# A guide for using SpaceEx from the terminal

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## 1 Introduction

This serves as a tutorial on how to use SpaceEx[1] from the terminal. There are two ways to do so: (i) running directly the executable file, and (ii) compiling the source code and then running the executable. The latter option is advised for advanced users.

## 2 Steps

The necessary steps are as follows.

1. **Set up Virtual Machine (necessary only for Window users)**. Note that it is not possible to directly run the executable file in Windows. It might be possible with cygwin but not advised. On the contrary, the recommended way would be to create a new Virtual Machine and install Linux (also possible with macOS).

    - **Download OS**. The first step is to download a 32- or 64-bit Linux distribution (e.g. Ubuntu[2] or Debian[3]). We recommend the 64-bit version as it supports the latest SpaceEx version.
    - **Download VM**. There are several options, notably Oracle VirtualBox[4] or VMmare Player[5]. Our recommendation would be the former.
    - **Set up new VM**. Once the VM application is downloaded, a new VM should be created and set up. For VirtualBox, simply open the application, navigate to option "new" (on top-left), select Linux and version (e.g. 64-debian), memory size (over 2 GB is typically enough), "create a virtual machine now", "VDI", "dynamically allocated" and size over "8 GB".

[1] `http://spaceex.imag.fr/`
[2] `https://www.ubuntu.com/download/desktop`
[3] `https://www.debian.org/distrib/`
[4] `https://www.virtualbox.org/wiki/Downloads` (1st option for Windows host)
[5] `https://my.vmware.com/en/web/vmware/downloads`

- **Install OS**. Now, a new virtual machine should be created (appears on the left) and you shall select "start". The option "Select Start-up disk" pops up and you should add the location of the downloaded ISO file (64-bit Linux). Now, it is possible to install Linux[6].
- **Set up Linux.** There are numerous tutorials on how to use Linux[7]. The necessary actions to setup your Linux for SpaceEx use follow.
  - Open terminal (Ubuntu: press Dash, Debian: press Activities, and then search for Terminal).
  - Gain root access by `$ su` (`$` is used for clarity, it should not be added) and insert your password.
  - `$ apt-get install sudo`
  - `$ sudo apt-get install build-essential`
  - `$ sudo apt-get update`

2. **Download SpaceEx**. Depending on the OS you have downloaded, select the corresponding executable file from SpaceEx website[8]. That is `SpaceEx command line executable v0.9.8f` for 64 bit Linux or `SpaceEx command line executable v0.9.8e` (64 bit Mac OS X)

3. **Run SpaceEx.**

   - use command `cd` to change directory (to the folder you saved the spaceex files). For example, `$ cd /home/user/Downloads/spaceex_exe`

     If you cannot cd with root privilege, press exit (to leave root) and then write the aforementioned command.
   - until you get familiar with paths and directories, save your xml and cfg files at the same path /home/user/Downloads/spaceex_exe
   - now, you are ready to run spaceex by writing in the terminal: `./spaceex -g config.cfg -m model.xml -o output`
   - Spaceex will run, show the steps on the terminal screen and save the results in the output file. The results could be numbers ( representing the vertices of the reachable sets) or text. More information can be found at the FAQ[9].

     It is possible to save the 2D results in GEN format and use the Matlab script for visualization (i.e. `plot_2d_vertices`[10]).
   - All the options can be found by writing the command `$ ./spaceex --help` on the terminal.

[6] There will be several questions but they are similar to a Windows installation.

[7] `http://www.makeuseof.com/tag/an-a-z-of-linux-40-essential-commands-you-should-know/` for the basic commands

[8] `http://spaceex.imag.fr/download-6`

[9] `http://spaceex.imag.fr/documentation/user-documentation/frequently-asked-questions-21`

[10] `http://spaceex.imag.fr/sites/default/files/downloads/plot_2d_vertices.m`

- To obtain the flattened/composed hybrid automaton in XML format, you can add the argument –output-system-file new_name

  **Example 1 (Timed bouncing ball)** *We illustrate the necessary commands on an example from the SpaceEx website (files enclosed in the github repository as well).*

- `$ ./spaceex -g bball_timed.cfg -m bball_timed.xml -o out.gen`. This command creates and saves the reachability results to a GEN file (the name of the file is *out*).
- `$ ./spaceex -g bball_timed.cfg -m bball_timed.xml -o out2.gen -v D6 --flowpipe-tolerance 0.01`. This command creates the *out2* GEN file, while specifying the accuracy of the computations and the verbosity level.
- `$ ./spaceex -g bball_timed.cfg -m bball_timed.xml -o out3.gen --initially "12<=x<=12.2 & v==0 & t==0"`. This command conducts reachability analysis for the specified initial conditions and creates the *out3* GEN file.

4. **Run multiple files**.

   - There are two ways to run multiple reachable computations. Either creating new cfg files with multiple configurations (e.g. different initial conditions) or run spaceex with different arguments in the terminal.
   - If you want to automatically run different configurations, you can run a bash file. Attached you can find a bash file with different configurations. Also, a way to automatically create several cfg files with different initial conditions and names is proposed. The file can be executed by writing in the terminal the following command `$ ./run_spaceex.sh`. If you have problem with permissions, try the command `$ sh run_spaceex.sh`.