MANCHESTER 1824
The University of Manchester

Overview of version 5.0

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The University of Manchester

DualSPHysics v5.0 Overview: Contents

1. DualSPHysics Software: code, team, validation process
2. New features of v5.0
3. Performance characteristics
4. New capabilities

DualSPHysics software

OPEN-SOURCE CODE

AVAILABLE FOR FREE

COLLABORATIVE PROJECT

LGPL LICENSE

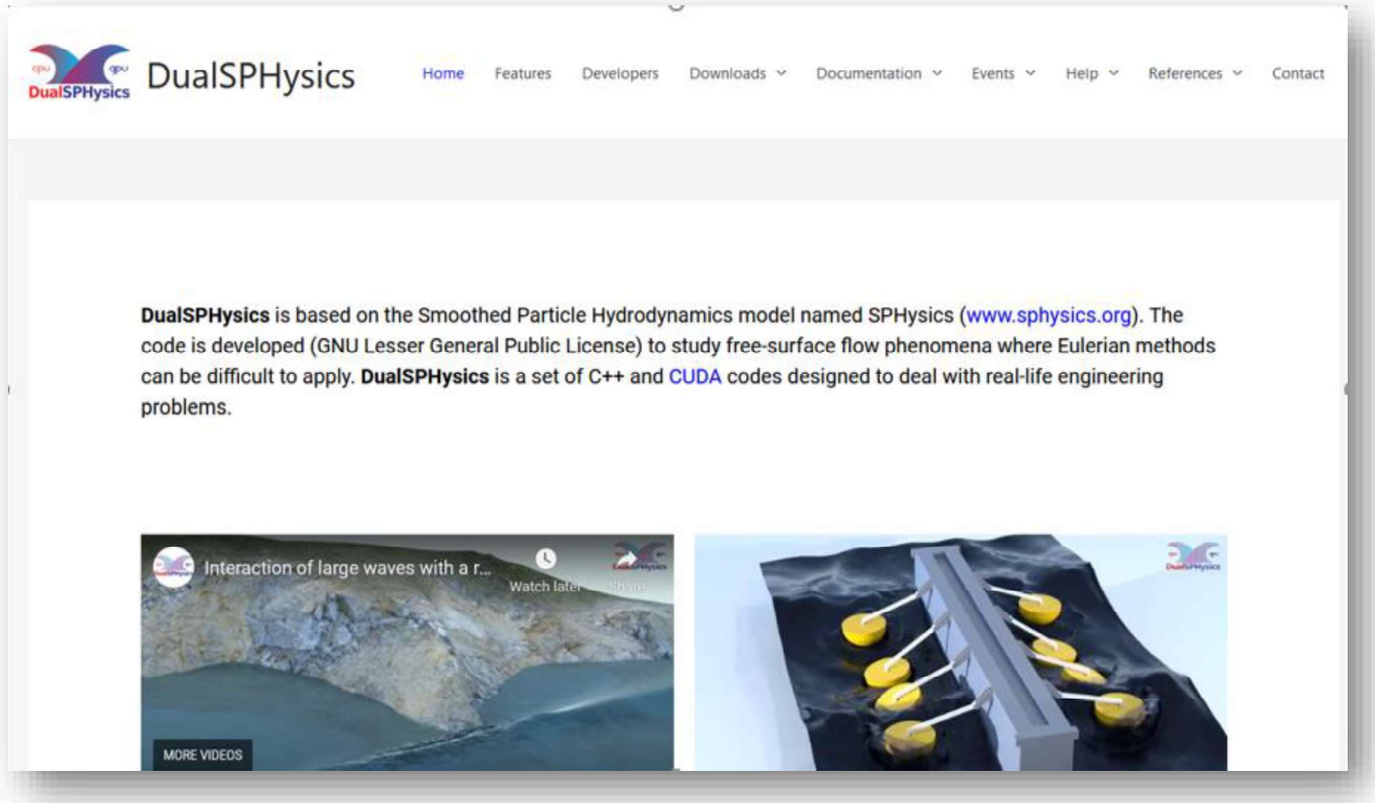
HIGHLY PARALLELISED

PRE- & POST-PROCESSING

VALIDATED

APPLIED TO REAL PROBLEMS

OPEN PROJECT



www.dual.sphysics.org

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Industrial interest:
NASA JSC, BAE Systems, Volkswagen AG, Forum NOKIA, NVIDIA, AECOM, HDR Engineering, ABPmer, DLR, CFD-NUMERICS, BMT Group, Oak Ridge National Laboratory, Rainpower Norway, Shell Company, ABB, FEMTO Engineering National Nuclear Laboratory, …

Wave energy companies:
American Wave Machines, Carnegie Clean Energy Ltd, Maine Marine Composites, National Renewable Energy Laboratory in U.S.A., Atria Power Corporation Ltd., Global Hydro Energy, WavePower

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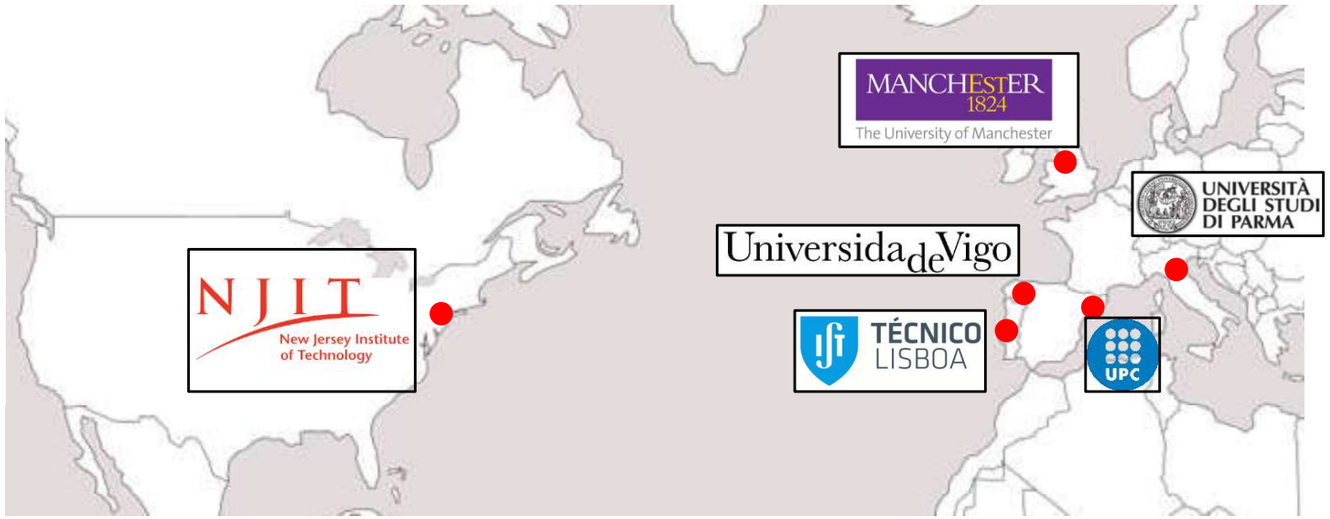

DEVELOPERS:
Universidade de Vigo, Spain
The University of Manchester, UK
Instituto Superior Tecnico, Lisbon, Portugal
Università degli studi di Parma, Italy
Universitat Politècnica de Catalunya, Spain
New Jersey Institute of Technology, USA

COLLABORATORS:
Flanders Hydraulics Research , Belgium
Universidad Politécnica de Madrid, Spain
TECNALIA. Inspiring Business, Spain
Imperial College London, UK
Universiteit Gent, Belgium
University of Salerno, Italy
Universidad de Guanajuato, Mexico
…

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LGPL (Lesser General Public License)
can be used in **commercial** applications

Software can be incorporated into both:
- free software and
- proprietary software

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GPU CPU

x100

Up to 20 million particles on a single GPU

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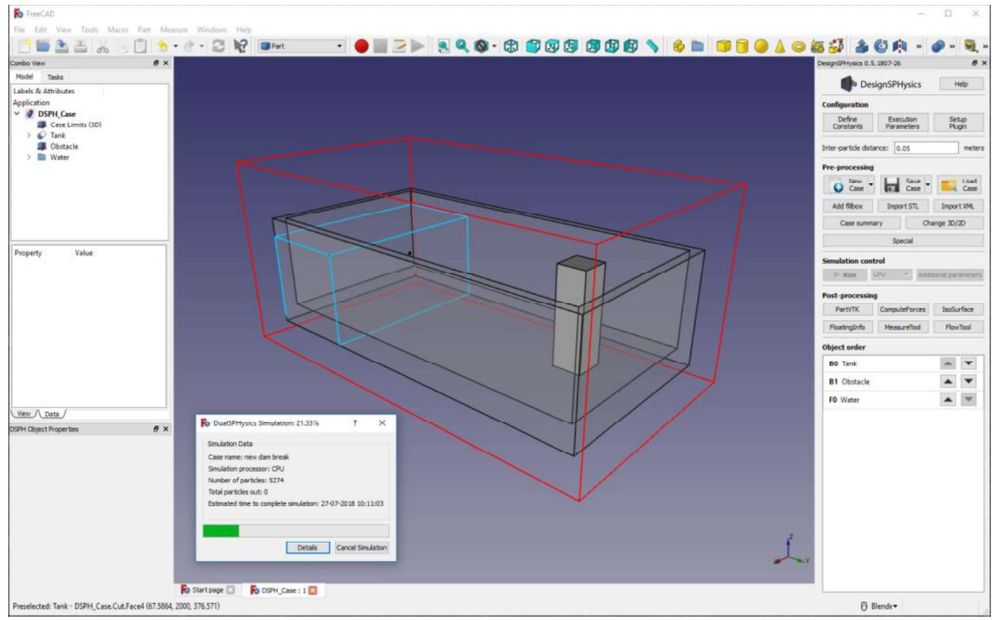
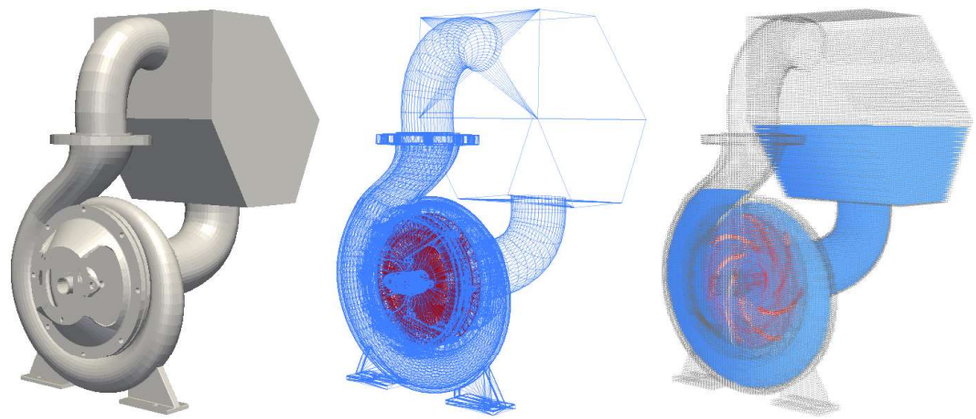
Graphical User Interface FreeCAD

Open Source parametric 3D CAD modeler





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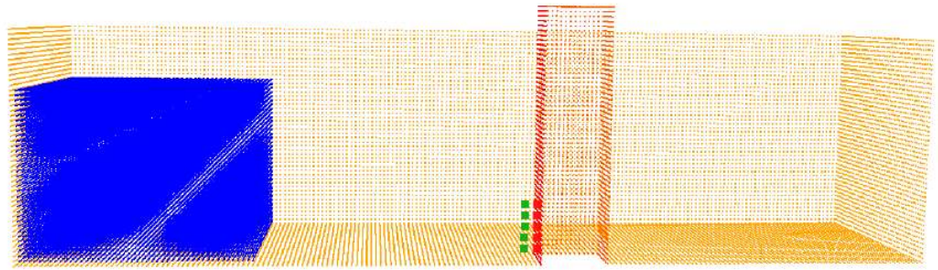
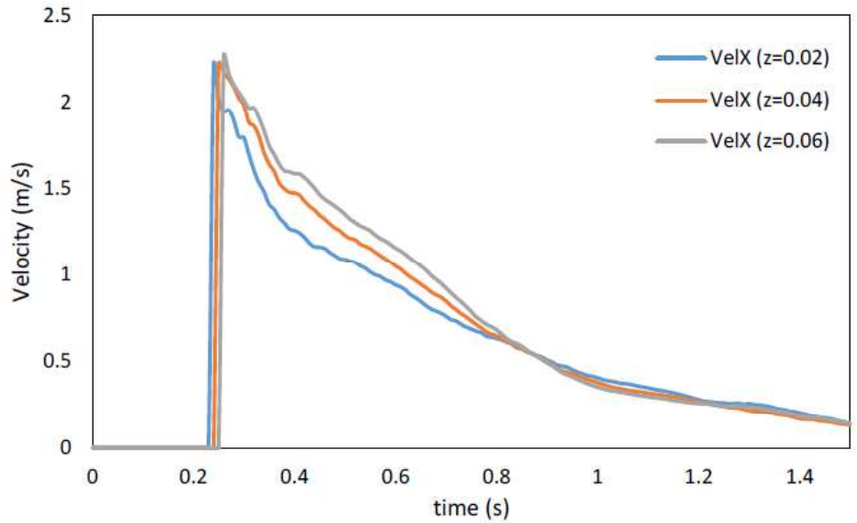
MEASURETOOL, FLOW TOOL





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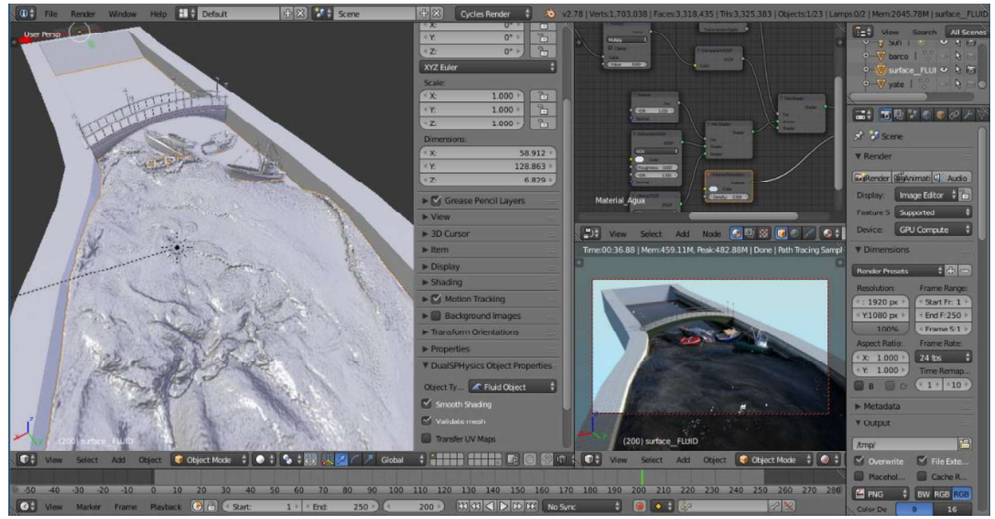
Advanced visualisation blender™



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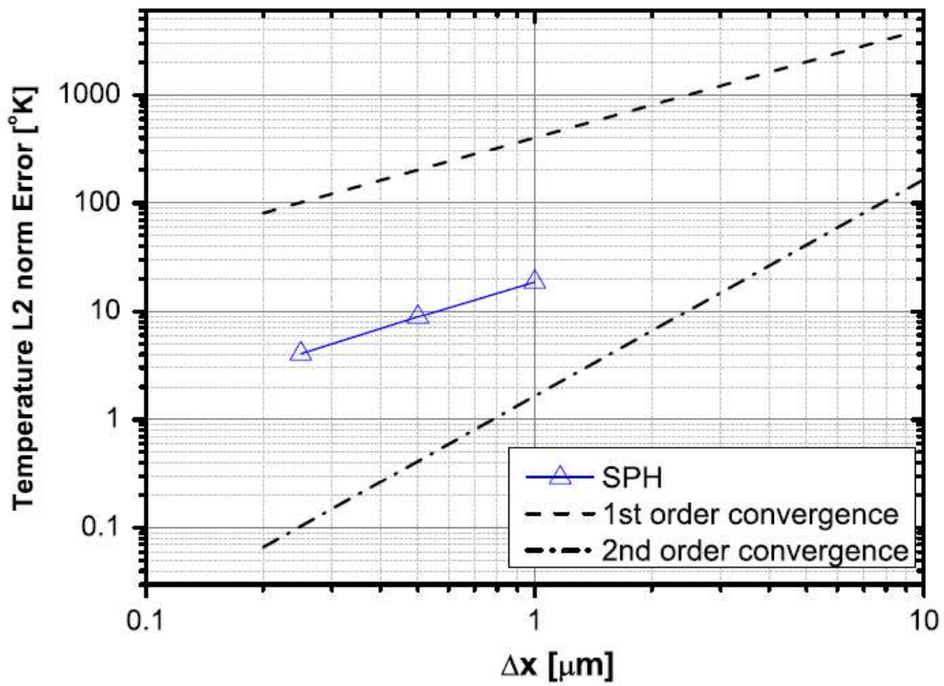
L2 ERROR NORMS ARE STANDARD



$$L_2(\phi) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\phi_{i,SPH} - \phi_{i,ex}}{\phi_{i,ref}}\right)^2}$$

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DualSPHysics Validation Workflow

1. Motivation for new work: e.g. new application / idea
2. Development work: 2-3 years PhD/Postdoc
3. Validation work: comparing with reference data (experiment/analytical solution)
4. Publish work in peer-reviewed journal papers (6 months – 2 years)
5. Prepare for release (see later)

DualSPHysics software

***Current capabilities (and many others)*:**

Pre-processing:

- DesignSPHysics - Fully integrated GUI with the option of scripting (eXtensible Markup Language)
- CAD design import tools (for VTK, PLY or STL)
- Binary file generation for use with million of particles
- Velocity, position transformations
- Impose forces, acceleration and motion to objects
- Large number of options for input, output and geometry generation and manipulations

Acceleration:

- State-of-the-art GPU acceleration on Nvidia GPUs
- OpenMP acceleration

Solvers:

- Single phase free-surface flow solver
- Discrete element method coupled with SPH
- Coupled with Project Chrono
- Non-Newtonian/Newtonian multi-phase solver
- Multi-phase gas-liquid solver
- Multi-phase liquid-granular material solver

Free-surface flows and wave mechanics

- Wave generation
  - Regular waves
  - Irregular waves
  - Solitary waves
  - Piston or flap generator
- Active wave absorption
- Passive wave absorption
- Multi-layer pistons (with/out AWAS)
- Relaxation zones
- Numerical gauge system
- Coupling with frequency and time domain solvers

Features and BCs (that favour speed and/or accuracy)

- Two wall boundary conditions
- Periodic conditions (with height change)
- Inflow-outflow boundary conditions
- Two viscosity formulation (including LES)
- Advanced density dissipation terms
- Two time integrators
- Advanced time-marching controls
- Advanced shifting options (per zone/type, etc.)
- Three smoothing kernel functions
- Two rigid interaction algorithms (plus Chrono)
- Single, mixed and double precision solver

DualSPHysics software

Post-processing tools:
A number of post-processing and visualisation tools are available in DualSPHysics

- ***Metrics*** such as “time for end of simulation”, computational times per feature, etc., restart checkpoints.

- ***PartVTK*** (VTK, ASCII)
  - Fluid, boundary, or any other type of particle
  - Any field variable (pressure, velocity, vorticity, etc)
  - Choice between fixed, moving, floating, type, mk, etc.
  - Excluded particles
- ***BoundaryVTK***
  - As above, exclusively for boundary particles

- ***MeasureTool*** - Analysis of numerical measurements
  - Measure any field variable at any position
  - Fixed in space
  - Changes with time
  - Detection of free surface flow

- ***ComputeForces***
  - Calculate the forces exerted on an object
  - Calculate moments about an axis
  - Fixed in space
  - Changes with time

- ***FloatingInfo*** - Obtain different data of the floating objects
  - Linear velocity, angular velocity,
  - Displacement of the centre,
  - Motions and angles of rotation

- ***IsoSurface*** – Creation of iso-surfaces for visualising large number of particles

- ***FlowTool***
  - Flow rate computations

- ***VisualSPHysics***
  - Visualisation plug-in specifically created for using Blender with DualSPHysics

DualSPHysics software

Test Cases with validation

- examples
  - main
    - 01_DamBreak
    - 02_Periodicity
    - 03_MovingSquare
    - 04_ExternalForces
    - 05_SloshingTank
    - 06_Wavemaker
    - 07_WavemakerFile
    - 08_WavesFlap
    - 09_WavesPiston
    - 10_WavesPistonAWAS
    - 11_Floating
    - 12_FloatingWaves
    - 13_Pump
    - 14_DEM
    - 15_Poiseuille
    - 16_SolitaryWaves
    - 17_WaveRunp
  - chrono
    - 01_Pendulum
    - 02_Spring
    - 03_FlexibleGate
    - 04_Pelamis
    - 05_OWSC
    - 06_Zipline
    - 07_DamBreakCubes
    - 08_WaterMill
    - 09_Turbine
    - 10_PointAbsorber
    - 11_PointAbsorber
    - 12_ExternalVelocity
  - moordyn
    - 01_MooredBox
    - 02_WavesMooring2D
    - 03_WavesMooring3D
    - 04_ConnectedBox
    - 05_SteppedTank
  - wavecoupling
    - 01_ML_CIEM
    - 02_RZ_RegularWaves
    - 03_RZ_IrregularWaves
    - 04_RZ_Flow2D
    - 05_RZ_FlowCylinder3D
    - 06_RZ_Coupling
  - inletoutlet
    - 01_FlowCylinder
    - 02_OpenChannel
    - 03_ReverseFlow
    - 04_Waves2D
    - 05_ShapesInlet3D
    - 06_Box4Inlet3D
    - 07_CurrentHull
    - 08_ImpingingJet
  - mdbc
    - 01_StillWedge
    - 02_Poiseuille
    - 03_Sloshing
    - 04_Dambreak
    - 05_FlowCylinder
    - 06_WaveTank
    - 07_WavesCylinder
  - mphase_liquidgas
    - 01_DamBreak
    - 02_ObstacleImpact
    - 03_WetDamBreak
    - 04_SloshingTank
    - 05_DEM
    - 06_SurfaceTension
  - mphase_nnewtonian
    - 01_WetDamBreak
    - 02_Dambreak3D
    - 03_LockGate
    - 04_SloshingMotion
    - 05_Poiseuille
    - 06_Impellers3D
  - motion
  - others
    - ChronoPointline
    - ExternalDtFile
    - ExternalViscoFile
    - FreeDrawMode
    - FtRestrictions
    - GaugeSystem
    - MotionFloating
    - RedrawGenCase
    - Restart
    - RotatedBox
    - SaveDt
    - TimeOut
    - Variables

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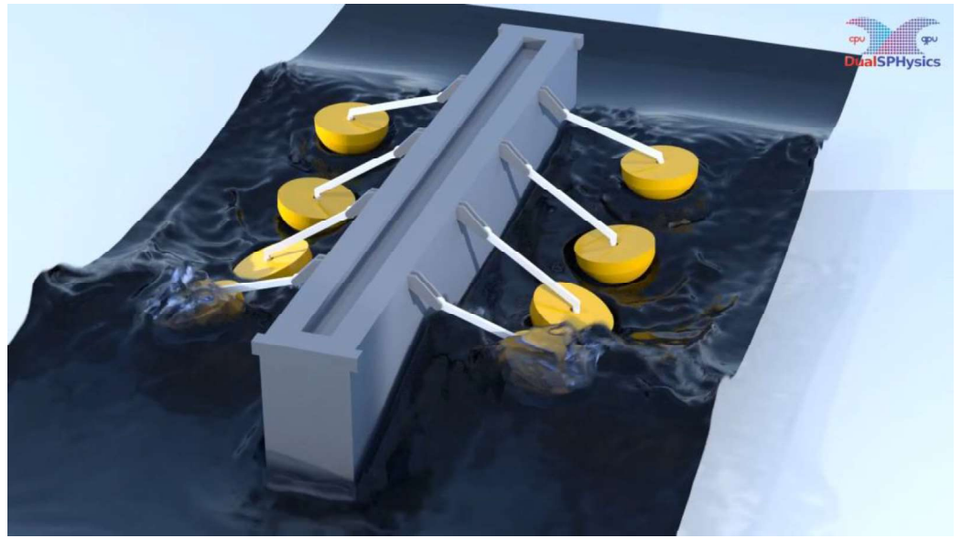

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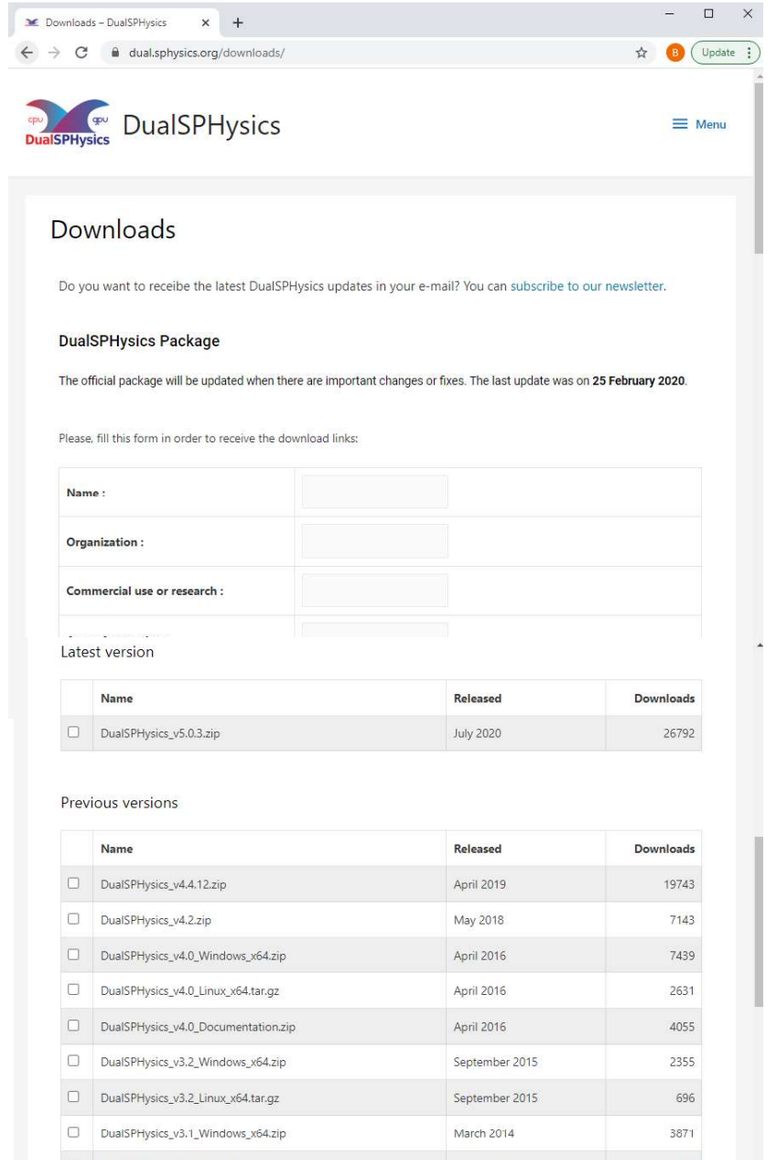
DualSPHysics Package
http://dual.sphysics.org



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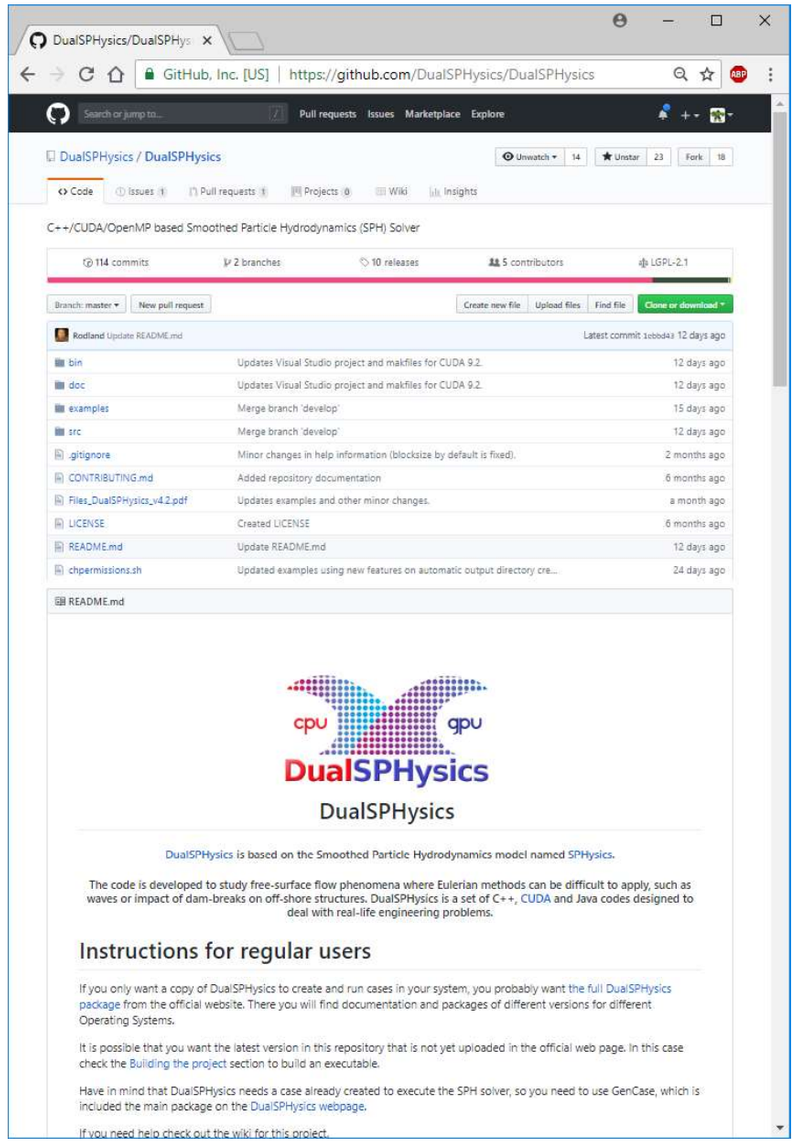
DualSPHysics Code on GitHub
https://github.com/DualSPHysics/DualSPHysics



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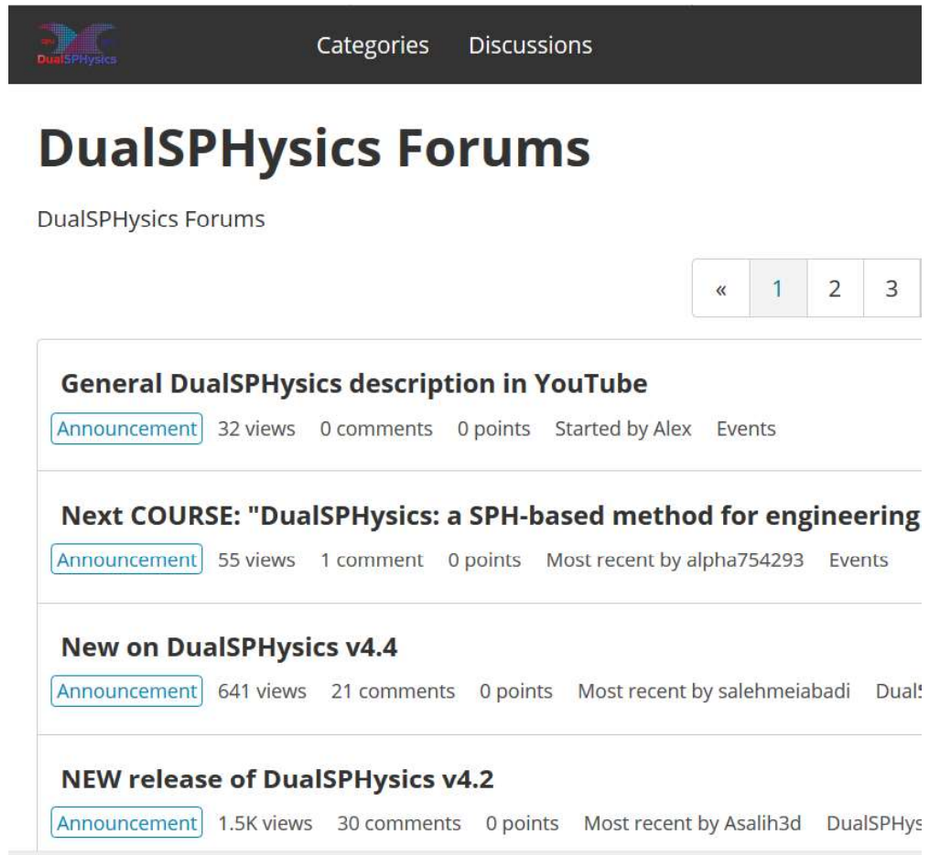
With 45,000+ downloads ACTIVE ONLINE FORUM



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DualSPHysics Development Strategy

1. Use code repositories continually:
   a. GitHub (public)
   b. GitLab (private for core developers only)
2. With multiple streams/threads, this requires constant communication: meetings, visits, Zoom calls, WhatsApp
3. Documentation Online & in the past using Doxygen, properly commented
4. Clean code for Beta version
5. Plan Beta Code Releases to coincide with the DualSPHysics Users Workshops
6. Release Code
7. Version Numbers: Major releases (e.g. 5.0) Minor releases (e.g. 4.4)

Collaboration example:

Inflow/Outflow: U-Parma + NYU + U-Vigo

MORE…

International DualSPHysics Users Workshop

1st DualSPHysics Users Workshop, University of Manchester, U.K., 8-9 September 2015
2nd DualSPHysics Users Workshop, University of Manchester, U.K., 6-7 December 2016
3rd DualSPHysics Users Workshop, University of Parma, Italy, 13-15 November 2017
4th DualSPHysics Users Workshop, Instituto Superior Técnico, Lisboa, 22-24 October 2018

5th DualSPHysics Users Workshop, Universitat Politècnica de Catalunya, Barcelona, March, 2021

MORE…

Conference and courses where the practical session was organized using DualSPHysics

NEXT: Barcelona, Spain, March 2021

22-23/01/2020: Numerical modelling of WEC using SPH models, Ourense, **Spain**

5-6/09/2019: DualSPHysics: SPH-based method for engineering, Salerno, **Italy**

20/02/2019: Smoothed Particle Hydrodynamics numerical methods, Parma, **Italy**

29/02/2019: Introduction to Smoothed Particle Hydrodynamics & DualSPHysics, Uni. Nac. Autónoma, **México**

13/12/2018: Introduction to SPH & DualSPHysics, Mälardalen University, **Sweden**

22/10/2018: 4th DualSPHysics Users Workshop, Instituto Superior Tecnico, Lisbon, **Portugal**

27/09/2018: Short Course on “CFD for Free Surface Flows by SPH”, University of Florence, **Italy**

25/06/2018: 13th SPHERIC Workshop, National University of Ireland, Galway, **Ireland**

19/06/2018: DualSPHysics: Numerical tool in coastal engineering and marine energy, CEDEX, **Madrid**

10/04/2018: SPH 2-day CPD Course, University of Manchester, **United Kingdom**

13/11/2017: 3rd DualSPHysics Users Workshop, University of Parma, **Italy**

17/10/2017: 1st SPHERIC Workshop in Asia. Beijing, **China**

12/06/2017: 12th SPHERIC Workshop, Universidade de Vigo, **Ourense**

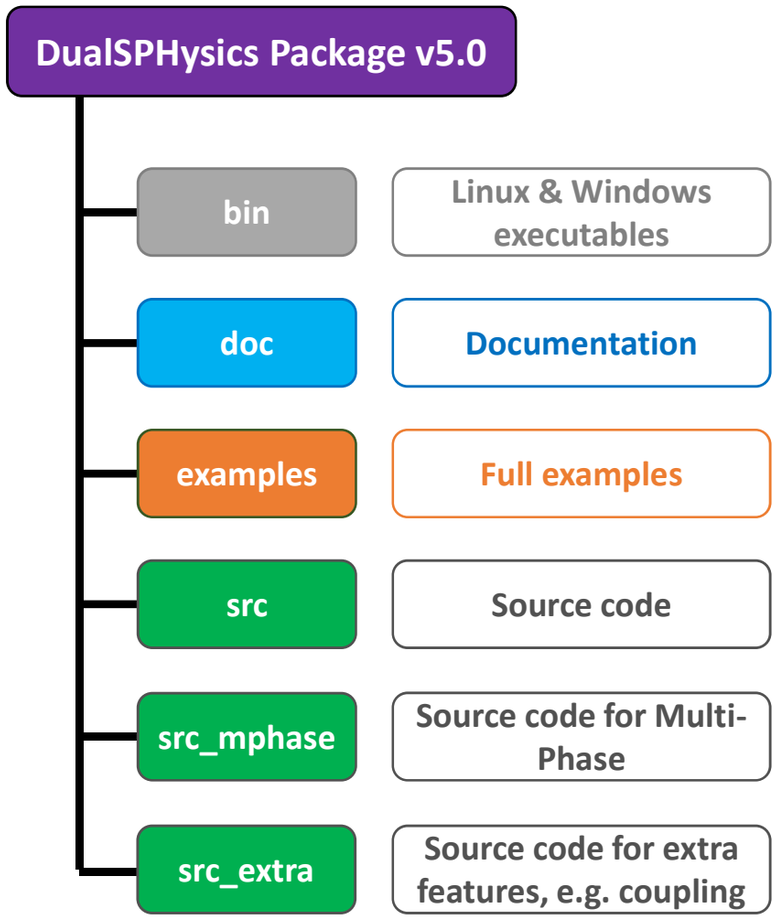
15/06/2015: 10th SPHERIC Workshop, Parma University, Parma, **Italy**

07/02/2014: SPH Workshop held at Flanders Hydraulics Research, Antwerp, **Belgium**

02/06/2014: 9th SPHERIC Workshop, Conservatoire National des Arts et Métiers in Paris, **France**

03/06/2013: 8th SPHERIC Workshop, SINTEF, Trondheim, **Norway**

DualSPHysics project - Download



Linux & Windows executables:

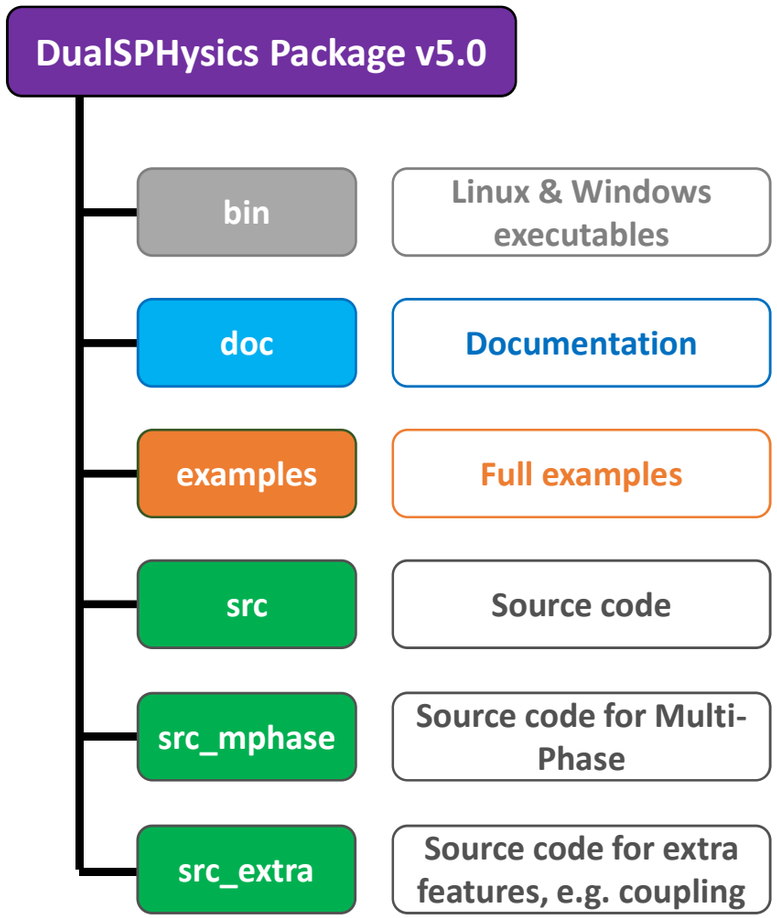
Pre-processing:
- GenCase

SPH solver:
- DualSPHysics5.0
- DualSPHysics4.0_LiquidGas
- DualSPHysics5.0_NonNewtonian

Post-processing (visualization):
- PartVTK4
- PartVTKOut4
- IsoSurface4

Post-processing (calculations):
- BoundaryVTK4
- ComputeForces4
- FloatingInfo4
- FlowTool4
- MeasureTool4

DualSPHysics project - Download



Documentation (guides and other help files) :

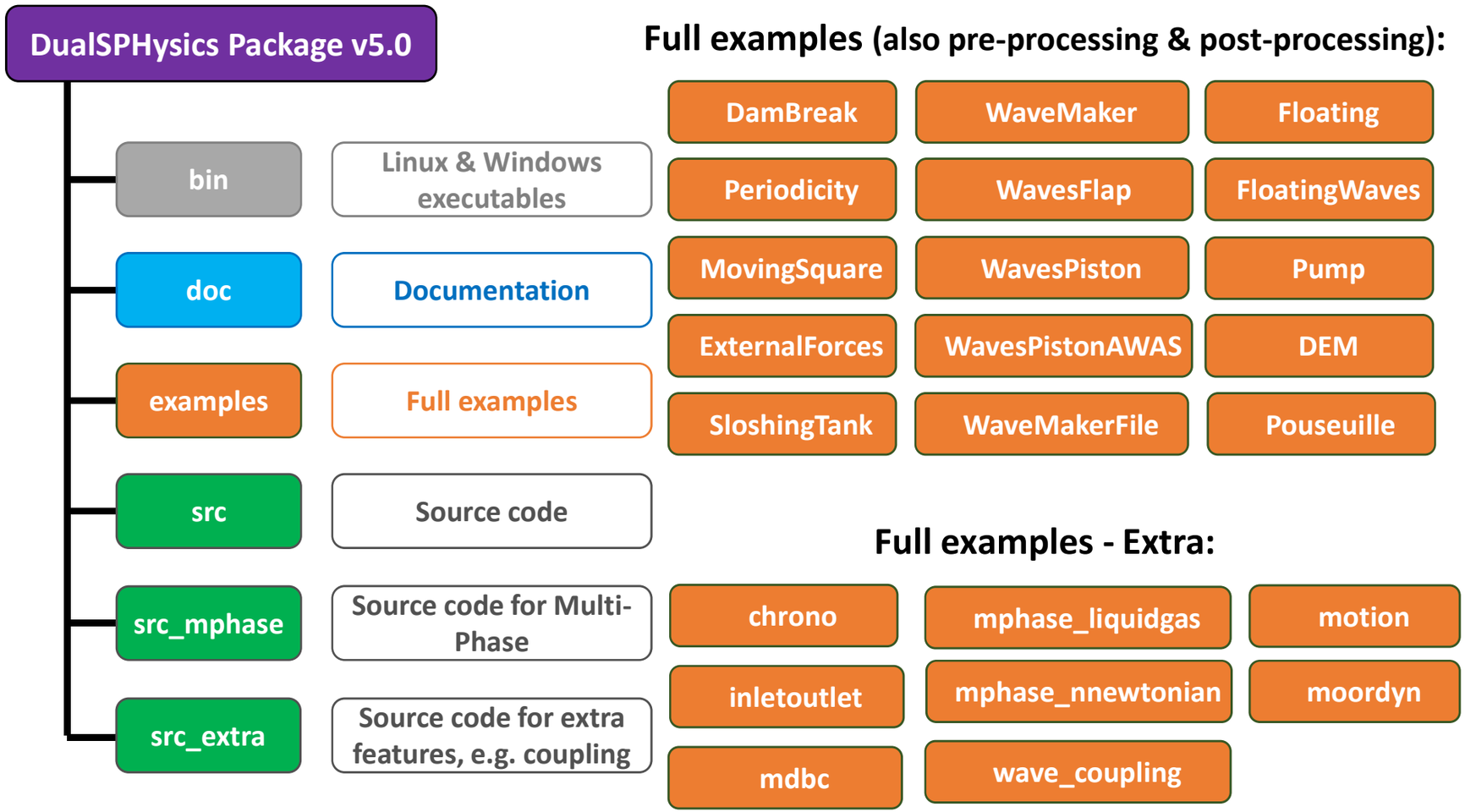
Pre-processing:
- XML_v5.0_GUIDE.pdf
- XML_GUIDE_CHRONO.pdf
- XML_GUIDE_INLETOUTLET.pdf
- XML_GUIDE_MDBC.pdf
- XML_GUIDE_MOORDYN.pdf
- XML_GUIDE_MPHASE_NNEWTONIAN.pdf
- ExternalModelsConversion.pdf

SPH solver:
- DualSPHysics_v5.0_GUIDE.pdf
- DualSPHysics_v4.0_LiquidGas_GUIDE.pdf

Post-processing:
- PostprocessingCalculations_v5.0.pdf

Help of executables
XML Templates for configuration

DualSPHysics project - Download



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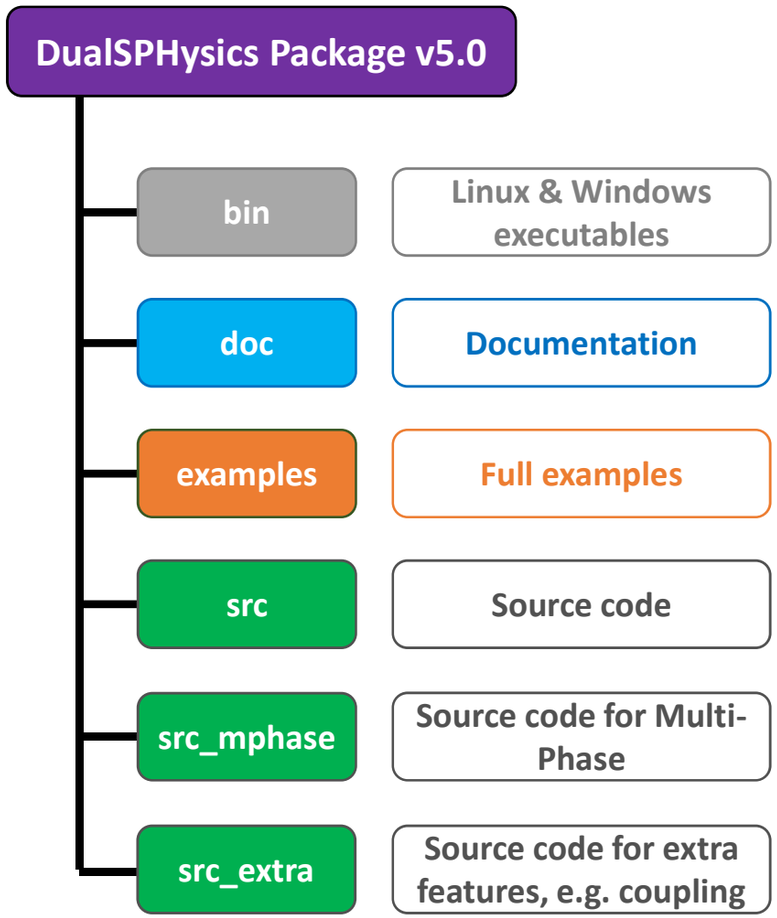


Source code ready to compile:

Codes:
- DualSPHysics v5.0
- DualSPHysics v4.0 LiquidGas
- ToVTK (data usage example)

Precompiled libraries:
- Linux (gcc4 & gcc5)
- Windows (Visual Studio 2015)

Compiling:
- Makefiles for Linux
- Project for Visual Studio 2015
- CMake file

DualSPHysics Novelties of 5.0

Pre-processing tools:
- New mode to create particles at free positions
- Definition of XML variables generating of complex cases
- Computation of normal vectors for boundary particles
- Option to create several layers of boundary particles

Fluid-driven objects:
- Problems dealing with objects with density very different from water are solved
- Floating objects can be combined with imposed linear and angular velocity

New SPH formulations:
- Density Diffusion Term (DDT) [Fourtakas et al. 2019]
- Modified Dynamic Boundary Conditions (mDBC) [English et al. 2019]

New coupling with MoorDyn++ library
- Mooring lines can be simulated modelling axial elasticity and bottom friction
- Several mooring lines can be connected to a floating device and a mooring line can be connected to different floating devices
- Numerical tensions are solved at fairleads and anchor points
- Maximum breaking tension can be also defined by the user

Improvements in performance
- Both CPU and GPU implementations use now double precision for arrays of position and for updating magnitudes
- GPU executions are more efficient using relative position of the particles instead of absolute position
- Greater robustness, usability and efficiency of the inlet/outlet implementation

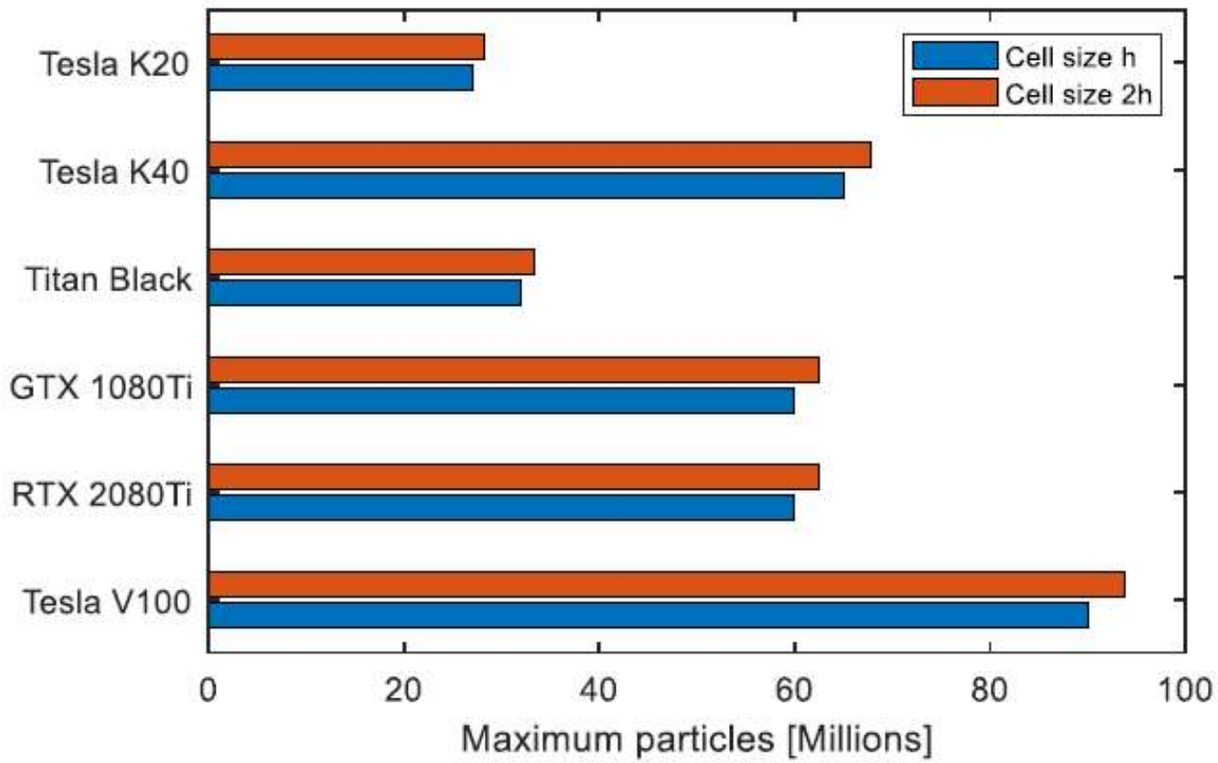
New functionalities in coupling with Project Chrono
- Collisions can be solved using non-smooth contacts or smooth contacts
- Multicore implementation is now available for collisions
- Springs can be simulated as linear dampers or Coulomb friction
- New constraints such as “pulleys” are now possible

New rheology models, non-Newtonian formulations and multiphase flows
- Velocity gradients calculated by (FDM) or an SPH gradient
- Explicit calculation of shear rates and apparent
- Viscous forces modelled by the [Morris et al. 1997] operator or the SPH deviatoric stress tensor
- Combination of Newtonian and non-Newtonian fluids (Newtonian, dilatant and pseudo-plastic)
- Power law, Bingham and any other non-linear fluid
- Platform for implementation of any non-Newtonian formulation
- Up to 9 different phases per simulation

DualSPHysics Performance

Maximum number of particles:

GPU memories have increased significantly over recent years:



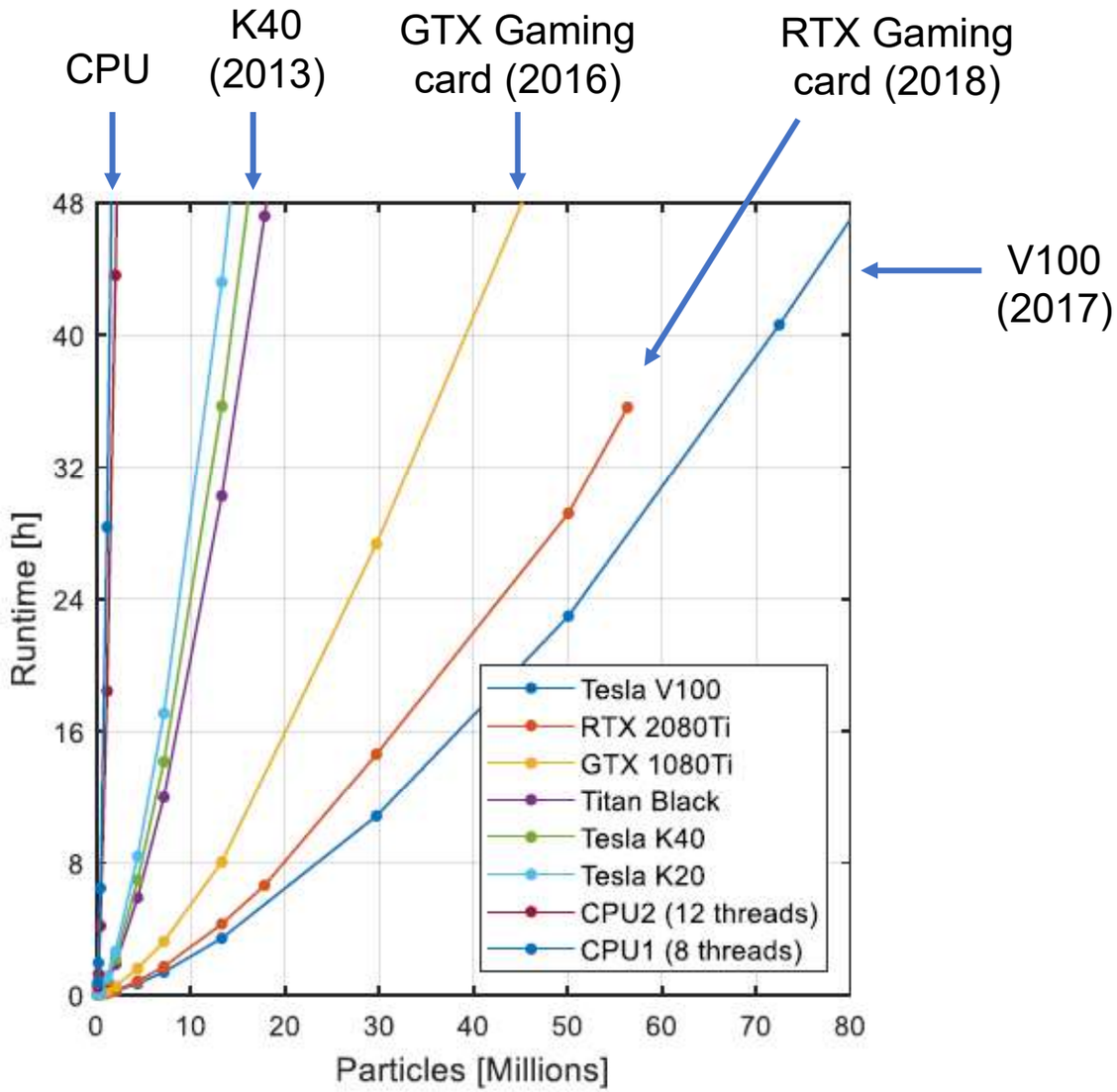
Dominguez et al. (2021)

Maximum number of particles according to the memory size of each GPU model.

DualSPHysics Performance

Simulation speeds:

The code and gpus are getting faster



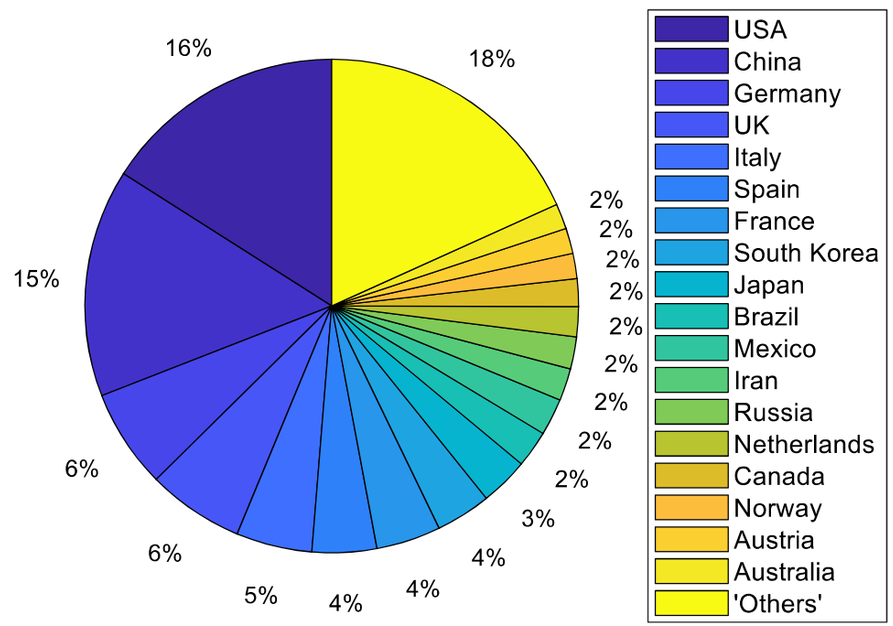
Dominguez et al. (2021)

DualSPHysics v5.0 Downloads

Download data of:

Approximately:
75% windows, 25% linux

v1.0	2011	701
v2.0	2012	6472
v3.0	2013	7953
v4.0	2016	10017
v4.2	2018	7100
v4.4	2019	19607
v5	2020	25817
		77667



DualSPHysics v5.0 new capabilities

Highlighted new capabilities:

New density diffusion term

New pre-processing tool & Boundary Conditions

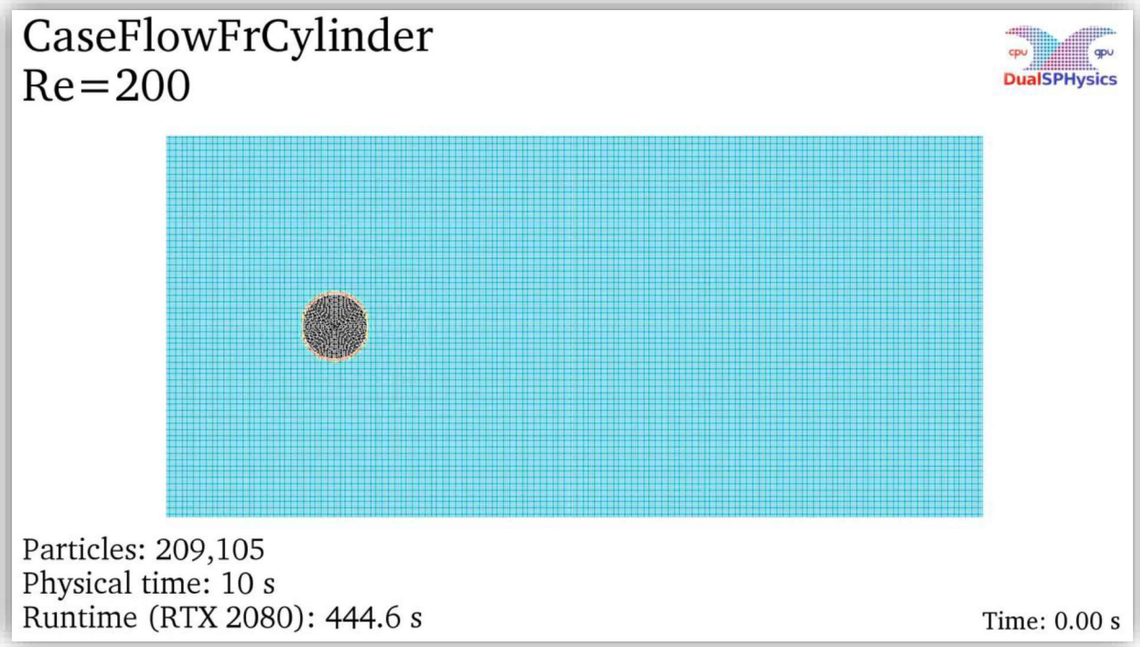
New rheology models, non-Newtonian formulations
and multi-phase flows

Open boundaries: inlet & outlet conditions

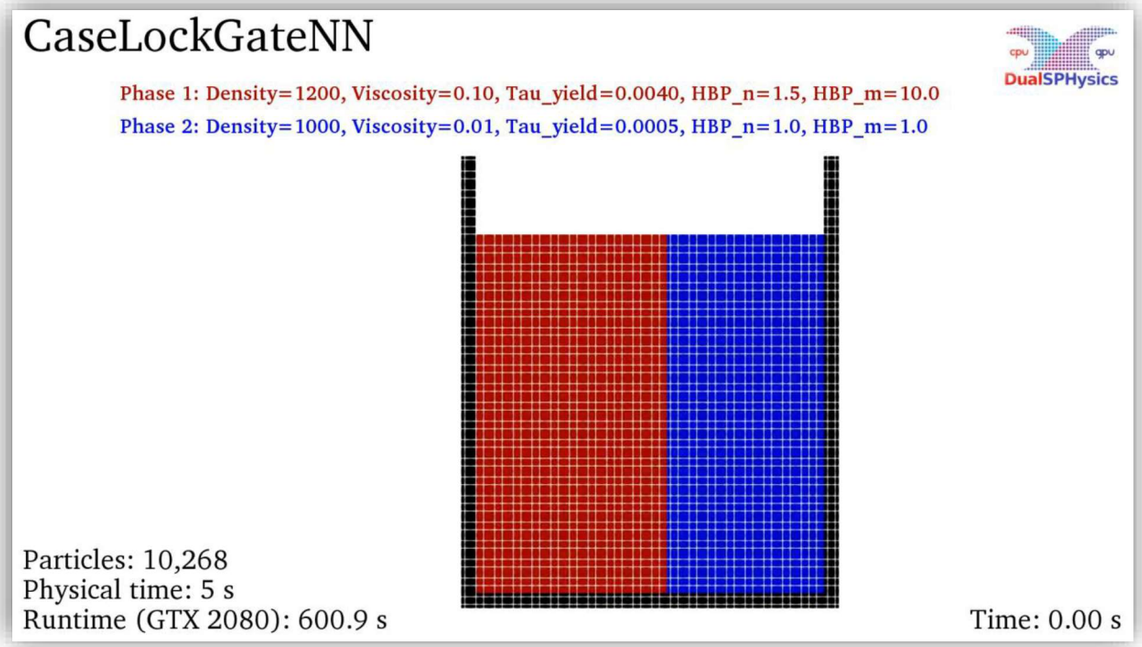
Coupling with MoorDyn library & Project Chrono

DualSPHysics v5.0 new capabilities

mDBC with Open boundaries:
inlet & outlet conditions



New rheology models, non-Newtonian
formulations and multi-phase flows



DualSPHysics v5.0 New Features to be presented here

Presentations:

New density diffusion term	Dr Renato Vacondio
New pre-processing tool & Boundary Conditions	Dr José Domínguez
New rheology models, non-Newtonian formulations and multi-phase flows	Dr Georgios Fourtakas
Open boundaries: inlet & outlet conditions	Dr Angelo Tafuni
Coupling with MoorDyn library & Project Chrono	Dr Alex Crespo