Articles nominated for the 3rd Joe Monaghan Prize

The 16th SPHERIC Workshop in Catania will be an exciting event for exchanging experiences and new findings within the SPH community but it will also determine the winner of 3rd Joe Monaghan Prize. A shortlist of candidate papers is ready and a secret ballot by the workshop attendees will assign the prize. The authors of the winning publication will give an invited lecture at the following SPHERIC Workshop.
After the call for nominations, which closed on the last 30th November, six articles were selected for the third edition of the "Joe Monaghan Prize". A specific commission of the SPHERIC Steering Committee checked the eligibility of each nominee. Only peer-reviewed journal articles published in the years 2013-2018 have been considered for this 2022 edition of the prize.
The selected articles are listed in the table below in alphabetical order and motivations given by each nominating institute (whose identity was kept anonymous) are provided.

#	Author	Title	Journal	Year	Grand Challenge
1	Canelas R.B., Brito M., Feal O.G., Domínguez J.M., Crespo A.J.C.	Extending DualSPHysics with a Differential Variational Inequality: modeling fluid-mechanism interaction	Applied Ocean Research	2018	4-5
2	Ferrand, M., Laurence, D. R., Rogers, B. D., Violeau, D., & Kassiotis, C.	Unified semi-analytical wall boundary conditions for inviscid, laminar or turbulent flows in the meshless SPH method	International Journal for Numerical Methods in Fluids	2013	2
3	Franz, T., Wendland, H.	Convergence of the Smoothed Particle Hydrodynamics Method for a Specific Barotropic Fluid Flow: Constructive Kernel Theory.	SIAM Journal of Mathematical Analysis	2018	1
4	Skillen A., Lind S., Stansby Steven, Rogers Benedict D.	Incompressible smoothed particle hydrodynamics (SPH) with reduced temporal noise and generalised Fickian smoothing applied to body–water slam and	Computer Methods in Applied Mechanics and Engineering	2013	1
5	Vacondio, R., Rogers, B. D., Stansby, P. K., Mignosa, P., & Feldman, J.	Variable resolution for SPH: a dynamic particle coalescing and splitting scheme	Computer Methods in Applied Mechanics and Engineering	2013	3
6	Violeau D., Leroy A.	On the maximum time step in weakly compressible SPH	Journal of Computational Physics	2014	1

PAPER #1

TITLE: Extending DualSPHysics with a Differential Variational Inequality: modeling fluid-mechanism interaction

AUTHORS: Canelas R.B., Brito M., Feal O.G., Domínguez J.M., Crespo A.J.C.

BIBLIOGRAPHIC DETAILS: Applied Ocean Research, Volume 76, July 2018, Pages 88-97, (2018).

GRAND CHALLENGE(S) ADDRESSED:

GC#4: Coupling to other models
GC#5: Applicability to industry

MOTIVATION:

This paper has completely revolutionised what most users and engineers can realistically simulate with SPH hitting both SPHERIC Grand Challenges GC#4 and GC#5 as a general-purpose simulation framework for multi-body problems with support for very large systems. As far as we are aware Canelas et al. (2018) were the first to achieve this for an open-source code. The paper hits multiple targets of (i) coupling two very different methods together (SPH + FEM) by introducing the Project Chrono library, (ii) coupling without introducing numerical instability, (iii) massively extending the applicability of the SPH method to applications that involve complex fluid-structure interaction.

Extending the applicability of the SPH method is absolutely crucial to making SPH acceptable for widespread use. Very few works have made much progress in pushing the applicability of SPH at the same time as extending the accessibility as part of an open-source SPH code free for all to use. This article stands out as being unique and ambitious. The article focuses on developing a rigorous theoretical framework and includes frictional constraints, non-smooth multi-body dynamics based on the differential variational inequality.

The paper demonstrates the typically high-standard of academic rigor with validation tests with convergence tests for FSI including a platform washout by a dam break, a swinging pendulum in viscous fluids, before showing a range of demonstration cases including the WaveStar Wave Energy Converter (WEC) with multiple floats, tidal turbine and a human-like multi-element object being carried by a flood wave through a complex geometry. Thanks to the novel developments in this paper, users have been able to apply DualSPHysics to an extraordinary range of new applications as evidenced by the presentations at the Users Workshops and journal papers published.

I have seen very few publications on SPH where the academic rigour of the article is world class directly addresses multiple SPHERIC Grand Challenges. It is a worthy candidate for the JJM prize and directly addresses two of the SPHERIC Grand Challenges so crucial for our field.

PAPER #2

TITLE: Unified semi-analytical wall boundary conditions for inviscid, laminar or turbulent flows in the meshless SPH method.

AUTHORS: Ferrand, M., Laurence, D. R., Rogers, B. D., Violeau, D., & Kassiotis, C. .

BIBLIOGRAPHIC DETAILS: International Journal for Numerical Methods in Fluids, 71(4), 446-472 (2013).

GRAND CHALLENGE(S) ADDRESSED:

- GC#2: Boundary conditions

MOTIVATION:

In the SPH method, two families are used in the literature to deal with solid boundaries: (i) volume-based methods such as the moving-ghost-particle method, and (ii) surface-based methods such as the one developed in the present paper, which are necessary to deal with complex geometries. This paper addresses precisely the surface-based method, particularly by proposing a semi-analytical manner to compute the renormalization factor which is crucial to compute accurately the boundary integral of the SPH operators. It is important to note that the proposed development is derived for inviscid, laminar and turbulent flows. The validation is performed and compared to other solid boundary treatment methods, on challenging test cases involving both complex geometries and free-surface. The authors have shown that using their surface-based method allows for (i) increasing the accuracy of the results on a Poiseuille flow at *Re = 10* in comparison to other existing solid boundary treatments [GC#2], (ii) recovering the hydrostatic solution even with complex geometries, both in terms of pressure and velocity, and providing better results than the other methods tested, (iii) a more regular pressure field when complex geometries are involved, with respect to other solid boundary treatments available in the SPH literature [linked to GC#1], and (iv) obtaining results that are similar to the ones obtained with a Finite Volume solver for a turbulent flow. To summary, the results are extended and convincing.

Furthermore, from our point of view, this paper is very important for the SPH community since it constitutes a solid base for several papers refering to the same topic. For example, (i) the study has been extended to 2D-incompressible SPH in "*Unified semi-analytical wall boundary conditions applied to 2-D incompressible SPH, Leroy et al., JCP 2014*", (ii) the extension of the present paper for 3D applications is given in "*Unified semi-analytical wall boundary conditions in SPH: analytical extension to 3-D, Mayrhofer et al., Numerical algorithm, 2015",* (iii) it is related to other papers from other research teams such as "*Fast and accurate SPH modelling of 3D complex wall boundaries in viscous and non viscous flows, Chiron et al., JCP 2019*", allowing to investigate problems involving complex flows in presence of complex geometries, such as the hydroplaning phenomenon (*Chiron et al.,* JCP 2019), the helicopter ditching (Oger et al. Journal of Hydrodynamics, 2020), the landslide phenomenon (Ghaïtanellis et al., Journal of Hydraulic Research, 2021).

For these reasons, we think that this paper deserves to be nominated for the Monaghan Prize.

PAPER #3

TITLE: Convergence of the Smoothed Particle Hydrodynamics. Method for a Specific Barotropic Fluid Flow: Constructive Kernel Theory.

AUTHORS: Franz, T., Wendland, H.

BIBLIOGRAPHIC DETAILS: SIAM Journal of Mathematical Analysis, 50(5), 4752-4784 (2018).

GRAND CHALLENGE(S) ADDRESSED:

- GC#1: Convergence, consistency and stability

MOTIVATION:

There are many papers in the considered period which have contributed to the progress of the Smoothed Particle Hydrodynamics (SPH) method. Turbulence models or particle shifting techniques, among other topics, have been investigated leading to cited and influential papers, known by all the SPH community. However, we dare to nominate one paper which may not be so well known but is, in our opinion, as relevant as those in regards to the progress, prestige and rigor of the method. In particular, it implied significant increase of knowledge regarding the Grand Challenge: Convergence, consistency and stability. The paper chosen,

Franz, T., Wendland, H. (2018). Convergence of the Smoothed Particle Hydrodynamics Method for a Specific Barotropic Fluid Flow: Constructive Kernel Theory. SIAM Journal of Mathematical Analysis, 50(5), 4752-4784. https://doi.org/10.1137/17M1157696

is the product of the work of Dr. Tino Franz and Dr. Holger Wendland, members of the "Applied and Numerical Analysis" group at the University of Bayreuth. It addresses the important topic of the convergence of the SPH method. In particular, the Euler equations, using a barotropic equation of state to link pressure and density, are studied. The convergence of a semi-discrete SPH scheme is established provided that the kernel function satisfies several requirements. The scheme is semi-discrete in the sense that the time appears as a continuous variable. Finally, examples of kernels satisfying the aforementioned requirements are provided. Regarding its influence in the work of our research group, this paper has motivated posterior publications looking at the convergence of the method in different specific cases. In particular, the Hydrostatic problem at the continuous level was addressed in [1]. As a continuation of that research, the discrete version of the hydrostatic problem was treated in [2]. That work, presented in the SPHERIC HARBIN 2020, was awarded with the "Outstanding Student Paper Prize". Along that line, further research has been conducted by studying the Laplacian operator at the continuous level, leading to the obtention of a proof of convergence for the heat equation, presented in the 2021 SPHERIC congress. During the last months, those results have been extended to more complex cases involving the advection-diffusion equation with non constant velocity fields and will be published soon. We found in the nominated paper, as a relevant achievement in the establishment of the convergence of the SPH method, the motivation to develop these works. As a final remark, we think the paper is influential because it presents a complete proof of convergence of a semi-discrete SPH system. These studies are very rare in literature. While other works have addressed the topic of convergence in the context of particle methods, this is one of the few referring to SPH specifically. We believe this is a very relevant achievement for the SPH community and hope that awarding the Joe Monaghan Prize to this work will inspire other researchers to deepen into the topic of convergence.

References

[1] F. Macià, P. E. Merino-Alonso, and A. Souto-Iglesias, "On the truncated integral sph solution of the hydrostatic problem," Computational Particle Mechanics, 2020. [Online]. Available: https://doi.org/10.1007/s40571-020-00333-6

[2] P. E. Merino-Alonso, F. Macià, and A. Souto-Iglesias, "On the numerical solution to the truncated discrete sph formulation of the hydrostatic problem," Journal of Hydrodynamics, vol. 32, no. 4, pp. 699–709, 2020.

PAPER #4

TITLE: Incompressible smoothed particle hydrodynamics (SPH) with reduced temporal noise and generalised Fickian smoothing applied to body–water slam and efficient wave–body interaction

AUTHORS: Alex Skillen, Steven Lind, Peter K. Stansby, Benedict D. Rogers,

BIBLIOGRAPHIC DETAILS: Computer Methods in Applied Mechanics and Engineering, Volume 265, Pages 163-173, (2013).

GRAND CHALLENGE(S) ADDRESSED:

- GC#1: Convergence, consistency and stability

MOTIVATION:

The paper presents the application of ISPH models to a class of very challenging free-surface flows which are difficult to model with conventional Eulerian schemes. In particular, the paper demonstrate the importance of adopting a partice correction algorithm to improve the accuracy of SPH spatial interpolation.

This work has inspired many other authors which have introduced the particle shifting in several different variants of SPH including ALE-SPH, delta-SPH etc. In my opinion particle shifting represents one of the most significant improvements introduced in SPH schemes in the period 2013 - 2018 not just in the ISPH scheme, but in all variants of SPH that are proposed in literature.

Many very complex engineering problems which where considered too complex 10 year ago, can be now successfully simulated with SPH mainly thanks to the introduction of particle shifting.

PAPER #5

TITLE: Variable resolution for SPH: a dynamic particle coalescing and splitting scheme

AUTHORS: Vacondio, R., Rogers, B. D., Stansby, P. K., Mignosa, P., & Feldman, J.

BIBLIOGRAPHIC DETAILS: Computer Methods in Applied Mechanics and Engineering, 256, 132-148 (2013).

GRAND CHALLENGE(S) ADDRESSED:

- GC#3: Adaptivity

MOTIVATION:

In this work a novel SPH variable resolution method is presented. It is based on the use of particle splitting and coalescing techniques which dynamically modify the particle sizes, providing high resolution only where it is needed. The proposed method guarantees the mass and momentum conservation for particles with different smoothing lengths. The algorithm is tested against analytical solutions for Poiseuille and Taylor–Green flows and also on other benchmark test-cases of increasing difficulty. This paper has a fundamental importance in GC#3, being a pioneering work for particle splitting and merging techniques and paving the way to more advanced adaptive schemes.

PAPER #6

TITLE: On the maximum time step in weakly compressible SPH

AUTHORS: Violeau D., Leroy A.

BIBLIOGRAPHIC DETAILS: Journal of Computational Physics, Volume 256, Pages 388-415 (2014). https://doi.org/10.1016/j.jcp.2013.09.001

GRAND CHALLENGE(S) ADDRESSED:

- GC#1: Convergence, consistency and stability

MOTIVATION:

The paper presents a rigorous study on stability of weakly compressible SPH. The authors present a theoretical stability criterion for the time step, depending on the kernel standard deviation, the speed of sound and the viscosity. The stability domain appears to be almost independent of the kernel choice for a given space discretisation. Numerical tests show that the theory is very accurate, despite the approximations made. The authors then extend the theory in order to study the influence of the method used to compute the density, of the gradient and divergence SPH operators, of background pressure, of the model used for viscous forces and of a constant velocity gradient. The influence of time integration scheme is also studied, and proved to be prominent. All of the above theoretical developments give excellent agreement against numerical results. It is found that velocity gradients almost do not affect stability, provided some background pressure is used. Finally, the case of bounded flows is briefly addressed from numerical tests in three cases: a laminar Poiseuille flow in a pipe, a lid-driven cavity and the collapse of a water column on a wedge.