

Application Containers

Introdução Engenharia Informática

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Exercises

Practical Exercises: Flatpak & AppImage

Objective: This class will guide you through the fundamentals of application packaging. You will start with a simple “Hello World” and progress to packaging a complete Python GUI application with its dependencies.

0. Setup: Configure Your Workbench

First, we must install all the tools required for building and testing our application packages.

1. **Update your system:** This command downloads the latest list of available software and upgrades all currently installed packages to their newest versions.

```
$ sudo apt update && sudo apt full-upgrade -y
```

2. **Install tools:** This command installs all the necessary components for our class.

- `curl` & `wget`: Utilities for downloading files from the internet.
- `file`: A utility to identify file types.
- `libfuse2`: A library required by AppImage to “mount” the application package as a virtual filesystem.
- `flatpak`: The command-line tool for running and managing Flatpak applications.
- `flatpak-builder`: The specific tool used to build Flatpak packages from a manifest file.
- `python3`, `python3-pip`, `python3-venv`: The Python interpreter, its package manager (`pip`), and the **virtual environment** tool (`venv`).

```
$ sudo apt install curl wget file libfuse2 flatpak \
flatpak-builder python3 python3-pip python3-venv
```

3. **Add Flathub:** This command adds the **Flathub** repository to your system’s Flatpak configuration, but only for your local user (`--user`). A “repository” (or “remote”) is a server that hosts Flatpak apps and runtimes. Flathub is the largest and most common repository, and we need it to download the “SDKs” (Software Development Kits) required for building.

```
$ flatpak --user remote-add --if-not-exists \
flathub https://flathub.org/repo/flathub.flatpakrepo
```

4. **Install appimagetool:** This downloads the `appimagetool` program, which is what compresses an AppDir directory into a single, executable AppImage file. We make it executable (`chmod +x`) and move it to `~/.local/bin`, a standard directory for user-installed programs.

```
$ mkdir -p ~/.local/bin
$ wget -O appimagetool \
"https://github.com/AppImage/AppImageKit/\
releases/download/continuous/appimagetool-x86_64.AppImage"
$ chmod +x appimagetool
$ mv appimagetool ~/.local/bin/
```

5. **Apply the PATH change:** The `PATH` is an environment variable that tells your shell (like `bash`) which directories to search for executable programs. By default, `~/.local/bin` is not always in the `PATH`.

We edit `~/.bashrc` (a file that runs every time you open a new terminal) to add this directory to your `PATH`. This makes `appimagetool` runnable from anywhere.

You can use `nano` to edit the file: `nano ~/.bashrc`. Add the following configuration to the *last* line of the file:

```
export PATH=${HOME}/.local/bin${PATH:+:${PATH}}
```

6. **Log out and log back in.** This re-loads your `~/.bashrc` file and applies the `PATH` change. To verify it's working, open a new terminal and type the following command. You should see the version information for the tool.

```
$ appimagetool --version
```

1. "Hello World" □

Let's package a simple shell script.

1.A: Flatpak "Hello World"

Flatpak uses a "manifest" file (in YAML format) to define everything about the application and how to build it.

1. Create a directory for this exercise:

```
$ mkdir ex1-flatpak && cd ex1-flatpak
```

2. Create the application script, named `hello.sh`. This can be created with any editor; one possibility is using `nano`: `nano hello.sh`

```
#!/bin/sh
echo "Hello from a Flatpak Sandbox!"
```

3. Create the manifest file, `pt.ua.deti.iei.HelloWorld.yml`. This file defines:

- `app-id`: A unique, reverse-DNS name for your app.
- `runtime / sdk`: The base system your app will run on and be built with.
- `command`: The program to run when the app starts.
- `modules`: The list of build steps. Here, we define one module that installs our `hello.sh` script into the sandbox's executable path (`/app/bin/`).

```
app-id: pt.ua.deti.iei.HelloWorld
runtime: org.freedesktop.Platform
runtime-version: '25.08'
sdk: org.freedesktop.Sdk
command: hello.sh
```

```
modules:
  - name: hello-module
    buildsystem: simple
    build-commands:
      # Installs the script into the sandbox's /app/bin/ folder
      - install -Dm755 hello.sh /app/bin/hello.sh
    sources:
      # Tells the builder to find 'hello.sh' in our project dir
      - type: file
        path: hello.sh
```

4. **Build the package:** This command runs `flatpak-builder` with several important options.

- `--user`: Builds and installs the app just for your user, without needing `sudo`.
- `--install`: Automatically installs the app after a successful build.
- `--install-deps-from=flathub`: Automatically finds and installs any missing SDKs or runtimes from Flathub.
- `--force-clean`: Deletes the `build-dir` to ensure a fresh build.

- **build-dir**: The name of the temporary directory to use for building.

```
$ flatpak-builder --user --install --install-deps-from=flathub \
--force-clean build-dir pt.ua.deti.iei.HelloWorld.yml
```

5. **Run and Cleanup**: flatpak run executes your application inside its sandbox.

```
$ flatpak run pt.ua.deti.iei.HelloWorld
$ flatpak uninstall --user pt.ua.deti.iei.HelloWorld
*$`cd ..` to exit the directory.*
```

1.B: AppImage “Hello World”

AppImage works by bundling an entire directory (named AppDir).

1. Create a directory for this exercise:

```
$ mkdir ex1-appimage && cd ex1-appimage
```

2. Create the AppDir and the main AppRun script. The AppRun file is a special script that acts as the entrypoint. It is the *first* thing that runs when you execute the AppImage. We also create a dummy icon.png file.

```
$ mkdir -p HelloWorld.AppDir
$ echo '#!/bin/sh' > HelloWorld.AppDir/AppRun
$ echo 'echo "Hello from an AppImage!"' >> HelloWorld.AppDir/AppRun
$ chmod +x HelloWorld.AppDir/AppRun
$ touch HelloWorld.AppDir/icon.png
```

3. Create a file named HelloWorld.AppDir/hello.desktop. This is a **.desktop file**, a standard way to tell the Linux desktop environment about your application. It defines the app’s Name, what command to Exec (our AppRun script), and what Icon to use. appimagetool *requires* this file.

```
[Desktop Entry]
Name=Hello
Exec=AppRun
Icon=icon
Type=Application
Categories=Utility;
```

4. **Build the package**: We run appimagetool on our AppDir. We must also specify ARCH=x86_64 because the tool cannot “guess” the architecture from a simple shell script. It needs this to name the final file correctly. If necessary change the ARCH variable to arm64. This will create Hello-x86_64.AppImage or Hello-arm64.AppImage on success.

```
$ ARCH=x86_64 appimagetool HelloWorld.AppDir
```

5. **Run and Cleanup**:

```
$ chmod +x Hello-x86_64.AppImage
$ ./Hello-x86_64.AppImage
```

```
# Cleanup
```

```
$ rm -rf Hello-x86_64.AppImage
```

```
cd .. to exit the directory.
```

2. Python CLI App: ASCII Tree 🌲

Let’s package a simple Python CLI app. We’ll create a pytree.py script that recursively lists directories in a tree format.

2.A: Run with Virtual Environment (Venv)

First, let's run the app natively to confirm it works. We will use a **Python virtual environment** to manage dependencies, even though this simple script has none.

A virtual environment (venv) is an isolated "bubble" for a Python project. It keeps its *own* Python interpreter and installed packages, so this project's packages (e.g., pygame) won't conflict with another project's packages.

1. Create a project directory:

```
$ mkdir ex2-pytree && cd ex2-pytree
```

2. Create the pytree.py script, and make it executable: `chmod +x pytree.py`.

```
#!/usr/bin/env python3
import os
import sys

def tree(startpath):
    """Prints a directory tree."""
    for root, dirs, files in os.walk(startpath):
        # Don't visit .venv or __pycache__
        if '.venv' in dirs:
            dirs.remove('.venv')
        if '__pycache__' in dirs:
            dirs.remove('__pycache__')

        level = root.replace(startpath, '').count(os.sep)
        indent = '    ' * (level - 1) + '    ' if level > 0 else ''

        print(f'{indent} {os.path.basename(root)}/')

        subindent = '    ' * level + '    '
        for f in files:
            print(f'{subindent} {f}')

if __name__ == "__main__":
    # Use current directory or a specified path
    path = sys.argv[1] if len(sys.argv) > 1 else '.'
    tree(os.path.abspath(path))
```

3. **Run the app:** Since this app has no dependencies, we can run it directly. After use `cd ..` to exit the directory.

```
$ ./pytree.py
# Try it on another directory
$ ./pytree.py /tmp
```

2.B: Package pytree as a Flatpak

1. Create a project directory:

```
$ mkdir ex2-flatpak && cd ex2-flatpak
```

2. Copy the pytree.py file from the previous exercise:

```
$ cp ../ex2-pytree/pytree.py .
```

3. Create the manifest `pt.ua.deti.iei.pytree.yml`. We use `org.gnome.Platform` as our runtime because it conveniently includes a Python 3 interpreter, so we don't have to build Python ourselves.

```
app-id: pt.ua.deti.iei.pytree
runtime: org.gnome.Platform
runtime-version: '48'
```

```

sdk: org.gnome.Sdk
command: pytree.py

modules:
- name: pytree
  buildsystem: simple
  build-commands:
  - install -Dm755 pytree.py /app/bin/pytree.py
  sources:
  - type: file
    path: pytree.py

```

4. Build and Install:

```

$ flatpak-builder --user --install --install-deps-from=flathub \
--force-clean build-dir pt.ua.deti.iei.pytree.yml

```

5. **Run and Cleanup:** When you run it the first time, it only lists the files *inside its own sandbox*. To make it useful, we must grant it permission to see our host files. `--filesystem=home` is a “portal” that pokes a hole in the sandbox, giving the app access to our home directory. After use `cd ..` to exit the directory.

```

$ flatpak run pt.ua.deti.iei.pytree

# It runs inside a sandbox, so it only sees itself!
# Let's give it access to our home directory to test it:
$ flatpak run --filesystem=home pt.ua.deti.iei.pytree ~/

$ flatpak uninstall pt.ua.deti.iei.pytree

```

2.C: Package pytree as an AppImage

1. Create a project directory:

```
$ mkdir ex2-appimage && cd ex2-appimage
```

2. Create the AppDir:

```
$ mkdir -p Pytree.AppDir && cd Pytree.AppDir
```

3. **Download and extract portable Python:** Here, we use `wget` to download a pre-built, portable version of Python. An AppImage is just a compressed filesystem, so we use `--appimage-extract` to unpack it. We then move its contents (`mv squashfs-root/* .`) into the root of our AppDir. Change the python URL if you use another architecture (such as arm or arm64).

```

$ wget "https://github.com/niess/python-appimage/releases/\
download/python3.10/python3.10.19-cp310-cp310-manylinux_2_28_x86_64.AppImage" \
-O python.AppImage
$ chmod +x python.AppImage
$ ./python.AppImage --appimage-extract
$ mv squashfs-root/* .
$ rm -rf python* squashfs-root/

```

3. **Copy your script:** We copy our script into the `usr/bin` directory provided by the portable Python we just extracted.

```
$ cp ../../ex2-pytree/pytree.py usr/bin/
```

4. **Update the AppRun entrypoint:** The portable Python package comes with its own AppRun script. We just need to edit its *last line* to call our `pytree.py` script instead of starting a Python shell. Finally, make it executable: `chmod +x AppRun`

```

#!/bin/bash
# If running from an extracted image, then export ARGVO and APPDIR
if [ -z "${APPIMAGE}" ]; then
    export ARGVO="$0"

```

```

    self=$(readlink -f -- "$0") # Protect spaces (issue 55)
    here="${self%/*}"
    tmp="${here%/*}"
    export APPDIR="${tmp%/*}"
fi

# Resolve the calling command (preserving symbolic links).
export APPIMAGE_COMMAND=$(command -v -- "$ARGV0")

# Export Tcl/Tk
export TCL_LIBRARY="${APPDIR}/usr/share/tcltk/tcl8.6"
export TK_LIBRARY="${APPDIR}/usr/share/tcltk/tk8.6"
export TKPATH="${TK_LIBRARY}"

# Export SSL certificate
export SSL_CERT_FILE="${APPDIR}/opt/_internal/certs.pem"

# Call Python
"$APPDIR/opt/python3.10/bin/python3.10" "$APPDIR/usr/bin/pytree.py" "$@"

```

5. Create a file named `pytree.desktop` and fill it. We also create a dummy `icon.png` file to satisfy `appimagetool`.

```

[Desktop Entry]
Name=PyTree
Exec=AppRun
Icon=icon
Type=Application
Categories=Utility;

```

```
$ touch icon.png
```

6. **Build, Run, and Cleanup:** After use `cd ..` to exit the directory.

```

$ cd .. # Go back to ex2-appimage directory
$ ARCH=x86_64 appimagetool Pytree.AppDir

$ chmod +x PyTree-x86_64.AppImage
$ ./PyTree-x86_64.AppImage

# Test it on your home directory
$ ./PyTree-x86_64.AppImage ~/

$ rm -rf PyTree-x86_64.AppImage

```

3. Python GUI App: Tic-Tac-Toe

3.A: Run with Virtual Environment (venv)

This step simulates what a user would do: download the source, extract it, and run it locally.

1. Create a directory and download the source: This archive (a `.tar.gz`) contains a top-level folder. `tar --strip-components=1` is a useful command to extract the *contents* of that folder directly into our current directory, ignoring the top-level folder itself.

```
$ mkdir ex3-tictactoe && cd ex3-tictactoe
```

```
$ wget "https://github.com/mariolpantunes/tictactoe/archive/refs/tags/tictactoe-1.0.tar.gz" \
-O tictactoe-1.0.tar.gz
```

```
# Extract the downloaded source
```

```
$ tar --strip-components=1 -zxvf tictactoe-1.0.tar.gz
```

2. **Create and activate the venv:** This time, creating a virtual environment is crucial because we have dependencies. You should see (venv) at the beginning of your terminal prompt. This means your shell is now using the Python and pip from inside the ./venv directory.

```
$ python3 -m venv ./venv
$ source venv/bin/activate
```

3. **Install dependencies from the file:** A requirements.txt file lists all the Python packages a project needs. pip install -r reads this file and installs them (like pygame) into the *active virtual environment*.

```
$ pip install -r requirements.txt
```

4. **Run the game:**

```
$ python main.py
```

5. **Deactivate the venv:** This command restores your shell to use the system's default Python. After use cd .. to exit the directory.

```
$ deactivate
```

3.B: Package Tic-Tac-Toe as a Flatpak

1. Create a new directory for this build:

```
$ mkdir ex3-flatpak && cd ex3-flatpak
```

2. **Create the manifest pt.ua.deti.iei.tictactoe.yml:** This manifest is more complex.

- finish-args: Sets PYTHONPATH so the Python interpreter inside the sandbox can find our minMaxAgent.py module, which we install in /app/lib/game.
- python-deps module: Manually specifies the URL and checksum (sha256) for the pygame source code. flatpak-builder downloads this and builds it from scratch.
- game module: Downloads the game's source code from its URL (just like wget did). The build-commands then install all the game's parts: the Python scripts, the assets folder, and the .desktop and icon files for application menu integration.

```
app-id: pt.ua.deti.iei.tictactoe
runtime: org.gnome.Platform
runtime-version: "48"
sdk: org.gnome.Sdk
command: game
finish-args:
  - --share=ipc
  - --socket=x11
  - --socket=wayland
  - --device=dri
  - --env=PYTHONPATH=/app/lib/game
modules:
  - name: python-deps
    buildsystem: simple
    build-options:
      env:
        MAKEFLAGS: -j$(nproc)
    build-commands:
      - pip3 install --isolated --no-index --find-links="file://{PWD}" --prefix=/app pygame
    sources:
      - type: file
        url: https://pypi.io/packages/source/p/pygame/pygame-2.6.1.tar.gz
        sha256: 56fb02ead529cee00d415c3e007f75e0780c655909aaa8e8bf616ee09c9feb1f
  - name: game
    buildsystem: simple
    build-commands:
      - install -d /app/lib/game/
      - install -Dm644 minMaxAgent.py /app/lib/game/minMaxAgent.py
```

```

- install -d /app/share/game/
- cp -r assets /app/share/game/
- install -Dm755 main.py /app/bin/game
- install -Dm644 pt.ua.deti.iei.tictactoe.desktop
  /app/share/applications/pt.ua.deti.iei.tictactoe.desktop
- install -Dm644 assets/icon.png
  /app/share/icons/hicolor/128x128/apps/pt.ua.deti.iei.tictactoe.png
sources:
- type: archive
  url: https://github.com/mariolpantunes/tictactoe/archive/refs/tags/tictactoe-1.0.zip
  sha256: 4210c04451ae8520770b0a7ab61e8b72f0ca46fbf2d65504d7d98646fda79b5a

```

4. **Build and Install:** After installing, your game should appear in your desktop's application menu!

```

$ flatpak-builder --user --install --install-deps-from=flathub \
--force-clean build-dir pt.ua.deti.iei.tictactoe.yml

```

5. **Run and Cleanup:** After use `cd ..` to exit the directory.

```

$ flatpak run pt.ua.deti.iei.tictactoe
$ flatpak uninstall pt.ua.deti.iei.tictactoe

```

3.C: Package Tic-Tac-Toe as an AppImage

1. Create a build directory:

```

$ mkdir ex3-appimage && cd ex3-appimage

```

2. **Download the game source:**

```

$ wget "https://github.com/mariolpantunes/tictactoe/archive/refs/tags/tictactoe-1.0.tar.gz" \
-O tictactoe-1.0.tar.gz

```

3. Create the AppDir:

```

$ mkdir -p TTT.AppDir && cd TTT.AppDir

```

4. **Download and extract portable Python:** This is the same as in Exercise 2.C.

```

$ wget "https://github.com/niess/python-appimage/releases/\
download/python3.10/python3.10.19-cp310-cp310-manylinux_2_28_x86_64.AppImage" \
-O python.AppImage
$ chmod +x python.AppImage
$ ./python.AppImage --appimage-extract
$ mv squashfs-root/* .
$ rm -rf python* squashfs-root/

```

5. **Extract your game source:**

```

$ tar --strip-components=1 -zxvf ../tictactoe-1.0.tar.gz

```

6. **Install dependencies from requirements.txt:** We use the *bundled* Python's `pip` to install packages. The `--target` flag tells `pip` to install `pygame` *inside* our AppDir's site-packages folder, not on the host system.

```

$ ./usr/bin/python3.10 -m pip install -r \
$ ./requirements.txt --target ./usr/lib/python3.10/site-packages/

```

7. **Copy your game files:** We move the game's scripts and assets into the AppDir.

```

$ mv main.py minMaxAgent.py assets usr/bin/

```

8. **Update the AppRun entrypoint:** This AppRun script is updated to set the `PYTHONPATH` variable. This tells the Python interpreter to look for modules in *two* places: our site-packages directory (to find `pygame`) and our `usr/bin` directory (to find `minMaxAgent.py`). Finally, make it executable: `chmod +x AppRun`.


```

#!/bin/bash
# If running from an extracted image, then export ARGVO and APPDIR
if [ -z "${APPIMAGE}" ]; then
    export ARGVO="$0"

    self=$(readlink -f -- "$0") # Protect spaces (issue 55)
    here="${self%/*}"
    tmp="${here%/*}"
    export APPDIR="${tmp%/*}"
fi

# Resolve the calling command (preserving symbolic links).
export APPIMAGE_COMMAND=$(command -v -- "$ARGVO")

# Export Tcl/Tk
export TCL_LIBRARY="${APPDIR}/usr/share/tcltk/tcl8.6"
export TK_LIBRARY="${APPDIR}/usr/share/tcltk/tk8.6"
export TKPATH="${TK_LIBRARY}"

# Export SSL certificate
export SSL_CERT_FILE="${APPDIR}/opt/_internal/certs.pem"

# Export PyGame
export PYTHONPATH="${APPDIR}/usr/lib/python3.10/site-packages:${APPDIR}/usr/bin"

# Call Python
"$APPDIR/opt/python3.10/bin/python3.10" "$APPDIR/usr/bin/main.py" "$@"

```

9. **Add metadata:** We move the .desktop file and copy the icon into the root of the AppDir so appimagetool can find them.

```

$ mv pt.ua.deti.iei.tictactoe.desktop ./tictactoe.desktop
$ cp usr/bin/assets/icon.png ./pt.ua.deti.iei.tictactoe.png

```

10. Build, Run, and Cleanup:

```

$ cd .. # Go back to ex3-appimage directory
$ appimagetool TTT.AppDir

$ chmod +x TicTacToe-x86_64.AppImage
$ ./TicTacToe-x86_64.AppImage

$ rm -rf *.AppImage tictactoe-v1.0.tar.xz

```

Conclusion

In these exercises, you packaged a Python application in two distinct ways: as a self-contained **AppImage** and as a sandboxed **Flatpak**.

While both methods achieve portability, this workshop highlights the significant advantages of the Flatpak ecosystem, especially for complex applications.

The **AppImage** process required us to *manually* create a bundle. We had to:

1. Download a portable Python interpreter.
2. Manually install dependencies into a specific site-packages folder.
3. Write a custom AppRun script to set environment variables like PYTHONPATH.

The **Flatpak** process, in contrast, is **declarative** and **reproducible**.

1. **The Manifest is the Recipe:** We simply *declared* all our needs in a single .yaml manifest file. This one file defines the app, its sources (like the GitHub URL), its Python dependencies, and its sandbox permissions.

2. **Runtimes are Efficient:** Instead of bundling a 100MB+ Python interpreter, we simply requested the `org.gnome.Platform`. This runtime is downloaded *once* by the user and shared across all their Flatpak apps, making our game package itself incredibly small and fast to build.
3. **The Build is Easier:** We didn't need to write any complex shell scripts. `flatpak-builder` handled all the work of downloading the SDK, building `pygame`, and placing files in the correct directories based on our simple `install` commands.

Overall, Flatpak's use of manifests and shared runtimes results in a build process that is far more automated, maintainable, and efficient for both developers and end-users.