CSE341: Programming Languages
Using SML and Emacs
Spring 2019

Contents

1 Overview

For roughly the first half of the course, we will work with the Standard ML programming language, using the SML/NJ (Standard ML of New Jersey) compiler. You will need SML/NJ and a text editor on your computer to do the programming assignments. Any editor that can handle plain text will work, but we recommend using Emacs and its SML Mode, which provides good syntax highlighting, indentation, and integration with an SML environment. While Emacs does not have the look-and-feel or tool-integration of many modern integrated development environments (IDEs), it is a versatile tool well-known by many computer scientists and software developers.

This document describes how to install, configure, and use Emacs, SML/NJ, and SML-Mode-for-emacs (henceforth SML Mode) on your computer. These instructions should work for recent versions of Windows, Mac OS X, and Linux.

We also describe how to use the machines in the CSE undergraduate Allen School labs or virtual machines, where most of what you need is already installed on both the Windows and Linux machines.

2 Using the Department Labs

If you use the machines in the Allen School labs or the Allen School virtual machines (`https://www.cs.washington.edu/lab/software/linuxhomevm`), then recent versions of Emacs and SML/NJ should already be installed for you, allowing you to skip Sections 3 and 5 below. So here is all you need to do:

1. Open Emacs. On Windows, go to the start menu, search for *emacs* and open the program. On Linux, go to *activities*, then *applications*, then the icon for *emacs*.
2. Read Section 4 to get familiar with Emacs.
3. Follow the instructions in Section 6 to install SML Mode for Emacs. You should need to do this only once.
4. Read Section 7.

If you are new to the Allen School labs, it would also help to read up on the lab information on where to save your files, expectations for lab behavior, etc. Suggestions for particularly important information to include in this document are welcome — don't be shy.

3 Emacs Installation

We strongly recommend any Emacs version 24.X or higher (for any X) so that you can use the most recent version of SML Mode. Earlier versions of SML Mode are fine, but they are more difficult to install. You can check the version of an Emacs installation in several ways, including the "About Emacs" option under the "Help" menu. Installing a current version 26.X (for any X) is easy, so we recommend doing so if you already have a version 23 or lower.

Directions depend on your operating system:

Windows:

Download a zip archive of a recent full version. For Version 26.1, use this link: `http://ftp.gnu.org/gnu/emacs/windows/emacs-26/emacs-26.1-x86_64-no-deps.zip`. (More information and other versions of Emacs are available at the GNU Emacs website, `http://www.gnu.org/s/emacs/`.)

Unpack the downloaded zip archive file `emacs-26.1-x86_64-no-deps.zip` by right-clicking it and choosing *Extract All*. This should produce a folder called `emacs-26.1-x86_64-no-deps`. You can rename and move this folder wherever you want, but pick a permanent name and place (i.e., do not move it again later).

You can now run Emacs, by going inside the `bin\runemacs.exe`. That may get annoying each time, so you can also do one of these:

- Create a Desktop shortcut or similar to this `bin\runemacs.exe` file.
- Just one time run the `bin\addpm.exe` program, which should create a *Gnu Emacs* folder to your *Start* menu. Then you can select *Gnu Emacs* → *Emacs* (or just type *emacs* in the search box) to launch Emacs.

Some recent Windows versions may have Windows Defender SmartScreen warn you that Emacs is an unrecognized app. We assure you it is okay to run Emacs on Windows: click "More Info" and then "Run anyway." You should not see this happen more than once.

Mac OS:

Download Emacs as a Mac OS X application from `http://emacsformacosx.com/`. Open the disk image file (*.dmg*) and drag the Emacs application to your Applications folder. If you prefer another version of Emacs, such as the more primitive one on the command line or Aquamacs (`http://aquamacs.org/`), you can use it, but make sure it is based on a version of Emacs 24.X or newer.

Alternately, you can install using `homebrew`.

(Mac OS ships with a very old version of Emacs. Installing a newer version as described above is recommended and should have no downsides.)

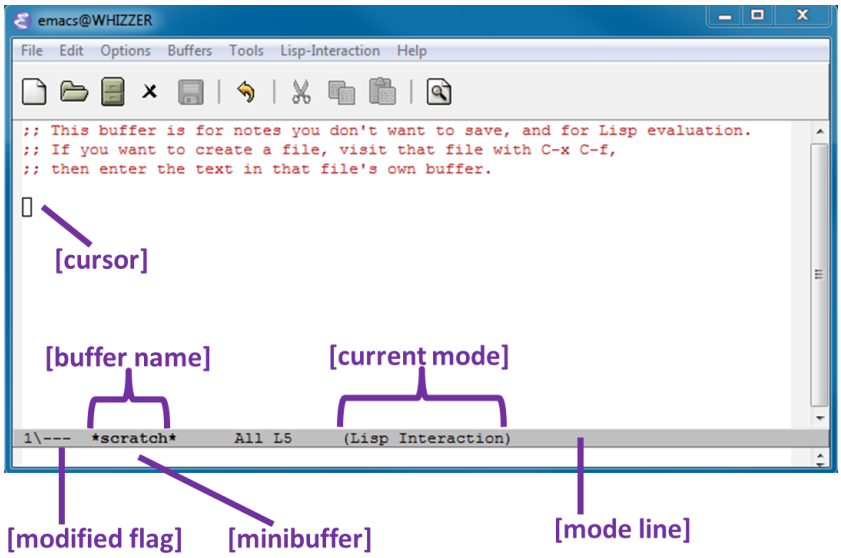
Linux:

Emacs is probably already installed. If not, use your package manager to install it. On Ubuntu and other Debian derivatives, try `sudo apt-get install emacs`. On Fedora, try `sudo yum install emacs`.

4 Emacs Basics

Using Emacs feels a little different than using other editors; it can take some getting used to, especially the keyboard shortcuts. Fortunately, Emacs has buttons and menus to help you adjust if that is your style. The following is a short primer on Emacs terminology and keyboard commands.

Beyond the basics described here, which should be all you need, there are countless free resources available. An introductory "tour" is at `http://www.gnu.org/software/emacs/tour/`. For more information, see the Emacs Reference Manual at `http://www.gnu.org/software/emacs/manual/html_node/emacs/index.html` (also available within Emacs from the Help Menu), the Emacs Wiki at `http://www.emacswiki.org/`, or the Emacs Tutorial (within Emacs from the Help Menu).



- The cursor is a rectangular block and is referred to as the **point**.
- The **mode line** displays information about the **buffer** displayed in the current **window**. A buffer is a logical "thing" that you are working on. When you open a file, it will be loaded into a buffer, typically with the same name as the file.
- Every buffer is edited in a **mode**. The most basic mode is **Fundamental**, which provides only the most basic Emacs editing features. There are modes for many different programming languages.
- There are many "special" buffers that do not correspond to loaded files. The one above is called ***scratch***. This buffer runs in Lisp Interaction mode, which means that you can interactively type and evaluate expressions in the Lisp programming language. But we won't do that.

Emacs uses many key combinations involving the **Control** and **Meta** keys. Such key combinations are denoted **C-x** (Control-x (lowercase)) or **M-x** (Meta-x). On keyboards that don't have Meta (just about all keyboards today), try *Alt* on PC keyboards or the funny-symbol-with-four-circles or *Option* keys on a Mac keyboard. (Emacs might complain about "Super" if you get the wrong one. If you or Emacs gets confused about what you are trying to type, use **C-g** to cancel your current command and start fresh.) If none of these work, use *Esc*, but when trying to type M-x, for example, type Esc *then* type x. (This is only if using Esc as Meta. The other Meta "substitutes" work as usual: hold while pressing the second key.)

A sequence of key presses is written like **C-a C-b M-x**, which would mean do the three actions in sequence: Control and lower-case a, then Control and lower-case b, then Meta and lower-case x.

The most important commands in Emacs:

- **C-x C-c**: Quit Emacs
- **C-g**: Cancel the current action

- **C-x C-f**: Open a file (whether or not it already exists)
- **C-x C-s**: Save a file
- **C-x C-w**: Write a file (probably more familiar to you as *Save as...*)

Cut, copy, paste:

- Highlight text with the mouse or by hitting **C-*Space*** to *set a mark* and then moving the cursor to highlight a region.
- **C-w**: Cut a highlighted region
- **M-w**: Copy a highlighted region
- **C-k**: Cut (*k*ill) from the cursor to the end of the line
- **C-y**: Paste (*y*ank)

Some other useful commands:

- **C-x 2**: Split the window into 2 buffers, one above the other (Use the mouse or **C-x o** to switch between them)
- **C-x 0**: Undo window-splitting so there is only 1 buffer
- **C-x b**: Switch to another buffer by entering its name
- **C-x C-b**: See a list of all current buffers

Getting help within Emacs: In addition to the help button/menu on the right...

- **C-h**: Help. Hitting this will display a short message in the minibuffer: `C-h (Type ? for further options)`.
- **C-h b**: Key *b*indings. This lists all key bindings that are valid for the current mode. Note that key bindings change from mode to mode.
- **C-h a**: Command *a*propos. After typing `C-h a` you can type a symbol and a window will appear that lists all symbols and functions that match that phrase.

More advanced Emacs hacks (optional):

If you are curious, try some of these once you have finished the rest of the setup instructions. They are unnecessary for any of the work we will do, but may be convenient.

- Change the colors of your syntax highlighting. M-x customize-themes is a good place to start.
- General customization interface: Open the *Options* menu and choose the first item under *Customize Emacs*. This will let you customize Emacs through a sort-of-graphical interface. It saves all your settings in a file in your "home" directory, `~/.emacs`.
- Much, much, much more: Emacs calls itself an *extensible* editor for a reason.

5 SML/NJ Installation

Directions *first* depend on your operating system, but then see "All Systems: Check your SML Installation" below.

The most recent version of SML N/J is 110.85 but using older versions is fine *except for 110.84 or 110.83, which you should not install*. The language is extremely stable, so older versions will not cause any issues except 110.84 and 110.83 have a small bug that manifests itself with one of our homeworks. Also older versions won't install cleanly on Mac OS X Mojave.

We do not expect any problems, but let us know if 110.85 causes issues.

Windows:

Download and run the `smlnj-110.85.msi` installer available at `http://www.smlnj.org/dist/working/110.85/`. This will add an item for *SML of New Jersey* to your *Start* menu and add a command `sml` that you can use at the command line.

Mac OS (without using Homebrew):

Download and run the `smlnj-x86-110.85.pkg` installer available at `http://www.smlnj.org/dist/working/110.85/`.

Once the installation is complete, use Emacs or another text editor to edit the file `.bash_profile` in your home folder. (In Emacs you can do this via: `C-x C-f ~/.bash_profile`, notice the three characters "tilde, slash, dot.") If the file does not already exist, create it. Add the following line to the file:

```
export PATH="$PATH:/usr/local/smlnj/bin"
```

This tells your shell (the program that you interact with in the terminal) to add the SML/NJ directory to the paths it searches to find programs. (If you are not using the bash shell, which Mac OS X has used by default since 10.3, the syntax will be different.)

Finally, you will need to run your `.bash_profile` to deploy the changes you have made into your environment for the present session. To do this, run:

```
source .bash_profile
```

You need to do this only once — afterwards, each new terminal that you open will automatically run the `.bash_profile` for you.

Mac OS using Homebrew: *avoid at this time*

As of April 3, 2019, the only version of SML N/J available via Homebrew is 110.84, which we cannot use due to a bug. So the simplest solution is just to use the without-using-Homebrew instructions above. Once Homebrew updates its SML N/J to 110.85, the instructions below should work fine again.

If you already use the Homebrew package manager and have Xcode installed, then you may find it easiest to install SML N/J via Homebrew. To do so, you can just run the command `brew install smlnj` in your shell. However, SML N/J will be installed somewhere different via this method — you can see where by typing `which sml` in your shell and using the result in the directions that follows (e.g., in your `.emacs` file).

Linux:

If your package manager has a package for SML/NJ, install it. If it installs an older version such as SML/NJ 110.72, that should be fine provided it does not use 110.84 or 110.83. Otherwise, follow the "Unix" instructions at `http://www.smlnj.org/dist/working/110.85/`.

All Systems: Check your SML Installation

1. Open a terminal window and type `sml` followed by *Enter/Return*. To open a terminal window:
   - Windows: *Start* → *All Programs* → *Accessories* → *Command Prompt*, **or** Windows 7 or 10 just use the Start Menu to search for the cmd.exe program and run it.
   - Mac OS: Open *Applications/Utilities/Terminal.app*.
   - Linux: Various ways: any shell should be fine.
2. You should see a prompt that looks like this:

   ```
   Standard ML of New Jersey v110.85 [built: ...]
   ```

   If you do not, then see below.
3. Make sure everything is working by typing a very simple SML program at the prompt:

   ```
   1 + 1;
   ```

4. Hit *Enter/Return*. In response, the SML interpreter should print something like this:

   ```
   val it = 2 : int
   ```

5. To exit the interpreter, type Control-Z and then Return on Windows and Control-D on Mac or Linux.

If everything worked, skip to the next section. Else if the sml command caused an error, then most likely SML/NJ is installed but is not being found in your "PATH".

For Windows, the PATH should have been set by the installer, but if it was not for some reason, you can set it manually as follows: Go to Start Menu, then Control Panel, then System, then Advanced System Settings, then Advanced (the tab that should be selected by default), then Environment Variables. Now change the user variable path to be everything already there followed by: `;C:\Program Files (x86)\SMLNJ\bin`.

For Mac OS X (or Linux), double-check that you edited your `.bash_profile` file correctly. Depending on your user settings, you may need to make the same additions to a file that is in the same directory as `.bash_profile` but is called `.bashrc` or `.profile` instead. (This is particularly likely if you have MacPorts installed.)

6 SML Mode for Emacs Installation

These instructions will not work for version 23 or earlier of Emacs. Contact the instructor if you need instructions for an older version.

SML Mode is an extension to Emacs that is not Emacs itself or SML/NJ itself. It displays SML code nicely with syntax coloring and clean indentation, and provides a way to run SML from within Emacs.[1]

To install the current version of SML Mode (currently 6.9), follow these instructions from within Emacs:

1. Run the command `M-x list-packages` (and then *Return/Enter*). If the `list-packages` command does not exist, your Emacs version is too old.

[1] Thanks to Stefan Monnier for maintaining SML Mode. The website is `http://www.iro.umontreal.ca/~monnier/elisp/`, but you do *not* need to go there to install SML Mode.

2. Find `sml-mode` and click on it with your mouse. If you do not see it or installing it does not seem to work, see below.
3. Click on `install` with your mouse.
4. Exit and restart Emacs.
5. Read below to see if you need to follow a couple more steps (more likely under Mac and Linux).

Troubleshooting and more manual method, use only if needed: If you could not find sml-mode, first note that while package names are mostly alphabetized, they may be in more than one group, making it seem like sml-mode is not present. Check the entire buffer. You can most easily search using C-s in Emacs. If you still do not see sml-mode, try killing the buffer (C-x k) and trying the previous step again (some users have reported having to try several times, frustratingly). If you still do not see SML Mode, then you can follow these more manual steps instead:

1. Visit `http://elpa.gnu.org/packages/sml-mode.html`.
2. Locate, and download the latest version (currently sml-mode-6.9.el) from that page.
3. In Emacs type M-x package-install-file ENTER.
4. At the prompt *Package file name:*, give the path to the just downloaded sml-mode-6.9.el, and type ENTER. This will split the window, and show the *Compile-log* with some lines about Compiling file, and perhaps a warning. If there are no errors, sml-mode should now be installed.

To verify that SML Mode is properly installed, let us check that it does indentation/coloring for SML files and that you can create the SML read-eval-print-loop (REPL) from within Emacs.

First, edit an existing or new SML file (try `C-x C-f test.sml` to create a new file if nothing else is handy). You should see the mode display at the bottom of the Emacs window change from Fundamental (or whatever it was) to SML. If you enter a line of code like `val n = 1;` you should see colors highlighting the keywords and variable names. When you are editing code, whenever you hit the *Tab* key, Emacs will try to reindent the current line appropriately.

Second, while the cursor is in an SML buffer (i.e., you are editing an SML file), run `C-c C-s`. This should split the window and create an SML prompt in a new buffer. In that buffer, you should be able to type `1+1;` at the prompt and see 2 as the result.

If you are seeing syntax highlighting, but the `C-c C-s` command fails with an error message, Emacs is probably having trouble finding the SML program. You can hopefully fix this as follows:

Mac OS: In Emacs, edit your `.emacs` file by `C-x C-f ~/.emacs` (that is tilde, slash, dot, emacs) to open the file. Paste in these lines:

```
(setenv "PATH" (concat "/usr/local/smlnj/bin:" (getenv "PATH")))
(setq exec-path (cons "/usr/local/smlnj/bin"  exec-path))
```

Save the file (`C-x C-s`). Exit and restart Emacs.

Linux: Find where `smlnj-110.85` was installed. Then follow the Mac OS instructions above, but replacing `/usr/local` with the appropriate path.

7 Using the SML/NJ REPL (Read-Eval-Print Loop) in Emacs

At this point, we are done installing! This section shows you how to run SML programs from within Emacs. It assumes you already have an SML file or can write your own SML program in a new one.

1. Edit a file with extension `.sml`. You should be in SML-mode, using *Tab* to indent your code well.

2. To create the `*sml*` buffer (which holds the REPL), type `C-c C-s` (and then *Return/Enter*) in the buffer with the `.sml` file. (Note: This will not work in the `*scratch*` buffer that Emacs starts in because this buffer is not in SML Mode.)

3. Keep the `.sml` file(s) you are working with for a particular assignment in the same folder. When you type `C-c C-s` to start the REPL from a buffer for `foo.sml`, the REPL will look in the right folder for `foo.sml` when you type `use "foo.sml"` and will look in the same folder for any other file you use such as `foo_tests.sml`. This is less confusing than trying to keep track of different folders and paths while using the REPL although that is possible.

4. To end and restart a REPL session, type `C-d` (to end it) and `C-c C-s` (and then *Return/Enter*) (to restart it). You must type `C-d` while in the `*sml*` buffer; you can type `C-c C-s` from the `*sml*` buffer or a buffer with a `.sml` file.

5. By ending and restarting a session, the new session has an empty environment. Your earlier interactions are still in the `*sml*` buffer, so you can save them, cut-paste them, etc., but they have no effect on the evaluation in the restarted REPL session.

6. Evaluation can go into an infinite loop.

   - This has likely occurred if you are not getting the "`-`" prompt back and nothing appears to be happening.
   - `C-c C-c` will interrupt evaluation and get you your prompt back.

7. If you forget to end your binding with a "`;`" character, the REPL will print an "`=`" character on the next line, which is just its way of saying, "you are not done – continue your binding," so type a "`;`" and hit *Return/Enter*. This is not an infinite loop (nothing is being evaluated; the REPL is waiting for you) so `C-c C-c` does not do anything.

8. If the printed result looks "pretty good," but part of what you expected to see has been replaced by a "`#`" or "`...`," do not worry. The REPL has a limit on how many characters it prints, which is good since you might make a large value, such as a list with tens of thousands of elements. You can adjust the limit if you want.

Advice You Will Wish You Followed!

In each REPL session, follow this pattern:

- First type `use "foo.sml";` for any SML files you want to use.
- Then use the REPL manually as long as you wish.
- After using the REPL to test something, do *not* use `use` to load (or reload) any more files.
- When tempted to violate the previous point, end and restart your REPL session before continuing.

Why: `use "foo.sml"` has a very simple semantics: it adds the bindings in the file to the environment in order. These may or may not shadow bindings from the last time you typed `use "foo.sml"`, depending on how `foo.sml` changed. This confuses even expert programmers until they train themselves to follow the pattern above.

If you find yourself typing the same non-trivial things repeatedly in the REPL, stop wasting your time.

- Move the repeated parts to a second file, e.g., `test.sml`.
- Then, when you restart your session, begin with `use "foo.sml"; use "test.sml";`.
- In fact, there is an even faster way:
  - Begin `test.sml` with the expression `use "foo.sml";`
  - Then begin your session with `use "test.sml";`

Note: Do *not* put `use "foo.sml"` in `test.sml` *and* begin your session with `use "foo.sml"; use "test.sml";`. That will evaluate the bindings in `foo.sml` twice, which is confusing.

If you develop some emotional attachment to the transcript of your `*sml*` buffer, you can save it to a file just like any other buffer. But after you do, it's not an `*sml*` buffer anymore, so you will have to create a new `*sml*` buffer from a buffer in SML Mode via `C-c C-s`.

Acknowledgments: These instructions were prepared starting with material created by Ben Wood, adapted from prior materials by Dan Grossman and Hal Perkins. Stefan Monnier provided fantastic feedback on this document and even created SML Mode version 6 to simplify SML Mode installation substantially.