

# What is new in preCICE?

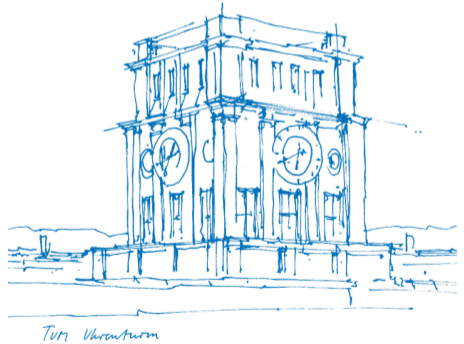
preCICE Workshop 2022

**Gerasimos Chourdakis**

**Frédéric Simonis**

Technical University of Munich

Recorded February 2022



# What is new in preCICE? The preCICE library

Speaker: Frédéric Simonis

## PETSc RBF - solver information

- Resulting state of the solver
- Why did it finish
- What was the last residual norm

Solver converged after 1 of 10000 iterations due to sufficient relative convergence.  
Last residual norm: 1.11399e-13, limits: relative 2e-09 (rtol 1e-09), absolute 1e-50, divergence 2e+30(dtol 1e+30)

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## PETSc RBF - solver behaviour

Solver	Log level	preCICE
converges	INFO	continues
diverges	ERROR	stops



## PETSc RBF - solver behaviour

Solver	Log level	preCICE
converges	INFO	continues
stops	WARNING	continues
diverges	ERROR	stops

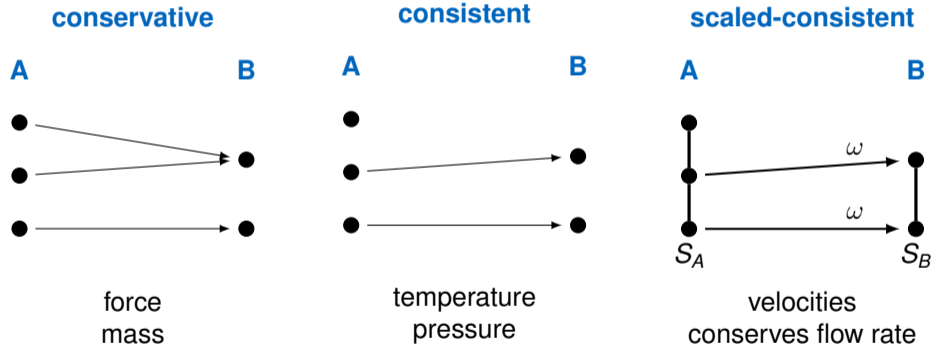
Reaching max iter is actionable.

## Readable convergence output

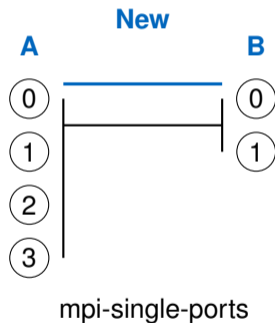
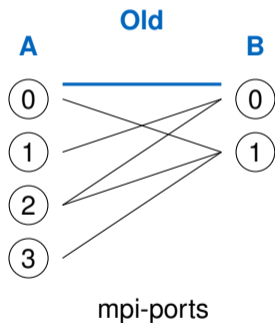
- User feedback
- Readable names ResRel (Forces)
- Convergence in fixed scientific format
- Iterations and timesteps in fixed width

```
$ tail -f precice-A-convergence.log
1      9      2.13325385e-01
1     10      3.84809185e-02
1     11      3.72078735e-04
1     12      3.34837628e-06
```

# Scaled-consistent mappings



## M2N communication - changed m2n:mpi



# Socket communication

## run preCICE without network connection fails #45



scheufks opened this issue on 23 Feb 2016 · 16 comments · Fixed by #1068



scheufks commented on 23 Feb 2016

Contributor



preCICE crashes if no network connection is available and communication is established via sockets.

```

221 221      using asio::ip::tcp;
222 222
223 -   tcp::resolver::query query(tcp::v4(), ipAddress, portNumber, tcp::resolver::query::canonical_name);
223 +   tcp::resolver::query query(tcp::v4(), ipAddress, portNumber, tcp::resolver::query::numeric_host);
224 224

```

## Memory usage of meshes

- Deep refactoring
- Reduced heap allocations
- Improved data locality

<b>primitive</b>	<b>rel. red.</b>
------------------	------------------

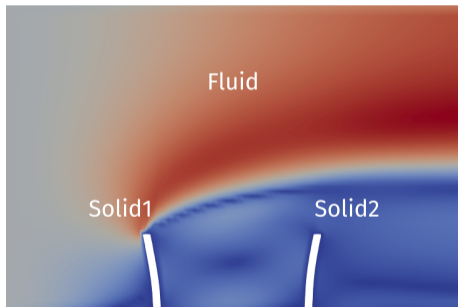
---

vertices	50%
----------	-----

edges	62%
-------	-----

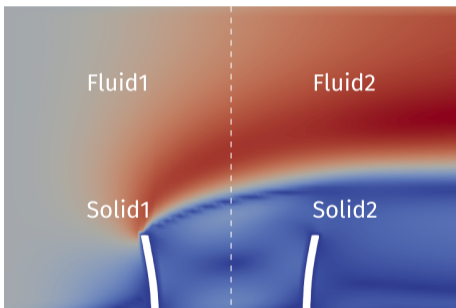
triangles	55%
-----------	-----

## Multi-coupling extension



```
<coupling-scheme:multi>  
  <participant name="Fluid" control="yes" />  
  <participant name="Solid1" />  
  <participant name="Solid2" />  
  ...  
</coupling-scheme:multi>
```

## Multi-coupling extension



Limitation: Non-centric controller needs to run in serial.

```
<coupling-scheme:multi>  
  <participant name="Fluid1" control="yes" />  
  <participant name="Fluid2" />  
  <participant name="Solid1" />  
  <participant name="Solid2" />  
  ...  
</coupling-scheme:multi>
```



## Adjusted build experience

\$ cmake ..

- Shared library
- Debug and trace logging
- Assertions

\$ cmake -DCMAKE\_BUILD\_TYPE=Release ..

- Shared library
- Optimized
- No debug or trace logging
- No assertions

# Experimental features

Explicitly activate in the config

```
<solver-interface experimental="true" dimensions=... >  
  ...  
</solver-interface>
```

## Experimental features - direct access

```
<participant name="MyParticipant">  
  <use-mesh name="Mesh" from="Other" direct-access="true" />  
  <write-data name="Data" mesh="Mesh" />  
</participant>
```

## Experimental features - direct access

```
// Specify region of interest
mid = precice.getMeshID("Mesh");
precice.setMeshAccessRegion(mid, aabb);

// Initialize preCICE
precice.initialize();

// Inspect received mesh
n = precice.getMeshVertexSize(mid);
precice.getMeshVerticesAndIDs(mid, n, ids, coords);

// Write data directly
did = precice.getDataID("Data", mid);
precice.writeBlockScalarData(did, n, ids, data);
```

## Upcoming changes

Mostly release 2.4.0

## Bigger features

### High-order and multi-rate time stepping with preCICE

preCICE Workshop 2020, Munich, Germany

[https://youtu.be/7NhBmcx\\_MmI](https://youtu.be/7NhBmcx_MmI)

### From low-order to high-order coupling schemes

preCICE Workshop 2022, Munich, Germany

Wed. 23 10:00–12:00 CET, 3rd talk

## Configuration checker

```
$ precice-tools check precice-config.xml  
ERROR: Data with name "forces" used by mesh "Solid" is  
not defined. Please define a data tag with name="forces".
```

- Available out of the box
- Checks XML structure  
Typos in tags and attribute names
- Checks names of  
Participants, Meshes, Data
- Cannot check coupling logic  
Is data actually exchanged in a coupling scheme?

## Exporter overhaul

```
<participant name="fluid">  
  <export:vtk />  
</participant>
```

```
$ ./fluid  
$ ls *vtk  
fluid-Mesh-dt1.vtk
```

```
$ mpirun -n 2 ./fluid  
$ ls *vtu  
fluid-Mesh-dt1.pvtu  
fluid-MeshA-dt1_r0.vtu  
fluid-MeshA-dt1_r1.vtu
```



# Exporter overhaul - VTK exporters

## VTK UnstructuredGrid

```
<participant name="fluid">
  <export:vtu />
</participant>
$ ./fluid
$ ls *vtu
fluid-Mesh-dt1.vtu
$ mpirun -n 2 ./fluid
$ ls *vtu
fluid-Mesh-dt1.pvtu
fluid-MeshA-dt1_r0.vtu
fluid-MeshA-dt1_r1.vtu
```

## VTK PolyData

```
<participant name="fluid">
  <export:vtp />
</participant>
$ ./fluid
$ ls *vtp
fluid-Mesh-dt1.vtp
$ mpirun -n 2 ./fluid
$ ls *vtp
fluid-Mesh-dt1.pvtp
fluid-MeshA-dt1_r0.vtp
fluid-MeshA-dt1_r1.vtp
```

## Exporter overhaul - CSV exporter

```
<participant name="fluid">  
  <export:csv />  
</participant>
```

```
$ ./fluid  
$ ls *.csv  
fluid-Mesh-dt1.csv  
$ mpirun -n 2 ./fluid  
$ ls *.csv  
fluid-MeshA-dt1_r0.csv  
fluid-MeshA-dt1_r1.csv
```

- Point data only
- Separate rank files
- Easy to postprocess  
R, Pandas, Matlab, LibreCalc, Excel
- pseudo coordinates

PosX;PosY;Rank;Temperature;ForcesX;ForcesY

## Exporter overhaul - CSV processing

```
def loadParallelCSVSeries(name)
    import re, glob, pandas
    l = [(re.search("dt(\\d+)", s).group(1), s)
          for s in glob.glob(f"{name}.dt*/*.csv")]
    return pandas.concat(
        [pandas.read_csv(file, sep=";").assign(dt=dt)
         for dt, file in l], ignore_index=True)
```

## Extended release builds

Debugging adapter using mesh connectivity?

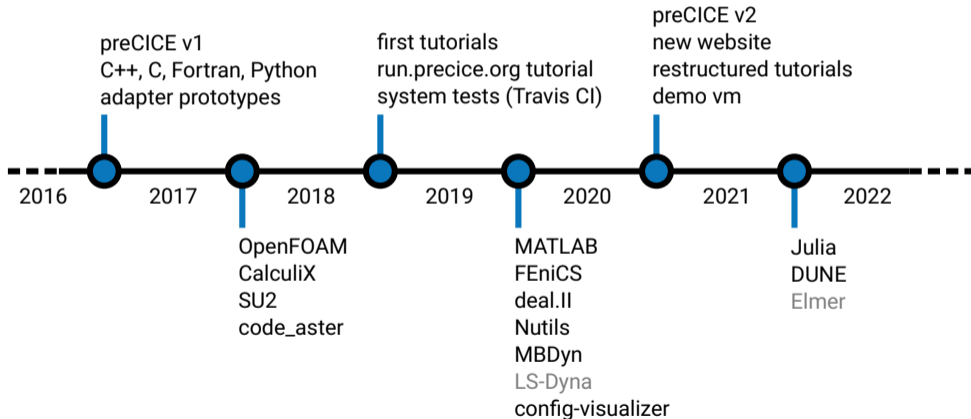
```
$ cmake -DCMAKE_BUILD_TYPE=Release \  
-DPRECICE_RELEASE_WITH_DEBUG_LOG=YES ..
```

**Slower, but usable.**

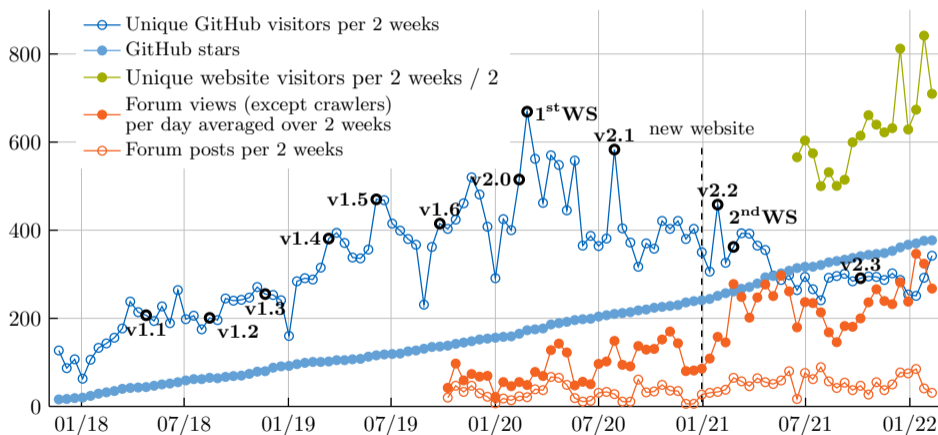
# What is new in preCICE? The preCICE ecosystem

Speaker: Gerasimos Chourdakis

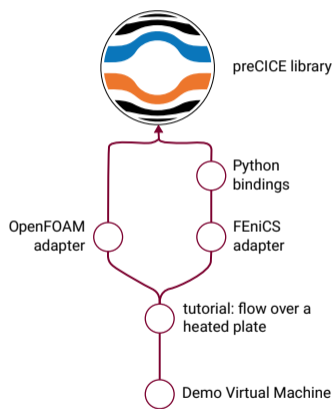
## From a library to an ecosystem



## Batteries included → more interest

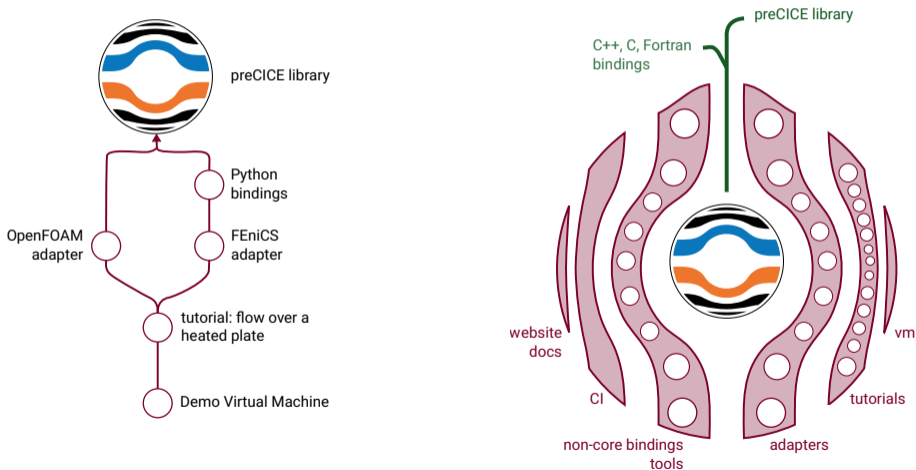


## Multiple components, in multiple layers





## Multiple components, in multiple layers



## Tutorials news

New structure, new cases  
and more

# Tutorials: starting points for your simulations

- Tutorials
- Introduction
- Perpendicular flap
- Flow over heated plate
- Partitioned heat conduction
- Turek-Hron FSJ
- Multiple perpendicular flaps
- Elastic tube 3D
- Elastic tube 1D
- Flow over heated plate nearest projection
- Flow over heated plate steady state
- Heat exchanger
- Partitioned heat conduction complex
- Partitioned elastic beam
- Partitioned pipe
- Volume-coupled diffusion

## A handful of exciting tutorials

Edit me

**Summary:** A handful of ready-to-run cases for you to build upon. Tutorials are meant as starting points to build your own coupled simulations. Our collection has grown rapidly over the past few years and [your contribution is very welcome!](#)

**Tip:** Is this your first time trying our preCICE? Read first the [Quickstart](#) guide or [watch a talk on YouTube](#).

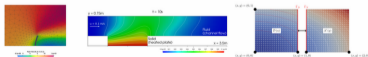
You can find all tutorial case files in the [tutorials repository](#). Get the [latest release](#), or clone the Git repository to easily update them in the future:

```
git clone --branch=master --depth 1 https://github.com/precice/tutorials.git
```

## Basic cases

We recommend that you start from one of the following cases, which you can quickly run on your laptop:

- **Flow in a channel with an elastic perpendicular flap:** A **fluid-structure interaction** scenario. Feel free to combine different solvers, among OpenFOAM, SU2, deal.II, FEniCS, Nutils, CalculiX, and DUNE.
- **Flow over a heated plate:** A **conjugate heat transfer** scenario. Try OpenFOAM, FEniCS, or Nutils.
- **Partitioned heat conduction:** The mathematician's dream: split the **heat equation** in two and glue it again. Pick your Dirichlet and Neumann solvers among FEniCS, Nutils, and OpenFOAM.



48 solver cases  
in 15 tutorials

# Tutorials: a new, modular structure

## Structure of a tutorial

Our tutorials generally follow a file structure similar to this:

```
- <tutorial>/           # e.g. perpendicular-flap/
- README.md           # description of the case
- precice.config.xml  # a works-with-all preCICE configuration file
- clean-tutorial.sh   # a symbolic link (see ../tools/)
- <visualization scripts> # gnuplot or simple Python scripts
- images/             # any images used by the documentation
- <participant1-solver1>/ # e.g. fluid-openfoam/
- run.sh              # a short script to run the solver1 case
- clean.sh            # a short script to clean the solver1 case
- <the solver1 files>
- <participant2-solver2>/ # e.g. solid-dealii/
- run.sh
- clean.sh
- <the solver2 files>
```




Contribute your own case setup!

# Tutorials: v202202.0

## New tutorials and several changes (workshop is coming!)

Latest

Compare ▾

 MakisH released this 6 days ago  v202202.0  5cab2c5 

New year, new tutorial cases!

In this scheduled release (part of the preCICE Distribution 2202.0 and in the context of the [preCICE Workshop 2022](#)), you can find:

- A new [volume coupled diffusion tutorial](#) with FEniCS
- Our first tutorial case with DUNE: a solid solver for the [perpendicular flap tutorial](#).
- An OpenFOAM version of the [partitioned heat conduction tutorial](#).
- A FEniCS version of the [elastic tube 3D tutorial](#).

Additionally, this release brings several changes. Most importantly, we changed the type of elements that CalculiX uses in the [perpendicular flap tutorial](#) (from `C3D8` to `C3D11`), which now performs very similarly to the rest of the cases. We also cleaned up several configuration files from confusing unnecessary details. See the [changelog](#) or [all file changes](#) for more details.

Once more, this release was a collective effort by the complete preCICE team. It includes code contributions by [@IshaanDesai](#), [@BenjaminRodenberg](#), [@DavidSCN](#), [@MakisH](#), further contributions by [@fsimonis](#), [@KyleDavisSA](#), and [@uekerman](#), as well as first-time community contributions by [@AndresPedemonteFIUBA](#), [@maxfirmbach](#), and [@mohamad-altaweel](#).

### Contributors



IshaanDesai, BenjaminRodenberg, and 8 other contributors

# Tutorials: new example for volume coupling

Tutorials
Introduction
Perpendicular flap
Flow over heated plate
Partitioned heat conduction
Turek-Hron FSI3
Multiple perpendicular flaps
Elastic tube 3D
Elastic tube 1D
Flow over heated plate nearest projection
Flow over heated plate steady state
Heat exchanger
Partitioned heat conduction complex
Partitioned elastic beam
Partitioned pipe
Volume-coupled diffusion

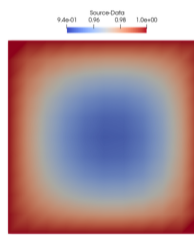
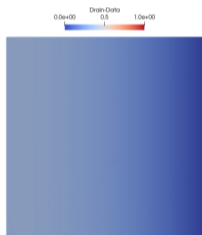
## Volume coupled diffusion



**Summary:** This tutorial illustrates volume coupling with a simple example.

### Setup

This case illustrates how to implement volume coupling in a simple toy problem. Two diffusion problems are coupled via volume terms. One domain (the source) has constant non-zero Dirichlet boundary conditions. The other domain (the drain) has Neumann boundary conditions and a zero Dirichlet boundary condition at the right edge of the domain. The quantity  $u$  flows from the source to the drain.



### Available solvers and dependencies

- FEniCS. Install [FEniCS](#) and the [FEniCS-adapter](#). Additionally, you will need to have preCICE and the python bindings installed on your system.

## Adapter news

New DUNE adapter, CalculiX adapter release, FEniCS adapter paper and more

# New DUNE adapter

precice / **dune-adapter** Public

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Code Issues 2 Pull requests Actions Projects Wiki Security Insights Settings

main 1 branch 0 tags Go to file Add file Code

**maxfirmbach** First prototype of the dune-precice module (dune-ad... 5f2364d on 7 Dec 2021 2 commits

📁 dune-precice-howto	First prototype of the dune-precice module (dune-adapter) for ...	3 months ago
📁 dune-precice	First prototype of the dune-precice module (dune-adapter) for ...	3 months ago
📄 README.md	First prototype of the dune-precice module (dune-adapter) for ...	3 months ago

☰ README.md

## dune-adapter

**experimental** preCICE-adapter for DUNE, a modular toolbox for solving partial differential equations

**Max Firmbach**  
maxfirmbach

- 📍 University of the Bundeswehr Munich
- 📍 Munich, Germany
- 🌐 <https://www.unibw.de/imcs/team/firmbach>



# CalculiX adapter release v2.19.0

## v2.19.0 - Finally! A release! Latest

[Compare](#)

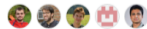
 MakisH released this 11 days ago  v2.19.0  4496e8f 

This is the first tagged release using the GitHub Releases. Most of the work here was done by [@boris-martin](#), with some help by [@MakisH](#), [@fsimonis](#), [@KyleDavisSA](#), [@IshaanDesai](#).

Highlights:

- Updates for CalculiX v2.19 ([#78](#))
- Added Debian packages for Ubuntu 18.04 and 20.04 ([#72](#))
- Fixed some memory leaks ([#76](#) [#77](#))
- Added the flag `-USE_MT` to the Makefile, enabling multi-threading in SPOOLES ([#34](#), implemented in [#78](#))
- Added experimental support for PaStiX ([#71](#) [#80](#) [#81](#))
- Added clang-format and formatted the code ([#83](#))

### Contributors



boris-martin, MakisH, and 3 other contributors

 [calculix-precice2\\_2.19.0-1\\_amd64\\_focal.deb](#)



**Boris Martin**  
boris-martin

# FEniCS adapter paper

SoftwareX 16 (2021) 100807



Contents lists available at [ScienceDirect](#)

## SoftwareX

journal homepage: [www.elsevier.com/locate/sofx](http://www.elsevier.com/locate/sofx)



Original software publication

## FEniCS–preCICE: Coupling FEniCS to other simulation software

Benjamin Rodenberg<sup>a,\*</sup>, Ishaan Desai<sup>b</sup>, Richard Hertrich<sup>a</sup>, Alexander Jaust<sup>c</sup>, Benjamin Uekermann<sup>b</sup>

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<sup>b</sup> Usability and Sustainability of Simulation Software, Institute for Parallel and Distributed Systems, University of Stuttgart, Germany

<sup>c</sup> Simulation of Large Systems, Institute for Parallel and Distributed Systems, University of Stuttgart, Germany



Also: 3D extensions  
in v1.3.0

### ARTICLE INFO

#### Article history:

Received 20 March 2021

Received in revised form 23 July 2021

Accepted 8 September 2021

#### Keywords:

FEniCS  
Fluid–structure interaction  
Conjugate heat transfer  
Multiphysics  
Coupled problems  
Finite element method  
preCICE

### ABSTRACT

The new software FEniCS–preCICE is a middle software layer, sitting in between the existing finite-element library FEniCS and the coupling library preCICE. The middle layer simplifies coupling (existing) FEniCS application codes to other simulation software via preCICE. To this end, FEniCS–preCICE converts between FEniCS and preCICE mesh and data structures, provides easy-to-use coupling conditions, and manages data checkpointing for implicit coupling. The new software is a library itself and follows a FEniCS-native style. Only a few lines of additional code are necessary to prepare a FEniCS application code for coupling. We illustrate the functionality of FEniCS–preCICE by two examples: a FEniCS heat conduction code coupled to OpenFOAM and a FEniCS linear elasticity code coupled to SU2. The results of both scenarios are compared with other simulation software showing good agreement.

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## Coming up

Julia bindings, Elmer adapter, ASTE updates

# Coming up: Julia bindings

## PreCICE.jl

license LGPL-3.0

This package provides Julia language bindings for the C++ library [preCICE](#). It is a Julia package that wraps the API of preCICE.

### Adding the package to a Julia environment or script

You can use the Julia bindings for preCICE by adding them as a package in a Julia environment or also directly including the package in a Julia script. For both usages you need to have preCICE installed on the system. For preCICE installation you can look at the [installation documentation](#). You can directly add the Julia bindings to your Julia environment in the following way:

```
julia> ]  
pkg> add https://github.com/precice/julia-bindings.git  
Then exit the package mode with ESC or Ctrl + c  
julia> using PreCICE
```

#### Contributors 3



pavelkharitenko



IshaanDesai Ishaan Desai



erikscheurer

#### Languages



# Coming up: Elmer adapter

## elmer-adapter

**experimental** preCICE-adapter for the open source multiphysical simulation software Elmer FEM

## Getting started

## Dependencies & Installation Instructions

- preCICE
  - Recommended: Install debian package, please refer to <https://precice.org/installation-overview.html> for installation
- Elmer
  - Recommended: Install debian package, please refer to <http://www.elmerfem.org/blog/binaries/>

### Packages

No packages published  
[Publish your first package](#)

### Contributors 2



**BenjaminRodenberg** Benjamin Rode...



**HishamSaeed** Hisham

### Languages



# Coming up: ASTE updates

precice / aste Public

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develop 10 branches 5 tags Go to file Add file Code

About Artificial Solver Testing Environment

kursatyurt Merge pull request #80 from kursatyurt/remove\_defaults 792f71b yesterday 320 commits

.github/workflows	Add clang build and make CI fail on warnings (#72)	18 days ago
cmake-modules	Squashed	3 years ago
contrib	Adjust recovery file name according to #81	2 days ago
docs	Merge pull request #22 from precice/mapping-tests	7 months ago
plotting	Make plotting labels configurable	4 years ago
src	Change wording	yesterday
.clang-format	Formatting using the preCICE clang-format (#24)	5 months ago
.gitignore	Test Modules for Reading and Writing (#29)	3 months ago
CMakeLists.txt	Add install option for ASTE (#70)	19 days ago
LICENSE	Initial commit	6 years ago
precice.xml	Migrate to v2	2 years ago

**Kürşat Yurt**  
kursatyurt  
Computational Science & Engineering student @ TUM

Contributors 7

## Outer layers

Demo Virtual Machine, preCICE Distribution  
and more

# Demo Virtual Machine

Docs v2.3.0

- Fundamentals ▾
- Installation ▴**
- Overview
- System packages
- Using Spack
- Building from source ▾
- Linking to preCICE
- Language bindings ▾
- Special systems
- Demo Virtual Machine**
- preCICE distribution
- Configuration ▾
- Tooling ▾
- Provided adapters ▾
- Couple your code ▾
- Dev docs ▾
- Documentation meta ▾

## Demo Virtual Machine

[Edit me](#)

**Summary:** A sandbox to try preCICE and all the adapters without having to install them on your system.

### Do I need this?

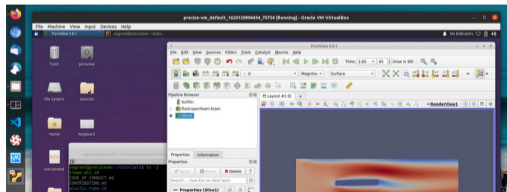
You probably only want to use this if you are very new to preCICE and want to learn, for example during our [preCICE Workshops or other conferences](#) where we may be present with a training session.

After trying this out for a few days, you probably want to just delete it and install only the components you need directly on your target system.

### What is this?

This is a [Vagrant](#) box, essentially a [VirtualBox](#) virtual machine image, with additional automation to make it easier for you to use and for us to maintain.

This contains all the solvers and adapters used in our tutorials, already built and configured for you to enjoy.





# A citable preCICE Distribution

Docs v2.3.0

- Fundamentals ▾
- Installation ▲
- Overview
- System packages
- Using Spack
- Building from source ▾
- Linking to preCICE
- Language bindings ▾
- Special systems
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- preCICE distribution
- Configuration ▾
- Tooling ▾
- Provided adapters ▾
- Couple your code ▾
- Dev docs ▾
- Documentation meta ▾

## preCICE Distribution Version v2104.0

Version 1.1



Chourdakis, Gerasimos; Davis, Kyle; Rodenberg, Benjamin; Schulte, Miriam; Simonis, Frédéric; Uekermann, Benjamin; Abrams, Georg; Bungartz, Hans-Joachim; Cheun Yau, Lucia; Desai, Ishaan; Eder, Konrad; Hertrich, Richard; Lindner, Florian; Rusch, Alexander; Sashko, Dmytro; Schneider, David; Totounferoush, Amin; Volland, Dominik; Vollmer, Peter; Ziya Koseomur, Oguz, 2021, "preCICE Distribution Version v2104.0", <https://doi.org/10.18419/darus-2125>, DaRUS, V1

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### Description ⓘ

The preCICE distribution is the larger ecosystem around preCICE, which includes the core library, language bindings, adapters for popular solvers, tutorials, and vagrant files to prepare a virtual machine image.

The compressed source files of this data set are only meant to archive [this specific version v2104.0](#) of the distribution. If you want to use preCICE, please follow the information on the [preCICE website](#).

v2202.0 released last week, to appear on DaRUS soon

## New reference paper

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### PRECICE v2: A SUSTAINABLE AND USER-FRIENDLY COUPLING LIBRARY

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A PREPRINT

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## What to cite?

**preCICE v1 paper:** Now, or whenever specifically writing about preCICE v1

**preCICE v2 paper:** Soon, whenever writing about preCICE

**Adapter papers:** Whenever using an adapter

**Distribution:** For reproducibility (specific versions)

## Wrapping up

## Don't miss

**Support program:** Talk by Benjamin Uekermann

**Developer talks:** Updates on:

- Macro-micro coupling
- Testing the ecosystem
- High-order coupling schemes
- Data mapping

**Summer meeting:** preCICE Minisymposium at ECCOMAS Congress 2022, June 5-9, Oslo

## 2022 resolution

be part of the “What’s new in preCICE” list  
in the preCICE Workshop 2023.

(or simply manage to catch up on all these updates)