible with the rest of the course.

Useful Features

You are now in a position to experiment with and explore your very own Linux system. You don't have to use the Graphic User Interface, but it saves a lot of time and a long learning curve. You are also in a position to experiment with useful tools of *VMware* or your virtualization platform. This section discusses several of them.

Suspending, Restarting, and Moving your Virtual Machine

A highly useful feature of *VMware* is that you can suspend a virtual machine and resume it later. In Ubuntu, simply click on the "gear" icon in the extreme upper-right of Figure 5 and select the *Suspend* menu command.[5] Moreover, you can log out of the host machine, return later, log again, and resume your suspended virtual machine.

You can even suspend a virtual machine, move it to another host system, and resume it. You may get a dialog box of Figure 2 saying that it noticed that your machine is in a different

[5] Alternatively, use the *Suspend* sub-command of the *Power* item of the *Virtual Machine* menu of Figure 4.

place than before and asking if you copied or moved it. Respond to this dialog saying that you *moved it*, so that *VMware* does not gratuitously change the MAC address.

USB flash drives

Your virtual machine and *Ubuntu* support the usual assortment of flash drives. If you plug in a USB device while the input focus is in the guest operating system, it will open in the guest or host system, depending up the settings of *VMware Player*. If it opens in the guest system, you can access the device from the desktop by clicking on the *Dash Home* tool.

Sometimes, *VMware* gets into the act and brings up a dialog box asking whether you want to connect the device to the host or the guest. Answer the dialog appropriately. Also, if you particularly do not want a device connected to the guest, go to the *Devices* menu in the *VMware Player* menu bar (Figure 4) and manage the device there.

Disaster Prevention

During the first few years when we used *VMware* virtual machines in Operating Systems courses, students stumbled on a number of idiosyncrasies that rendered their virtual machines totally inoperable, trapping their work inside. As we have refined this course, this kind of disaster occurs less frequently, but still occasionally.

Therefore, *it is always a good idea to back up your own work*. The best way to do this is to copy the relevant files onto a USB flash drive or to e-mail it to yourself. From time to time, we have tried other methods of protecting students from lost work — particularly, configuring virtual machines with separate drives for the **`/home`** directory — but none of them has proven very practical.

Conclusion

That's it. Enjoy your virtual machine. You are now ready for your first kernel project. When you are ready to take a break, you may power off your virtual machine by invoking the "leave" tab from the *Start* menu and selecting the appropriate option. You may also "Suspend" the virtual machine by simply exiting *VMware Player*.

Documentation

Documentation for *VMware Player* can be found here:–

http://www.vmware.com/support/pubs/

Documentation about *Ubuntu Desktop* can also be found on-line at

https://help.ubuntu.com/

This includes a getting started guide, a user's manual, an administrator's manual, and other information. Do not try to print these. Together, they are well over 1000 pages.

Appendix: VirtualBox

VirtualBox is an alternative virtualization system distributed without cost by Oracle (formerly Sun Microsystems). You can download and install it from here:–

https://www.virtualbox.org/wiki/Downloads

Download the virtual machine for this course from

http://www.cs.wpi.edu/~cs2011/d14/Resources/Mini-Ubuntu_12.04.3.ova

Note that this is the exact same virtual machine, but packaged in a different format. This file is about 2.4 gigabytes. It will download fairly quickly on the WPI campus, but it could take a long time to off-campus locations with slow network service.

After installing *VirtualBox* and downloading the virtual machine, simply open the **`Mini_Ubuntu_12.04.3.ova`** file to begin the import process.

VirtualBox will extract all necessary files by default into the C:\Users\username\VirtualBox VMs directory (or the equivalent on the Mac and Linux platforms).

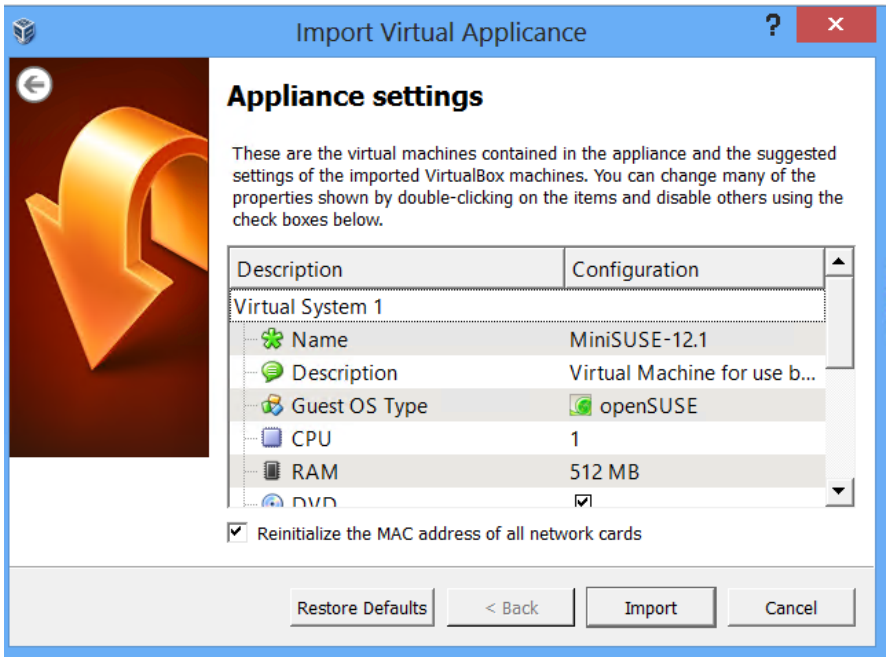

Figure 8

If your computer does not automatically load *VirtualBox* upon opening the **`.ova`** file, you can also import it by starting *VirtualBox* and selecting "Import appliance…" from the File menu.

VirtualBox will also use the MAC address of the virtual machine from the .ova file by default when you import it. *Very, very bad things happen* when two or more computers get onto the same network with the same MAC address. When importing the VM, *make sure* you select 'Reinitialize the MAC address of all network cards.'

Once the VM is imported, simply press the 'Start' button to load it.

Note: You may see multiple notices when you first boot the VM. The first states the following about the **keyboard capture settings**: You transfer the input focus of the mouse and keyboard to the virtual machine by clicking in its window. You can return the input focus to the host desktop by pressing the right Control Key or clicking away from the VM. If the input focus is in the wrong place, the virtual machine won't hear you type and won't notice you moving the mouse.

Others you might see might alert you the first time you click in the VM window, letting you know that it is now capturing input, or that the VM is set for 16 bpp, or fi-

nally that mouse integration has been disabled. You should click 'OK' or 'Capture' through all of these prompts.

Continue setting up your virtual machine as described in the paragraphs near Figure 3.

Note: The Professor and course staff have not fully explored the idiosyncrasies of using *Virtual Box* versus *VMware*. If you choose this option, you must provide your own support.