10th International SPHERIC Workshop

By Renato VACONDO, head of the Local Organising Committee

The University of Parma (Italy) was delighted to host the 10th international workshop organized by SPHERIC. The workshop once again proved to be a very popular event with a record 84 abstracts submitted from which 57 were chosen to be presented during the event.

120 delegates attended this tenth consecutive workshop held from June 16th to June 18th 2015, preceded by a training day attended by 36 participants. After an introduction to the SPH method by Prof. Stefano Sibilla (University of Pavia, Italy) taking both beginners and experienced practitioners through the basics of SPH, Prof. Antonio Souto-Iglesias (Technical University of Madrid, Spain) gave a stimulating lecture on the comparison between SPH and MPS meshless methods. In the afternoon participants have been introduced to the open-source code DualSPHysics, under the guidance of A.J.C. Crespo, J.M. Domínguez (University of Vigo, Spain), B.D. Rogers and G. Fourtakas (University of Manchester, UK).

Over the next three days, the 15 workshop sessions (see below) gave an excellent overview of the varied SPH activity occurring around the world. To assess the progress of the SPH method over the years the same two keynote speakers of the first edition of the workshop (2005) were invited. Prof. J.J. Monaghan (Monash University, Australia) presented the “Evolution of SPH” whereas Prof. R.A. Dalrymple (Johns Hopkins University, USA) demonstrated how the method is being successfully applied to simulate breaking water waves.

The banquet took place at the “Fondazione Magnani Rocca” where a presentation was made by new Chair of SPHERIC Benedict D. Rogers (The University of Manchester, UK) to thank David Le Touzé (ECN, France) for his outstanding work as Chair of SPHERIC during the last five years. During the Banquet the Joe Monaghan Prize was awarded to Dr. Andrea Colagrossi for the paper “Colagrossi, A., Antuono, M., Le Touzé, D. (2009) Theoretical considerations on the free-surface role in the smoothed-particle-hydrodynamics model, Physical Review E 79:056701” which makes outstanding advances in SPHERIC Grand Challenges of convergence and boundary conditions.

During the closing ceremony, the Libersky student prize was awarded to Samuel Braun from KIT, Karlsruhe, Germany. Dr. X. Hu announced that the 11th SPHERIC workshop will be organized by the Technische Universität München (TUM) in Munich from 13th to the 16th of June 2016.

The workshop organisers also wish to thank our generous sponsors: Nvidia, the Municipality of Parma and Unione Parmense degli industriali.

Contact: renato.vacondio@nemo.unipr.it
DAY 1: Tuesday 16 June 2015

Keynote lecture: J.J. Monaghan, Monash Univ., Australia

Session 1: Multiphase Flow 1
Chair: A. Colagrossi
- SPH model for stochastic Navier-Stokes and advection-diffusion equations, J. Kordilla, A.M. Tartakovskiy, W. Pan
- Simulation of dispersion in a porous media with multiphase Smoothed Particle Hydrodynamics, C.E. Alvarado-Rodríguez, A. Barreiro, J.M. Domínguez, A.J.C. Crespo, M. Gómez-Gesteira, J. Klapp
- 3D SPH simulation of bubble rising and coalescing in viscous fluids, P. Sun, A. Zhang, F. Ming
- A 3D SPH integrated model for granular flows with transport of solid bodies: model couplings and enhanced boundary treatment based on surface wall elements, A. Amicarelli, G. Agate

Session 2: Convergence
Chair: D. Violeau
- Influence of particle disorder and smoothing length on SPH operator accuracy, G. Chaussonnet, S. Braun, L. Wieth, R. Koch, H.-J. Bauer
- CRKSHP – A conservative reproducing kernel smoothed particle hydrodynamics scheme, C. Raskin, N. Frontiere, J. M. Owen
- High-order and adaptive procedures for SPH-ALE simulations based on Moving Least Squares method, G.-A. Renaut, J.-C. Marongiu, S. Aubert

Session 3: Multiphase flow 2
Chair: S. Sibilla
- Validation of robust SPH schemes for fully compressible multiphase flows, I. Zisis, R. Messahel, B. van der Linden, M. Souli, B. Koren
- Two phase mixtures in SPH – A new approach, D.J. Price, G. Laibe

Session 4: Alternative approaches
Chair: N. Quinlan
- Finite Volume Particle Method for fluid-structure interaction, E. Jahanbakhsh, C. Vessaz, A. Maertens, F. Avellan
- The Discrete Vortex Hydrodynamics method: similarities and differences with SPH, A. Colagrossi, E. Rossi, S. Marrone
- Free surface application of the PFEM (particles + finite elements) methodology to submerged cylinders, J.M. Gimenez, L.M. González, E. Ferrer
- Solution of stationary Stokes and Navier-Stokes problems using a Least Square Residual Method with a Modified Finite Particle Method, A. Montanino, D. Asprone, A. Reali, F. Auricchio

Session 5: Incompressibility
Chair: X. Hu
- ISPH simulation of the motion of elliptic particles under external electric field, N. Tofghi, M. Ozbulut, J.J. Feng, M. Yildiz
- Investigations into high-order incompressible SPH, S.J. Lind, P.K. Stansby
- On enhancement of energy conservation properties of ISPH and MPS methods, A. Khayyer, H. Gotoh, Y. Shimizu, K. Gotoh

Discussion Panel 1: Enforcing incompressibility in SPH
Chair: A. Souto-Iglesias
Day 2: Wednesday 17 June 2015

Session 6: Adaptivity 1
Chair: J.-C. Marongiu
- A novel multi-scale technique for projection-based particle methods, H. Gotoh, N. Tsuruta, A. Khayyer
- An approach to error-estimation-based adaptivity in Smoothed Particle Hydrodynamics, F. Spreng, P. Eberhard
- Particle refinement applied to SPH method: stability, accuracy and CPU analysis, L. Chiron, G. Oger, M. De Leffe, D. Le Touzé
- DualSPHysics with adaptivity: towards the simulation of real engineering problems with variable resolution, R. Vacondio, A.J.C. Crespo, J.M. Domínguez, B.D. Rogers, M. Gómez-Gesteira

Session 7: Stability
Chair: J.J. Monaghan
- Choosing the time step in ISPH, D. Violeau, A. Leroy
- Stable smoothed particle magnetohydrodynamics in very steep density gradients, B.T. Lewis, M.R. Bate, J.J. Monaghan, D.J. Price
- How the fragmentation pattern of an expanding steel ring depends on statistical variation, resolution, initial particle distribution, and particle regularization, S. Børve, J.F. Moxnes
- A consistent continuous particle reordering in weakly-compressible SPH through an ALE formalism, G. Oger, S. Marrone, D. Le Touzé

Session 8: Water waves
Chair: P.K. Stansby
- Simulating the impact of extreme sea waves on offshore structures with SPH, R.H.A. Ijzermans, K. Pan, K.A. Kochanski, B.D. Jones, A. Thyagarajan, V. Ramohalli Gopala, B.W.H. van Beest, J.R. Williams, J.M.V.A. Koelman
- Optimisation of a coastal defence geometry using SPH, J. Hall, T.C.S. Rendall, C.B. Allen

Session 9: Free-surface flow
Chair: D. Le Touzé
- Simulating oil flow for gearbox lubrication using SPH, M.Z. Mettichi, Y. Gargouri, P.H.L. Groenenboom, F. el Khaled
- A generalised transport-velocity formulation for smoothed particles hydrodynamics, C. Zhang, X.Y. Hu, N.A. Adams

Session 10: Adaptivity 2
Chair: B.D. Rogers
- Error minimizing SPH particle merging for constructing multi-resolution hierarchies, J. Fischer, L. Linsen, P. Rosenthal
- Reducing the particle refinement error of the density summation and the kernel gradient, C. Bergmeister, M. Meister, D. Winkler, W. Rauch
- Application of an adaptive Smoothed Particle Hydrodynamics formulation to hydrodynamic problems driven by surface tension, D. Schnabel, A. Mueller, P. Eberhard
- Skewed kernel function approach for the simulation of shock fronts using SPH, S.S. Prasanna Kumar, B.S.V. Patnaik

Discussion Panel 2: Is adaptivity useful?
Chair: B.D. Rogers

Steering Committee meeting
Workshop Banquet
DAY 3: Thursday 18 June 2015

Session 11: High Performance Computing

**Chair:** R. A. Dalrymple

- **SHIXDOF 2 QUAgpussph: nonlinear coupled ship motions and sloshing in free surface tanks**, J.L. Cercos-Pita, G. Bulian, A. Souto-Iglesias
- **Exploring an efficient parallel implementation model for 3-D Incompressible Smoothed Particle Hydrodynamics**, X. Guo, B.D. Rogers, S. Lind, P.K. Stansby, M. Ashworth

Session 12: Boundary conditions 1

**Chair:** A. Souto-Iglesias

- **A framework for permeable boundary conditions in SPH: Inlet, Outlet, Periodicity**, S. Braun, L. Wieth, R. Koch, H.-J. Bauer
- **Open boundary conditions for ISPH with the unified semi-analytical boundary conditions**, A. Leroy, D. Violeau, M. Ferrand, L. Fratter, A. Joly
- **Inflow/ outflow with Dirichlet boundary conditions for pressure in ISPH**, P. Kunz, M. Hirschler, M. Huber, U. Nieken
- **Application of the unified semi-analytical wall boundary conditions to multi-phase SPH**, A. Ghaïtanellis, D. Violeau, A. Joly, M. Ferrand, A. Leroy

Session 13: Coupling different methods

**Chair:** A.J.C. Crespo

- **Energy considerations in SPH/FEM coupling**, C. Hermange, D. Le Touzé, G. Oger
- **A partitioned approach for the coupling of SPH-ALE and FE methods for transient FSI problems with incompatible time-steps**, J. Nunez Ramirez, J.-C. Marongiu, Z. Li, A. Comniscure
- **An hybrid Finite Volume – SPH method for incompressible flows**, C. Gianguzzi, A. Monteleone, E. Napoli

Session 14: Boundary conditions 2

**Chair:** A. Khayyer

- **Multi-node fixed ghost particles for SPH simulations**, D.D. Meringolo, F. Aristodemo, P.H.L. Groenenboom, P. Veltri
- **A new higher-order consistent wall boundary formulation for SPH**, M. Schörgenhuber
- **Semi-analytical wall boundary conditions for locally flat geometries**, A. Mayrhofer, G. Bilotta, A. Hérault

Session 15: New applications of SPH

**Chair:** P. Groenenboom

- **SPH simulation of co-rotating twin-screw extruders**, I. Kondor, A. Eitzlmayr, J. Matić, G. Koscher, J. Khinast
- **Comparative SPH and MD modeling of shock-produced ejecta from grooved metal surface**, M.S. Egorova, S.A. Dyachkov, V.V. Zhakhovsky, A.N. Parshikov
- **A novel SPH reconstructed Immersed Boundary Method for partially immersed rigid boundaries and flexible membrane boundaries in 2-D**, A.M. Nasar, B.D. Rogers, A. Revell, P.K. Stansby
- **An alternative SPH formulation to model chemotaxis**, D. Avesani, M. Dunbser, A. Bellin

Closing and awards
A Framework for Permeable Boundary Conditions in SPH:
Inlet, Outlet, Periodicity

S. Braun, L. Wiedh, R. Koch, H.-J. Bauer, Institut für Thermische Strömungs maschinen, Kaiserstraße 12, 76131 Karlsruhe, Germany

This work received the award for best student paper (Libersky Prize) at the 10th Int. SPHERIC Workshop, Parma (Italy), June 2015.

For SPH simulations of fuel atomization in aircraft engines, permeable boundary conditions (BCs) are required. We present a method for implementing inlet, outlet and periodic BCs for subcritical, weakly compressible flows. The present approach requires only basic SPH interpolations and, therefore, has a negligible computational footprint.

![Figure 1 – Buffer (grey) and regular (white) particles separated by markers (squares).](image)

Like other approaches for implementing inflow and outflow BCs in SPH (Lastiwka et al., 2009; Vacondio et al., 2010), a buffer zone is introduced, which serves to avoid kernel truncation at the boundary faces. The thickness of the buffer zone corresponds to the radius of influence of the kernel (Figure 1). The major innovation of our method is to introduce so called marker particles, by which the permeable boundary faces are defined. They also serve as probing points. Consequently, the boundary faces do not have to be described analytically or based on thresholds, but are defined during the pre-processing of the computational domain. By copying a certain physical value of the markers to associated buffer particles, a Dirichlet BC is achieved. A Neumann BC is generated by probing via a Shepard corrected kernel interpolation and applying this value to the corresponding buffer particles. Periodic boundary conditions are constructed by generating copies of particles in the vicinity of periodic markers and by modifying their positions corresponding to the representative translation vector. Translational and rotational periodicity can be taken into account.

In order to avoid instabilities and to keep the computational domain filled with particles, the physical quantities at the marker positions must be slightly modified. Small scale oscillations at the inlet are suppressed by adjusting the inter-particle spacing inside the buffer zone. Large scale instabilities, which may cause resonance effects, are damped by adapting the prescribed pressures or velocities at the boundaries.

Due to its simplicity, the proposed approach does not alter the computational performance of our parallel MPI-based SPH code. The computational time spent in functions related to permeable BCs is in the order of 0.25%. The parallel performance is not affected either. In Figure 2 the scalability results of a 2D and a 3D simulation (2.6M/200M particles) incorporating inlet and outlet BCs are depicted.

![Figure 2 – Speedup over number of cores for 2D and 3D test case with inlet/outlet BCs.](image)

An example of a typical simulation which requires inlet and outlet BCs is a prefilming airblast atomizer. It is shown in Figure 3. The domain consists of a prefilmer lip (wall), inlets at the left, an outlet at the right, lateral periodic BCs and confining walls on top and on bottom. The liquid film (black spheres) is driven to the prefilmer trailing edge, where it accumulates, flaps and finally disintegrates into droplets. For simulations with 150M particles, 3 ms physical time can be computed in roughly 3 weeks on 1000 CPUs.

![Figure 3 – 3D simulation of breakup event; the computational domain incorporates inlet, outlet and periodic (lateral) BCs.](image)

Contact: samuel.braun@gmx.de

References


An Approach to Error-Estimation-Based Adaptivity in SPH

F. Spreng & P. Eberhard, Institute of Engineering and Computational Mechanics, University of Stuttgart, Pfaffenwaldring 9, 70569 Stuttgart, Germany

This work received the 2nd prize in the competition for the best student paper at the 10th Int. SPHERIC Workshop, Parma (Italy), June 2015.

As the SPH method gains more and more attention in the field of engineering, also the problems investigated with it become more and more complex and, hence, numerically demanding. Here, variable resolution techniques, e.g. (Vacettido et al., 2013) or (Spreng et al., 2014), are revealed to be powerful tools. They allow for a dynamic adaptation of the spatial discretization of certain parts of a continuum at runtime and, thereby, help to increase the overall computational efficiency. However, in the case of real technical applications, for which a priori knowledge of the system behavior is usually not available, the choice of adequate adaptivity criteria is a crucial and difficult task, which is in many cases not easily completed by the user. To address this issue, two discretization-error-based decision criteria telling even in such cases where and when to adapt the spatial resolution of an SPH domain have been developed and are now presented in this paper. Therefore, this contribution can be considered as a first step towards error-estimation-based adaptivity in SPH.

The first proposed criterion estimates the discretization error by Taylor series expansion over the approximation error in the flow velocity divergence (Fatemi and Manzari, 2011). The second one, a more heuristic approach, which is numerically less expensive than the previous criterion, indicates the discretization error by an evaluation of the variance in the flow velocity existing over a particle's kernel support. The local error resulting from one of the two introduced criteria is then assessed on a global scale, i.e. in relation to the error values of the other particles.

Because of their system- and scale-independent formulation, the presented criteria are applicable to a broad range of different setups including both liquids and solids while the amount of necessary user interaction is reduced to a minimum at the same time. For instance, the two-dimensional simulation of a notched tensile test allows for a thorough discussion of the benefits gained from the suggested error-based criteria in the context of real-world problems, and also for a comparison on their efficiencies. When employing a stress-based refinement criterion, the spatial resolution of the notched tensile specimen shows a time-dependent evolution, although the stress distribution itself does not. Contrary to this time-dependent character of the stress-level-based adaptivity process, the refinement areas of the two error-based criteria are independent of the chosen strain rate and, accordingly, of the absolute level of local, i.e. particle specific, error. Despite the fact that the areas of higher spatial resolution shown in Figure 1 differ in shape and size, both proposed strategies give a better approximation of the stress distribution of the real specimen than what can be obtained with a statically coarse discretized setup. Besides, the two error-based simulations take significantly less time until completion in comparison to a statically fine as well as the dynamically discretized model employing a stress-based criterion while still being able to resolve the high gradients in stress observed near the roots of the two notches, see Figure 2.

Figure 1 – Spatial discretization of the notched tensile specimen (red: refined particle; blue: original particle).

Figure 2 – Longitudinal stress over normalized ligament position for the notched tensile specimen.

Contact: peter.eberhard@itm.uni-stuttgart.de

References


Inflow/ outflow with Dirichlet boundary conditions for pressure in ISPH

P. Kunz, M. Hirschl, M. Huber & U. Nieken, Institute of Chemical Process Engineering, University of Stuttgart, Böblingen Str. 78, D-70176 Stuttgart

This work received the 3rd prize in the competition for the best student paper at the 10th Int. SPHERIC Workshop, Parma (Italy), June 2015.

In the present work we propose a new algorithm for open boundary treatment in ISPH. Our aim is the simulation of multi-phase flow of immiscible fluids through solid structures like a gas injection nozzle in a bubble column reactor or transport of fluids through porous media (Figure 1).

Figure 1 – Pressure field during a drainage process in porous media.

A robust treatment of open boundaries is also crucial when simulating flows where the fluids are replaced several times during one simulation. Therefore we introduce an implementation of true Dirichlet boundary conditions of the projected pressure field in order to induce flow which is driven by a pressure gradient.

A rotational pressure-correction scheme to deal with pressure boundary conditions has been introduced by Hosseini and Feng (2011) in ISPH, but they still used a Neumann boundary condition for the pressure field. In contrast to that approach we use the classical projection scheme of Cummins and Rudman (1999). In contrast to WCSPH, pressure and density are treated separately in ISPH. Therefore we can handle a limited particle deficit at the inflow/outflow region with the corrected SPH formulation of Bonet & Lok (1999).

In this work we define Dirichlet boundary conditions of the projected pressure field at the inlet and outlet using the same technique of mirrored particles that Cummins and Rudman (1999) used for the Neumann boundary condition. In order to define the Dirichlet boundary condition for pressure exactly on the open boundary we mirror the particles across the open boundary and use a linear projection to define the pressure across the open boundary. For a mirrored particle \( j' \) this strategy leads to a pressure of:

\[
p_j' = p_a + (p_v - p_f) = 2p_v - p_f
\]

where \( p_a \) is the desired pressure at the inlet or outlet. Only real particles in the domain have an entry in the linear equation system to solve the pressure Poisson equation. The influence of the mirrored particle \( j' \) is added to the off-diagonal entry of particle \( j \). Hence the pressure matrix and the right hand side in addition of the influence of the mirrored particles get the form:

\[
\frac{2}{V_i} \sum_j \left( \frac{1}{r_{ij}} \left( \frac{V_j^2 + V_{j'}^2}{2} (p_j - p_f) \right) \frac{\partial \tilde{W}_{ij}}{\partial r_{ij}} + \frac{2}{V_i} \sum_{j'} \left( \frac{1}{r_{ij'}} \left( \frac{V_j^2 + V_{j'}^2}{2} (p_j - (2p_v - p_f)) \right) \frac{\partial \tilde{W}_{ij'}}{\partial r_{ij'}} \right) \right)
\]

The new approach shows accurate results for the pressure and velocity field compared with analytical solutions of a Poiseuille flow and reference calculations of a flow around a cylinder at \( Re = 10.34 \) using FVM (OpenFOAM, see Figure 2).

Figure 2 – The upper plot shows the comparison of the velocity field at \( Re = 10.34 \) between a SPH (top) and FVM (bottom) simulation. In the lower plot the pressure fields are compared in the same way.

Contact: philip.kunz@icvt.uni-stuttgart.de

References


The 2015 Joe Monaghan Prize

N. Quinlan, National University of Ireland Galway

The Joe Monaghan Prize was created to recognise SPH researchers who have made outstanding advances in recent years on one or more of the SPHERIC Grand Challenges (convergence, numerical stability, boundary conditions, and adaptivity). The prize is named in honour of the unique contributions made by Prof. Joe Monaghan in the foundation of SPH, and in its continuous development since 1977. For the inaugural Prize in 2015, peer-reviewed journal articles published from 2008 to 2012 were considered eligible. Nominations were sought from SPHERIC members in the second half of 2014. The following eligible articles were shortlisted:


A secret ballot of attendees at the 10th SPHERIC workshop in Parma has held to determine the winner. The Prize was presented by Prof. Monaghan himself for the rigorous theoretical work of Andrea Colagrossi, Matteo Antuono and David Le Touzé on the treatment of free-surface boundaries in SPH. Dr. Andrea Colagrossi of CNR-INSEAN, the Italian Ship Model Basin, accepted the award on behalf of the team. In the worlds of the researchers who nominated this article for the Prize, ‘generally, free-surface boundary conditions are said to be ‘intrinsically’ satisfied in SPH, but previously, there were no rigorous justifications for this statement. This article explains why the anti-symmetrized divergence is consistent when approaching the free surface, and unveils very important issues of pairs of divergence and gradient formulations regarding their consistency and conservation properties in modelling free surface boundary conditions.”

Figure 1 – Prof. Joe Monaghan (left) and Dr. Andrea Colagrossi.

The shortlist contains articles that are already familiar to SPHERIC members, and casts light on some excellent and important work that has not been so well known in our community. On the occasion of the 10th SPHERIC workshop, the presentation of the inaugural Joe Monaghan Prize is a fitting reminder of extraordinary achievements.

Contact: nathan.quinlan@nuigalway.ie