A Makefile for Developing Containerized \LaTeX Technical Documents

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Abstract—We propose a Makefile for developing containerized \LaTeX technical documents. The Makefile allows the author to execute the code that generates variables, tables and figures (results), which are then used during the \LaTeX compilation, to produce either the draft (fast) or full (slow) version of the document. We also present various utilities that aid in automating the results generation and improve the reproducibility of the document. We lastly release an open source repository of this paper that uses the Makefile.

I. INTRODUCTION

Developing technical documents that present both computationally generated results (variables, tables and figures) and natural text, is a central aspect of computational research. One programming paradigm that was proposed as a solution is literate programming [1], in which the author inserts snippets of code and the output of its execution, alongside natural text. Applications of literate programming include Jupyter [2] which allows publishing code, results and explanations in a executable format, Python\LaTeX [3] which allows Python to be executed in \LaTeX and ActivePapers [4] in which code can be executed using the Java Virtual Machine.

Although literate programming provides many advantages for demonstrative projects and immediate visual feedback during experimentation, its ‘dual nature’ constrains authors in using specifically designed text editors and/or source code formats thus leading to ‘app/vendor lock-in’ situations. Moreover, the overlap between natural text and results code makes literate programming difficult to debug and version control.

We propose a Makefile for developing containerized \LaTeX technical documents. By using portable technologies that withstood the test of time, we ensure the stability and portability of the proposed Makefile. We write this paper using a repository that consists of the Makefile and choose Docker as the container technology and the Python programming language for generating the results.

For the rest of the paper we will refer to:

- **results code** as the scientific-oriented programming language code (main.py) that produces the variables, tables and figures,
- **results** as the variables, tables and figures that are generated by the results code,
- **\LaTeX code** as the natural text (ms.tex) and bibliography (ms.bib),
- **code** as both the results code and \LaTeX code,

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II. THE MAKEFILE

The proposed Makefile can be used for developing documents that consist of results generated from results code executed within a container. The three tools that are used by the Makefile are the Make program which is a build automation tool, \LaTeX which is a typesetting system for publishing high quality research documents, and the container technology (such as Docker) which allows portable execution of code between different hardware, operating systems and environments.

The pseudoalgorithm of the Makefile is as follows:

```
artifacts/$(document_pdf): $(latex_code) artifacts/$(results)
run container latex
artifacts/$(results): $(results_code)
build image $(results_image)
run container $(results_image)
clean:
  rm -rf artifacts/
```

Listing 1. Pseudoalgorithm of the Makefile.

The default target runs the container for the \LaTeX compilation while the results target builds the image and runs the container that generates the results. When the author edits a file from results code or \LaTeX code, only the required
compilation is automatically triggered with Make. Forc
compilations without change could be done using the touch utility that updates the modification time of a file.

The basic commands of the Makefile are the following:

```make
make  # Generate draft artifacts (fast).
make FULL=1  # Generate full artifacts (slow).
make clean  # Remove artifacts/ directory.
```

Listing 2. Basic Makefile commands.

The author may use the Makefile for developing documents in the following way:

1) clones/downloads the repository which consists of the Makefile and the set of files as depicted in Fig.[1]
2) creates and develops the results code.
3) creates and develops the \texttt{\LaTeX} code.
4) executes make for fast development iterations and experimentation,
5) executes make FULL=1 for distribution or publication and
6) executes make clean to restore to a clean state.

The only requirements that the Makefile imposes on code is the presence of results code that generates the draft and full versions of the document and the presence of results code and \texttt{\LaTeX} code for saving/loading the results to/from artifacts/ respectively. An example of a results code that generates the draft version document in the field of neural networks would be a conditional that sets the number of epochs and training/validation/test samples to a low value.

III. THE MAKEFILE UTILITIES

In this section we present useful utilities that can be combined with the Makefile to automate results generation and improve the reproducibility of the document.

A useful \LaTeX package for automatically presenting variables from results in \LaTeX code is \texttt{datatool} with the following example use:

```latex
\DTLfetch{keys-values}{key}{lr}{value}
\DTLloaddb{keys-values}{artifacts/keys-values.csv}
```

Listing 3. \LaTeX datatool example of loading a file that contains pairs of keys and values (artifacts/keys-values.csv) generated by a results code and getting the value of a key named lr.

When using Python, a useful function for results code is \texttt{pandas.DataFrame.to\_latex} which automatically converts a dataframe table to a \LaTeX table:

```python
def df = pd.DataFrame(table)
df.to\_latex("artifacts/metrics.tex", float_format="%.2f")
```

Listing 4. Convert Pandas DataFrame (df) to \LaTeX table (artifacts/metrics.tex) in results code.

There are some considerations need to be taken into account when reproducibility is needed. Regarding \LaTeX a culprit against reproducibility is the time-date metadata embedded in the pdf output. These can be disabled using the following commands into the \LaTeX code or as extra arguments during \LaTeX compilation (as done by default in the Makefile):

```latex
\pdfinfoomitdate=1
\pdfsuppressapstexinfo=-1
\pdftrailerid{}
```

Listing 5. \LaTeX pdf reproducibility commands.

Regarding the results code for Python, we can achieve deterministic stochasticity by setting the random seeds to a specific value such as:

```python
# build-in random module
random.seed(0)
# numpy
np.random.seed(0)
# tensorflow
tf.random.set_seed(0)
torch.backends.cudnn.deterministic = False
torch.backends.cudnn.benchmark = True
torch.cuda.manual_seed_all(0)
torch.manual_seed(0)
```

Listing 6. Python reproducibility commands for popular libraries.

Additionally, an author can use the \texttt{cmp} utility to compare documents (generated in a different session, operating system or underlying hardware) byte by byte, and diffoscope for identifying sources of non-determinism as follows:

```bash
# Generate the first draft document version.
making=
# Backup the first resulting pdf.
# Update the modification timestamp of main.py.
touch main.py
# Generate the second draft document version.
# Compare draft document versions byte by byte.
# in a human readable form.
diffoscope artifacts/ms.pdf artifacts/ms-previous.pdf
```

Listing 7. Test draft document version reproducibility. This can also be used as a test script when pushing or pull requesting to a remote repository.

IV. EXAMPLE USE CASE OF THE MAKEFILE

This section provides a use case of the Makefile and also serves as a manual for developing \LaTeX documents with Python as the results code programming language. We train, validate and test MobilenetV2 neural networks [5] in PyTorch, on MNIST [6], FashionMNIST [7], KMNIST [8] and QMNIST [9]. We use the default train, validation and test datasets and compare the use of ReLU, ReLU6 [10] and SiLU [11] activation functions in the MobilenetV2 model.

Making use of the \texttt{datatool} package the values of the following variables are not directly referred in the main .tex file but they are instead read by an intermediate .tex file created by the results code: the number of epochs is 20, the batch size is 64 and the learning rate for SGD is 0.01. Additionally, making use of random seed setting we consistently get the same figures as shown in Fig.2 and Fig.3. We also use the \texttt{pandas.DataFrame.to\_latex} command which automatically converts a dataframe table to a \LaTeX table (as shown in Table 1).

V. DISCUSSION

The proposed Makefile is based on plain text file editing and can be used with any operating system that supports containers and Make. Make has existed for decades and has passed the test of time, while the container technology was standardized with the Open Container Initiative and there exist alternatives...
such as Podman that could be used as drop-in replacements for Docker. Moreover the Makefile can be combined with any version control system, container registry provider and text editor thus preventing ‘app/vendor lock-in’ situations.

Use cases of the Makefile include:

- regression testing and debugging, to ensure that changes to code do not alter results,
- common development environment across multiple authors,
- coauthors, reviewers, journal editors or other researchers can easily reproduce the document with few requirements.

**Conclusion**

Creation, usage and publication of technical documents are one of the top challenges for reproducible technical documents [12]. The proposed Makefile aids to this purpose by providing a way to write reproducible technical documents using the standard tools that many of the academics already use (ElifpX, Docker, Make) in a portable, efficient and future-proof way.

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