

15-424/15-624/15-824 Lab 0 **Revision 1**
Installing Mathematica and KeYmaera X

1 Installation

KeYmaera X is an automated theorem prover that you will use for every lab assignment in this course. Mathematica is also used as a powerful back-end arithmetic solver. For your convenience, we provide instructions on installing Mathematica and running KeYmaera X from your own computer. However, if you are unable to do this, the lab assignments can be completed using KeYmaera X 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).

Note: Unless you have a very under-powered machine, we suggest you install KeYmaera X locally.

After installing Mathematica, installing KeYmaera X should be straightforward.

Step 1: Install Mathematica, Download KeYmaera X, and run KeYmaera X We provide instructions for three settings – CMU Mac Clusters, CMU Linux Clusters, and local installation.

Option 1: Run KeYmaera X from a CMU Mac Cluster

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

```
$ mathematica
```

Then download and open the file found here:

```
http://keymaeraX.org/keymaerax.jar
```

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

```
$ java -Xss20M -jar keymaerax.jar
```

Skip to step 2.

Option 2: Run KeYmaera X 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 on-screen directions (if any), until the Mathematica welcome screen appears, and then exit. This only needs to be done the first time you use Mathematica.

Then run the following from the command line:

```
[user@unix1 ~]$ wget http://keymaeraX.org/keymaerax.jar
[user@unix1 ~]$ java -Xss20M -jar keymaerax.jar
```

Skip to step 2.

Option 3: Run KeYmaera X from your personal computer.

First, download the CMU student version of Mathematica version **10** from this url:

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

NOTE: The installation file is **large**, so the download may take some time.

Follow the detailed installation instructions in the **README** file to install Mathematica and retrieve a license key from the Wolfram website.

Before proceeding, activate Mathematica by launching Mathematica and entering the license key that you obtained by following the instructions in the README file included with Mathematica.

Is Mathematica Installed?

To check that Mathematica is installed:

- Open a terminal and run the math command. You should get a prompt like "In[1]:=". Type 1=1 and hit enter. You should see some reasonable output :) If you see some message about license information, follow the directions in the **README** file that came with Mathematica.
- If you do not know how to open a terminal window, Google "[your operating system] open terminal". Google will give you some instructions right on the search page.

Next, open KeYmaera X:

Download it here: <http://keymaeraX.org/keymaerax.jar>

Open keymaerax.jar or run `java -Xss20M -jar keymaerax.jar` from the command line. Double-clicking on keymaerax.jar may not work:

- If you are on a Mac, open the folder containing keymaerax.jar in Finder, and then right-click on keymaerax.jar and select **Run**
- If you are on a Windows machine, try running `java -jar keymaerax.jar` from the command line if double-click does not work.

- If you are on a Linux machine, run `java -Xss20M -jar keymaerax.jar` if double-clicking does not seem to have any effect. You may also need to set the executable bit by running `chmod +x keymaerax.jar`.

You may safely ignore any Java security warnings.

Step 2: Access the KeYmaera X Web User Interface By now, you should have run `java -Xss20M -jar keymaerax.jar` or otherwise launched KeYmaera X. When doing so, you should have seen a loading screen with a progress bar. After a few moments, a web browser window should automatically open the KeYmaera X web-based user interface. If this does not happen, open a web browser and go to `http://127.0.0.1:8090`.

Is KeYmaera X Running?

KeYmaera X runs in the background. To check if KeYmaera X is running, simply access the web page `http://127.0.0.1:8090` from your web-browser.

Step 3: Login to KeYmaera X Login as username: `guest` and password: `guest` and accept the license agreement.

Step 4: Configure KeYmaera X to use Mathematica You should see a yellow bar at the top of the screen prompting you to configure Mathematica. Click on the **Configure now.** link and click the **Reset to _ default** (where `_` is the name of your operating system) next to each of the input boxes. Then, click **Save Configuration**. Wait until you see a message telling you to restart KeYmaera X.

Note: The clusters use a non-default path for Mathematica. For the clusters, use the following paths:

- MathKernel: `/usr/local/depot/mathematica-10.1/Executables/MathKernel`
- JLink: `/usr/local/depot/mathematica-10.1/Executables/MathKernel`

Wait for a dialog to appear indicating that KeYmaera X has been reconfigured. When the dialog appears, close the dialog and **restart** KeYmaera X by clicking the power button in the top right-hand corner of the web UI.

Updating KeYmaera X

KeYmaera X is constantly being updated. The current version status is displayed on the footer of any page. Currently, you should see the text

```
KeYmaera X version 4.1b1 (latest release)
```

Sometimes you will see the text

```
(version _ is now available from keymaeraX.org)
```

instead of (latest release). This indicates that your keymaerax.jar is out of date. To update, delete your current keymaerax.jar and download the latest release of KeYmaera X from <http://keymaeraX.org/keymaerax.jar>.

2 Playing around

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

- **Exercise 1: Prove a property using KeYmaera X and Mathematica.**

Load lab0.key (included in lab0.zip) into KeYmaera X:

- Click on **Models** in the menu bar at the top of the page.
- Enter a Model Name (anything will do; e.g., Lab 0 Part 1).
- Click the "Select File" button and locate the lab0.key file.
- Click **Upload**.
- The new model should appear in the list of models. Find the model and click the down arrow next to **show proofs** in the **Actions** column. Select **Start new proof** from the drop-down.
- In the **Custom tactic** box, enter:

```
master
```

and click **Execute**. Wait for a couple of minutes while the Master proof search procedure executes.
- Eventually a **Proof Found** dialog should appear. Click the **Validate Proof** button to double check that the proof is complete.

Finally, **copy/paste** the contents of the **Custom tactic** box into a file called **tactic.belle**. In this case, the file tactic.belle should just contain the text **master**

- **Exercise 2: Finding Counter-examples using KeYmaera X.**

Let's interact with KeYmaera X a little bit more now by using examples from assignment 0 (which you should have completed by now, 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 valid? 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.

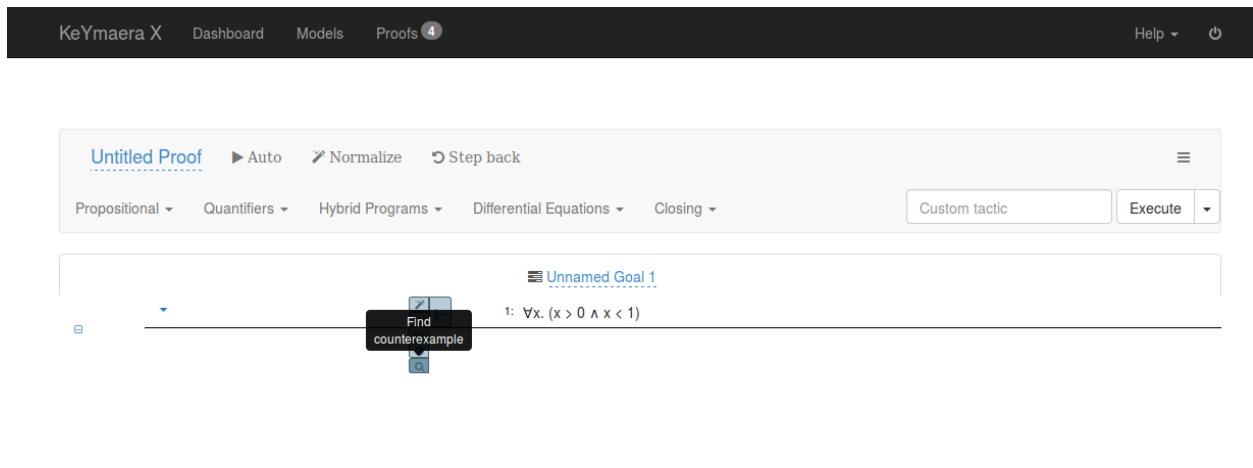


Figure 1: Trying to find a counterexample for the formula.

Find a counterexample for the above formula:

- Open the **lab0-forall.key** file in a text editor and look at the syntax. Now create a new model from the lab0-forall.key in KeYmaera X and start a new proof for the model.
- Explore the interface. elect 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.
- To find a counter example, holding your mouse over the **turnstile** (\vdash) symbol. A menu will appear with various options that apply to the current goal. Click the magnifying glass icon to find a counter-example to this formula. A window should pop up with counter-examples. Make sure that the counter-example that KeYmaera X found is indeed a counter-example.

- **Exercise 3: Write a formula yourself.** Create a new file called **lab0-transitivity.key** (a template is included). Using KeYmaera's syntax from the cheatsheet¹ and the **lab0-**

¹<http://keymaeraX.org/KeYmaeraX-sheet.pdf>

forall.key example, write down the formula for transitivity of the real numbers.

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

There is a template file included with the code handout for this assignment in **lab0-transitivity.key**. After filling out the template with your answer, load your new **lab0-transitivity.key** file into KeYmaera X and make sure that it parses correctly.

3 Submission Instructions

For lab submissions in this course, we will use Autolab (<https://autolab.andrew.cmu.edu/courses/15424-s16>). When submitting a lab, you will receive a preliminary binary grade (0/1). If you receive a score of 0, it means there was some error in your submission – a missing file, a file that KeYmaera X could not parse, etc. If you receive a score of 1, then your submission is in valid form. The AutoLab binary score indicates whether your submission is valid and does not necessarily indicate your final grade on the lab!

Your final submission for Lab 0 should be in the form of a **single .zip file** containing exactly and only 4 files:

lab0.key – The model file lab0.key distributed with this lab.

tactic.belle – The file you created in Exercise 1 containing a tactic that constructs a completed proof for lab0.key. In this case, tactic.belle should contain exactly the text `master`.

lab0-transitivity.key – A file containing your answer to Exercise 3. A template is provided in the code handout associated with this lab.

keymaerax.sqlite – Your local KeYmaera X database, which stores your entire prover session (not just the final tactic that finished the proof). Think of this as your electronic scratch work. Your database is located in a subdirectory of your home directory:

```
.keymaerax/keymaerax.sqlite
```

Create a comment on the top of each model file that contains your andrew ID on its first line. For example, if your Andrew ID is hbovik:

```
/**
 * hbovik
 * ...more comments here...
 */
```

should be the first 4 lines of any .key file you submit in this course. Do not include any other personally identifiable information in your submission!

Why am I turning in my database?

KeYmaera X provides an excellent user interface for exploratory proof search. You should take a moment to familiarize yourself with the user interface; we'll be covering the various features in-depth in a future lecture. The user interface works by automatically constructing **tactics** – small proof-search programs – that correspond to various point-and-click actions.

Although the user interface is useful for exploration, you should ultimately turn in a well-documented tactic script. We also want you to turn in your `keymaerax.sqlite` database so that we can consider your scratch work in the user interface if you're not able to construct a complete proof, or if you can construct a complete proof but cannot turn that proof into a self-contained tactic script.

Don't worry too much for now, we'll cover both KeYmaera X and tactics in future recitations and lectures! Just be sure to always include both the database and a tactic script in every submission that requires a proof.

(Note: you should be aware that your database contains hashes of passwords for any user accounts you create in KeYmaera X.)

4 Installation FAQ

We know this is new software, and all new software has bugs. We want you to be able to spend as much of your time as possible focusing on the assignment instead of dealing with bugs, so please reach out to us when something seems broken and we will respond as quickly as possible.

Finally, please ask for help from your TAs during installation! You may also share tips on installing and upgrading KeYmaera X with (and ask for help from) your fellow students. (However, remember that sharing the specifics of lab solutions with other students does violate the academic integrity policies of the course.)