

15-424/15-624 Lab 0
Installing Mathematica and KeYmaera

1 Installation

KeYmaera is an automated theorem prover that you will use for every lab assignment in this course. Mathematica is also used as a powerful backend arithmetic solver. For your convenience, we provide instructions on installing Mathematica and running KeYmaera from your own computer. However, if you are unable to do this, the lab assignments can be completed using KeYmaera from any CMU cluster with Mathematica installed (see here for a list of clusters that support Mathematica: http://www.cmu.edu/computing/clusters/software/cluster_software.html).

We have also uploaded a video that walks through the KeYmaera installation process: <http://youtu.be/mA2ttUfMo7Q>. The YouTube channel for the entire tutorial series can be found at <http://video.symbolaris.com/>.

1. Setup KeYmaera and Mathematica

Option 1: Run KeYmaera from a CMU Mac Cluster

Download and then open the file found here:

<http://www.ls.cs.cmu.edu/KeYmaera/keymaera-installer.jar>

Alternatively, you may open the file via the terminal with this command:

```
$ java -jar keymaera-installer.jar
```

Skip to step 2.

Option 2: Run KeYmaera from a CMU Linux Cluster

Check that Mathematica is installed and all licenses are in proper order by opening it from the command line:

```
[user@unix1 ~]$ mathematica
```

Follow onscreen directions (if any), until the Mathematica welcome screen appears, and then exit. This only needs to be done the first time you use Mathematica.

Run the following from the command line. The `keymaera_config.tar` file automatically sets the location of Mathematica and must be saved in your home directory. The

config file can be found in lab0.zip. Note that the unpackaged directory is the hidden directory named .keymaera.

```
[user@unix ~]$ tar -xvf keymaera_config.tar
[user@unix ~]$ wget http://www.ls.cs.cmu.edu/KeYmaera/keymaera-installer.jar
[user@unix ~]$ java -jar keymaera-installer.jar
```

The above instructions also apply to running KeYmaera remotely via linux.andrew.cmu.edu. Setup a vnc server to interact with the KeYmaera window.

Skip to step 2.

Option 3: Run KeYmaera from your personal computer.

First, install Mathematica:

Download the CMU student version of Mathematica from this url:

(NOTE: The installation file is **large**, so the download may take some time. Also, you will need to set up an account on Wolfram, and then sign in and submit an activation key request. You can complete both of these actions from the website linked in the Mathematica installation doc and the FAQ in Section 3 of this assignment.)

<http://www.cmu.edu/computing/software/all/mathematica-student/download.html>

Follow the detailed installation instructions and use the provided license key that are included as a **README** in the downloaded file.

Next, open KeYmaera:

Download it here: <http://www.ls.cs.cmu.edu/KeYmaera/keymaera-installer.jar>

Open keymaera-installer.jar.

2. Follow the installation directions and choose the most recently released version. When installation is complete, KeYmaera will launch.
3. In KeYmaera's first dialogue box, check that the Mathematica path points to the location where Mathematica is installed. Change it to point to Mathematica if it doesn't already.

On the CMU Mac clusters this should be automatic.

On the CMU linux clusters, if the keymaera_config.tar package was unpackaged correctly **in your home directory**, the fields should also be filled in automatically with the paths:

```
Mathematica Path: /usr/local/lib/mathematica
MathKernel Path: /usr/local/lib/mathematica/Executables/MathKernel
J/Link native dir: /usr/local/lib/mathematica/SystemFiles/Links/JLink/
                    SystemFiles/Libraries/Linux-x86-64
```

Click OK.

4. You will likely get a **Configuration Warning** since you do not have all of the possible add-ons for KeYmaera already installed. If Mathematica, MathKernel, and JLink are not listed as missing, you are probably alright. **Click Yes**.

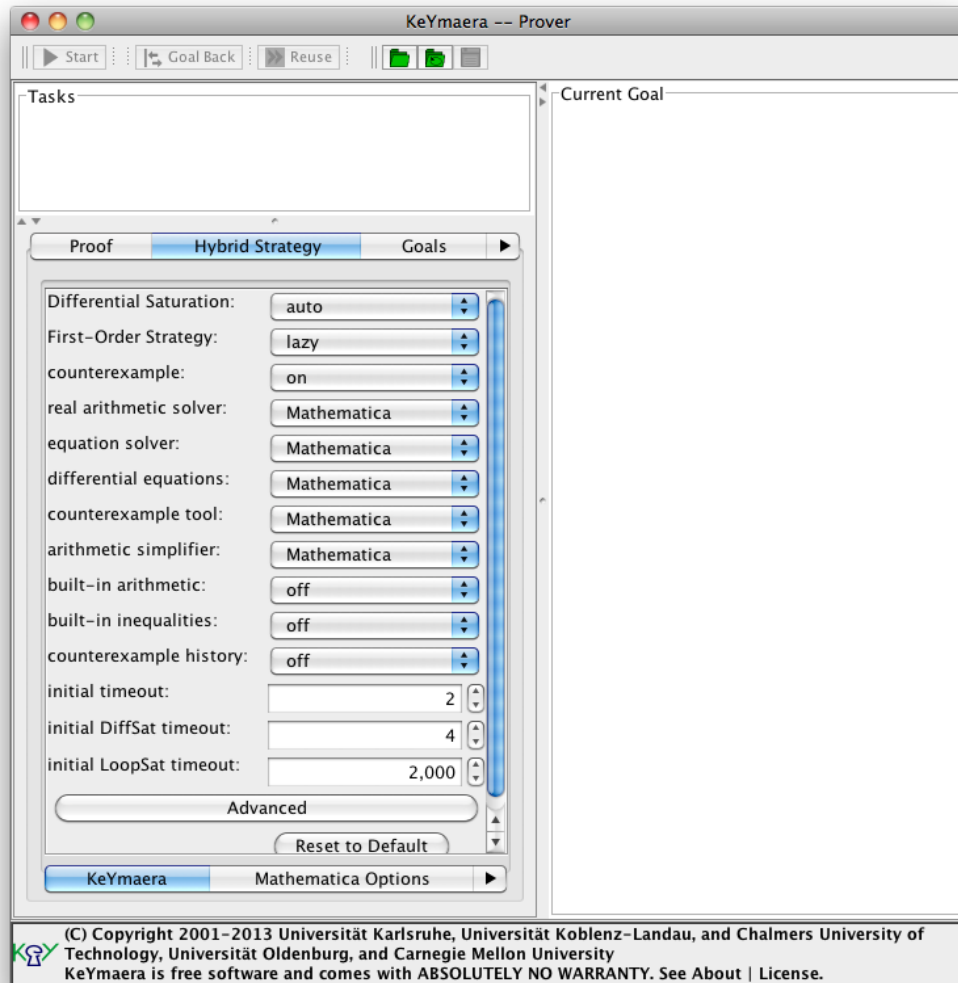


Figure 1: Mathematica should be selected as the solver for the five operations shown above.

5. After successfully opening KeYmaera, click on the **Hybrid Strategy** tab, and confirm that Mathematica is the selected solver for the five operations shown in Figure 1.

KeYmaera is constantly being updated. If the KeYmaera launcher tells you, at the bottom, that there's a new version of the launcher or of KeYmaera - **update it!** The updates happen for a reason!

2 Playing around

Here are a couple of exercises so that you can start getting familiar with KeYmaera.

- **Prove a property** using KeYmaera and Mathematica.

Load `lab0.key` (included in `lab0.zip`) into KeYmaera (File → Load). Click the start button. This theorem proves automatically, so after a few seconds, you will see a dialogue box that declares the property is proved and gives useful statistics, like the number of nodes and branches required. To view more statistics about your proof, like the computation time or memory usage, go to Proof → Show Proof Statistics.

Save your proof (File → Save) as `lab0.key.proof`.

If you would like to see more proofs or explore more of KeYmaera’s functionality, go to File → Load Projects, to browse other projects and completed proofs.

- **Submission**

For lab submissions in this course, we will use autolab (<https://autolab.cs.cmu.edu/15424-f14>). Submit the file **lab0.key.proof** in lab0.

Let’s interact with KeYmaera a little bit more now by using examples from assignment 0 (which you should be well on your way to completing, right?). Think of the formula $\forall x(x > 0 \wedge x < 1)$, i.e., for all real numbers x , x is greater than 0 and x is smaller than 1. Is this formula true? If not, why? Can you find a counter-example?

Counterexamples are assignments of variables that falsify the formula, and therefore the existence of a counterexample implies the formula is false. KeYmaera prefers to check whether formulas are true, so it won’t try to find a counterexample unless we ask for it explicitly.

- **Find a counterexample** for the above formula.

Open the **lab0-forall.key** file in a text editor and look at the syntax. The syntax used by KeYmaera is described in the KeYmaera Cheatsheet¹. Now open `lab0-forall.key` in KeYmaera. You should see a more user-friendly representation of the formula.

To ask KeYmaera for the counterexample, select the whole formula by hovering the mouse over the $\forall x$. Notice how different parts of the formula are highlighted depending on what you are mousing over. With $\forall x$ under the mouse, the entire formula should be highlighted. Right-click, then select “Find Counterexample” as in Figure 2. This means you will apply the Find Counterexample rule to the highlighted part of the formula. A window pops up if KeYmaera finds a counter-example, which it should! Make sure that it is indeed a counter-example.

¹<http://symbolaris.com/info/KeYmaera-cheat.pdf>

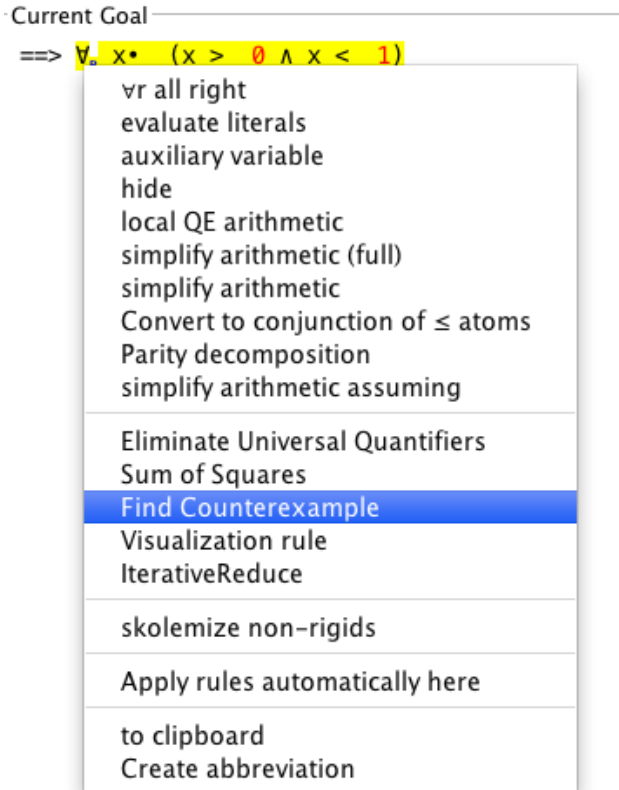


Figure 2: Trying to find a counterexample for the formula.

- **Write a formula yourself.** Create a new file called **lab0-transitivity.key**. Using KeYmaera’s syntax from the cheatsheet, write down the formula for transitivity of the real numbers.

$$\forall x (\forall y (\forall z ((x > y \wedge y > z) \rightarrow x > z)))$$

Open lab0-transitivity.key in KeYmaera and **make sure that it parses correctly!**

- **Submission**

Submit the file **lab0-transitivity.key** under lab0 in autolab.

3 Installation FAQ

The following is a list of common issues that students have had when installing KeYmaera. There is also a more comprehensive FAQ on using and installing KeYmaera, which can be found here: <http://symbolaris.com/info/KeYmaera-FAQ.html>

Requesting a Mathematica Activation Key (Step 1, Option #3)

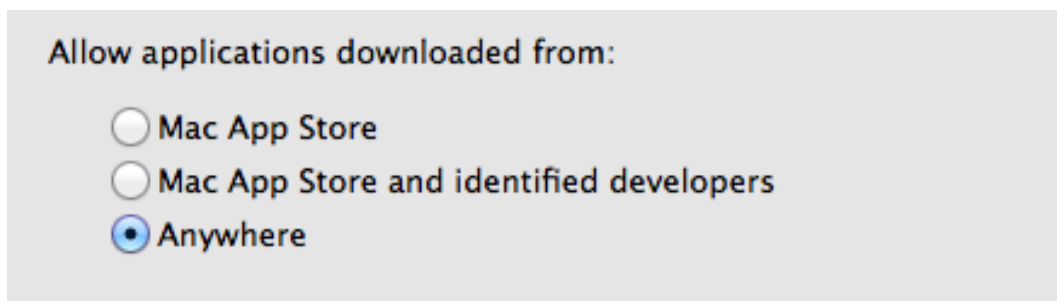
After you create an account on Wolfram, you should return to the activation key request site, sign in, and submit the form. After the form is submitted, your activation key will appear on screen and will be emailed to you. <https://user.wolfram.com/portal/requestAK/e405f7113ecb08e274cd83627f7b464ebe56cf84>

KeYmaera Installer Certificate (Step 2)

On a Mac, if you get this error about the digital signature when trying to open keymaera-installer.jar:



Go to System Preferences >> Security and Privacy. Under the General tab, Allow applications downloaded from: "Anywhere."



On Windows, KeYmaera Installer closes when I click "Start KeYmaera" (Step 2)

Most likely, the CLASSPATH that is being generated is wrong. Try to install KeYmaera to a path that does not contain any spaces. For this: Delete your .keymaera directory (probably located either in your home directory or maybe Documents folder). Then just rerun the installer and select a directory that has no spaces in the path. It's a good idea to use C:\KeYmaera for testing purposes.

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KeYmaera on 32bit Linux: must change J/Link path manually (Step 3) The installer/launcher nicely populates the MathKernel and the J/Link paths after entering the “Mathematica path”, but it defaults to .../Linux-x86-64 for the J/Link path, which is not right for a 32bit machine, where the path should be .../Linux.

With the wrong path, the symptom is cryptic: a waiting cursor and an unfinished task after loading the .key file, starting the proof completes several goals, but gets stuck at “1%” (no errors in the console). Changing the J/Link path manually fixes things.