Modern Software Development for JUNO offline software

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Outline

• Introduction

• Modern software development for JUNOSW
  • Development using CMake and Git
  • Deployment using junoevn, container, and Gitlab runner

• Summary and plan
Introduction

- JUNO: Jiangmen Underground Neutrino Observatory
  - Rich physics program [1]
    - Neutrino Mass Ordering and Precise measurement of 3 oscillation parameters
    - Reactor neutrinos, Supernova burst neutrinos, Geo neutrinos, Atmospheric neutrinos, and Solar neutrinos
  - JUNO detector
    - 700 m deep underground
    - Central detector: 20 kton LS with 3%@1MeV of energy resolution.
    - Water Cerenkov detector and Top Tracker
  - Lifetime: 20+ years

The development of JUNOSW (originally called JUNO offline) starts in 2012.

- **Operating System**
  - SL5 -> SL6 -> CentOS 7

- **Compiler**
  - GCC 4.1.2 -> 4.4.7 -> 4.9.4 -> 8.3.0 -> 11.2.0

- **Build tool and version control**
  - CMT -> CMake
  - SVN/Trac -> Git/Gitlab

**Applications:** SNiPER Algorithms
**Core Software:** SNiPER framework, ROOT I/O, Database, etc.
**External Libraries:** ROOT, Geant4, Boost, Python, etc.

For details, see Xingtao’s talk.
Modern software development in JUNOSW

• Following the best practices from HSF [1], the migration to CMake/Git had been done for JUNOSW.
  • Use CMake to reduce the building time and support the different use cases for online and offline environments.
  • Adopt the git-based workflow to improve the code quality with code review and CI.
• To migrate smoothly, helper scripts have been developed.

CMake (1)

• When moving from CMT to CMake, follow the instructions in Modern CMake [1].

• CMake macros and functions are developed to simplify the usage of CMake.
  • All the packages in JUNOSW are built in the same manner.
  • The source code files under “src” are automatically used to build the library.
  • Targets are used to describe the dependencies.
  • Extra environment variables could be set.

CMT
package Geometry
use Detector
use Externals
macro_append \root-config --evelibs:
macro_append Boost_linkopts ":lboost_filesystem lboost_system"
set JUNO_GEOMETRY_PATH "$(GEOMETRYROOT)"
apply_pattern install_more_includes more="Geometry"
library Geometry *.cc
apply_pattern linker_library library=Geometry
apply_pattern install_python_modules

cmake
include (PKG)
PKG(Geometry
  DEPENDS
    Identifier
    boost_filesystem boost_system
  SETENV
    JUNO_GEOMETRY_PATH="${CMAKE_CURRENT_SOURCE_DIR}")

In order to support both online and offline environments, the following strategies are used:

- A script called “build.sh” is used for both cases. Use the environment variable to switch the build mode.
- When the online mode is detected, the main CMakeLists.txt will load CMakeLists.online.txt instead of CMakeLists.default.txt.
- Generator expressions are used to control the build flags.

```bash
function run-build() {
    local installdir="$<install-dir>
    local builddir="$<build-dir>
    check-build-dir
    check-install-dir

    pushd $<builddir>
    cmake .. $<(check-var-enabled graphviz) \
        $<(check-var-enabled wtkthic) \
        $<(check-var-enabled online) \
        $<(check-var-enabled PerformanceCheck) \
        -DCMAKE_CXX_STANDARD=17 \
        -DCMAKE_BUILD_TYPE=$<(cmake-build-type) \
        -DCMAKE_INSTALL_PREFIX=$<installdir \
        || error: "ERROR Found during cmake stage. "

    local njobs=$<(nproc)
    cmake --build . $<njobs || error: "ERROR Found during make stage. "
    cmake --install . || error: "ERROR Found during make install stage. "

    popd
}

if(BUILD_ONLINE)
    message(STATUS "Using online OEC packages lists")
    include ($<${CMAKE_SOURCE_DIR}/CMakeLists.online.txt)
elseif (EXISTS "$<${CMAKE_SOURCE_DIR}/CMakeLists.user.txt")
    message(STATUS "Using user customized package lists")
    find_package(junosw)
    include ($<${CMAKE_SOURCE_DIR}/CMakeLists.user.txt")
else()
    message(STATUS "Using default package lists")
    include ($<${CMAKE_SOURCE_DIR}/CMakeLists.default.txt")
endif()

$<NOT:$<BOOL:$<BUILD_ONLINE>>:Parameter>
git-junoenv

• When using SVN and CMT, developers could check out and build some packages instead of the whole project.

• In order to support this feature, a shell script called git-junoenv is developed to extend git, managing the packages to be checkout and built.
  • The core part is still the sparse checkout in git. The git ls-files is used to list the available packages.
  • When a package is checked out, it will be also registered in CMakeLists.user.txt. When building the project, CMake will use CMakeLists.user.txt.

$ git junoenv init-project junosw && cd junosw  # get the junosw without packages
$ git junoenv list-pkgs                        # list all the available packages
$ git junoenv add-pkg Reconstruction/OMILREC   # checkout a package
junoenv (1)

- It is a collection of shell scripts to deploy external libraries and JUNOSW.
  - Modularized by bash functions, which are inspired by ENV [1].
  - About 50+ external libraries are supported. About 30+ libraries are deployed.
  - Patches for the external libraries are also maintained in the same project.
  - The versions are collected for each release.

```bash
function juno-ext-libs-git-version- { echo 2.37.3 ; }
function juno-ext-libs-cmake-version- { echo 3.24.1 ; }
function juno-ext-libs-python-version- { echo 3.9.14 ; }
function juno-ext-libs-python-wheel-version- { echo 58.1.0 ; }
function juno-ext-libs-python-pip-version- { echo 22.2.2 ; }
function juno-ext-libs-python-cython-version- { echo 0.29.28 ; }
function juno-ext-libs-python-numpy-version- { echo 1.22.3 ; }
```

When deploying the software into CVMFS, the prefix is different from the original prefix when building software.

- However, we can’t run “make install” again on the CVMFS server.

- Use the paths with the same length and replace the prefix path
  - Inspired spack [1]
  - Solves the problems when the libraries or files are hardcoded with full paths.
  - Use “sed” to replace the paths for both libraries and software links.

# 2023.04.19

```bash
srcdir() { echo /tmp/ihep.ac.cn/juno/b/centos7_amd64_gcc1120/Pre-Release/J23.1.0-rc0 ; }
dstdir() { echo /cvmfs/juno.ihep.ac.cn/centos7_amd64_gcc1120/Pre-Release/J23.1.0-rc0 ; }
```

Docker image

• Two types of Docker images are prepared
  • Lightweight image with CVMFS clients installed.
  • Full image with all the external libraries installed.

<table>
<thead>
<tr>
<th>Use cases</th>
<th>Lightweight image</th>
<th>Full image</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI; Develop in users’</td>
<td>CI; Develop in users’ computer</td>
<td>Develop in users’ computer</td>
</tr>
<tr>
<td>computer (need network)</td>
<td>(offline)</td>
<td>(offline)</td>
</tr>
<tr>
<td>Image size (compressed)</td>
<td>372.87 MB (CentOS 7)</td>
<td>17.29 GB (CentOS 7)</td>
</tr>
<tr>
<td></td>
<td>20.37 GB (Ubuntu 22.04)</td>
<td></td>
</tr>
<tr>
<td>Privileged in Docker</td>
<td>Needed (required by CVMFS)</td>
<td>Not necessary</td>
</tr>
</tbody>
</table>

The lightweight image is used in the Gitlab CI. CVMFS is mounted first. Then the runtime environment is setup.

When the external libraries are upgraded, the CI could access them by using the latest release.
Gitlab Runner

- Gitlab Group Runners are deployed in a self-hosted Kubernetes cluster.
  - Gitlab agents are used to connect Gitlab and Kubernetes. Then the Gitlab runners are managed by the Gitlab agents.
  - All the configurations are managed in GitLab repositories.
Summary and plan

• Modern development and development for JUNOSW
  • CMake macros are developed and a high-level script is used by users.
  • git-junoenv is developed to partially check out and build packages.
  • junoenv is used to deploy JUNOSW and external libraries.
  • Docker and Kubernetes are also used to support CI.

• Plan: evaluate the migration from junoenv to spack
  • Spack is a package management tool, which has already been adopted in the Key4hep [1].
  • We hope to benefit from spack, including the reuse of the existing libraries and validation of the software stack by other experiments. This could be important when moving to new operating systems or architectures in the future.

Abstract

• The Jiangmen Underground Neutrino Observatory (JUNO), under construction in South China, primarily aims to determine the neutrino mass hierarchy and the precise measure oscillation parameters. The data-taking is expected to start in 2024 and plans to run for more than 20 years. The development of JUNO offline software (JUNOSW) started in 2012, and it is quite challenging to maintain the JUNOSW for such a long time. In the last ten years, tools such as Subversion, Trac, and CMT had been adopted for software development. However, there are some new requirements, such as how to reduce the building time for the whole project, how to deploy offline algorithms to an online environment, and how to improve the code quality with code review and continuous integration. To meet the further requirements of software development, modern development tools are evaluated for JUNOSW, such as Git, GitLab, CMake, Docker, and Kubernetes. This contribution will present the software development system based on these modern tools for JUNOSW and the functionalities we have achieved: CMake macros are developed to simplify the build instructions for users; CMake generator expressions are used to control the build flags for the online and offline environments; a tool named git-junoenv is developed to help users partially checkout and build the software; a script is used to build and deploy the software on the CVMFS server; a Docker image with CVMFS client installed is created for continuous integration; a GitLab agent is set up to manage GitLab runners in Kubernetes with all the configurations in a GitLab repository. In late 2022, the migration had been done.