Multi-level Multi-phase Fluid Animation

1. Excellence

1.1 Quality and credibility of the research/innovation project; level of novelty, appropriate consideration of inter/multidisciplinary and gender aspects

1.1.1 Introduction, objectives, state-of-the-art, and overview of the project

Fluid is fascinating and has attracted great interest from both artists and scientists for centuries. Leonardo da Vinci has pinioned the fluid visualisation 500 years ago when he studied the turbulence flow and nowadays researchers are still developing in-depth knowledge and understanding of fluid dynamics. Fluid animation is a challenging topic which requires merge of knowledge and expertise from both science and art. This project, MultiFluid, is designed to advance the related technologies and boost art creation in the related field, providing mobility of a talented fellow (ER), [redacted] of profound scientific background (detailed in the CV of B2) from a third country to work in the world leading centre [redacted]) on computer animation (CA) in Bournemouth University (BU), where he will have a unique chance to work with his supervisor [redacted] and on-site artists to bring better understanding of fluid animation and develop innovations. Multidisciplinary research will also receive support from the [redacted] A specialist, [redacted] a world-renowned VFX company whose projects include blockbuster films such as *The Lion King* and *Dumbo*, will provide industrial insight and offer consultancy for this project.

We have seen great success of fluid animation and visual effects (VFX) in block buster movies, since *The Perfect Storm* pioneered the visualisation of ocean waves in 2000. Technology has driven the radical changes in the industry. Nowadays, stunning scenes are presented in most recent films with high details and realistic dynamics of fluid. Production of such high-quality images demands skilful technicians and talented artists which associated with high labour cost and long production time (up to 1million Euro per minutes animation in film making). This is associated with the following main conflicts: 1) simulation resolution (typically 256x256x256) is often limited and image resolution in films is high (usually 2k or 4k are used) – simulation cannot produce sufficient visual details; 2) animation requires control from the artists or directors for effects that conflicts usual physical laws and simply apply the physical rules and solving the mathematical equations is not always working, 3) some complex physics in fluid interaction is far too complex to model and animate.

Aim: MultiFluid is designed to stand on the front of fluid computer animation (CA) and tackle most challenging issues to address the industrial needs of stunning CA. It is ambitious but timely to develop a novel theoretical framework for fluid animation using grid-particle hybrid enhancement to resolve the three main conflicts as mentioned above. Its innovation rests on two supporting pillars in implementation: 1) a coherent multi-level simulation approach to provide refinement to the fluid details (resolving the convergence issue in multi-scale particle-based simulation) and offer effective controls in animation, 2) a multi-phase interaction and phase-transition model to consider complex physics beyond the state of the art. A collection of **Fluid Animation Enhancement Techniques (FAETs)** will be implemented respectively.

The current market research shows that the total value of the global animation industry in 2018 was €259 billion[1]. US, Japan and China together dominates the market, meanwhile EU only has a 17.6% on it[1]. With high labour cost and the limited growth of local market, exporting advanced animation technology is an effective way for Europe to improve its global market share and become competitive. FAETs developed in MultiFluid are an enabling technology aiming to remove the technological barrier in fluid animation production – only a fraction of animators can produce quality animation of fluid and it takes 6-12 months to train a novice to master the fluid animation software due to the complexity of the tools, not to mention the prerequisites of mathematics and physics which most animators/artists don't have. Using a hybrid grid-particle set-up, MultiFluid will develop FAETs tools that will minimise the prerequisites for its learners - it will help reduce the training time to 2-4 months with a user-centred design, which makes the technology accessible.

Three main research objectives are to be achieved through well aligned workplan (Fig 1 illustrates how the FAETs related to the three main objectives can be used in animation production): **(O1)** *Develop a fine **surface detail enhancement** technique,* using post-processing technology: By calculating the surface curvature (to add Lagrange waves to the fluid surface), the fidelity and efficiency of the fluid animation will be enhanced. The key here is to maintain the consistency of the fine details and fluid features when adding to the low-resolution simulation with grid-particle hybrid enhancement. **(O2)** *Develop an **art effect enhancement** technique:* This is based on the mesh model and the motion skeleton, which controls the shape of the fluid by controlling the particle groups and surface curvature. User-friendly control handles and new descriptive features (rather than physical ones) will be developed in artist friendly tools. It will greatly improve the controllability and capacity of fluid animation tools. **(O3)** *Physics **modelling enhancement** technique:* This is to achieve the effect of melting, freezing and

[1] "Global Animation, VFX & Games Industry: Strategies, Trends & Opportunities 2019", 2019.01; "Global and China Animation Industry Report 2019-2025", 2019.06; "European Animation, VFX & Games Industry: Strategies, Trends & Opportunities 2019",2019.01.

dissolution-diffusion, increasing the study of convection and vortex through temperature field/concentration field. The grid-particle framework will improve the fidelity in physics and provide computational efficiency.

State of the art: To date, coarse fluid now can be refined by using user-defined parameters, showing a variety of different styles[2]. In the movie "Moana", Disney used the *fluxed animated boundary method* [5] to personified ocean animation. In terms of phase-transition, researchers started to use hybrid method[6] to simulate it and got better results than those with particle methods. However, there are gaps to be filled on the enhancement techniques covering the various dimensions of the fluid animation. Researchers have addressed the problem individually and there is lack of a consistent theory framework to solve these problems. On one side the community has developed task-driven solutions which are case by case. On the other side there is difficult to transfer a specified tool for other purpose or it creates barriers for reusing existing animation data for other production. We see an exploration of genres of tools in fluid animation/simulation and animators are sometime confused to find a most suitable one for their creation.

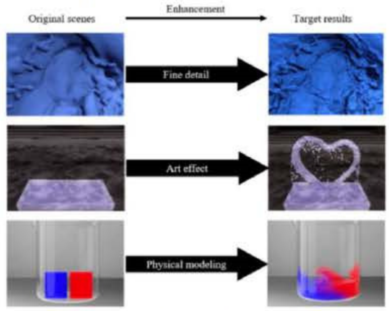

Fig1: A demonstration of Fluid Enhancement Techniques - from top to bottom: detail enhancement technique, art effect enhancement technique, and physical enhancement technique. Images from [2 3 4] respectively show the concepts.

The ER will develop a grid-particle hybrid approach to benefit the stakeholders by combining the advantages of both grid-based solver and particle-based solver, offering 3 key enhancement routes in a consistent manner.

In graphics community, ***the surface detail enhancement*** method has been developed to enhance the appearance and surface details of the low-resolution fluid. However, it is prone to error and compromises the visual fidelity to some extend (accuracy is not guaranteed, and simulation may violate physical laws) when comparing to a high-resolution simulation, which is time consuming. An example of existing method is shown in Fig 2. Besides, researchers tend to develop the methods on pure particle (PBM and SPH) or grid/mesh resolution (FVM and FEM). Hybrid methods like FLIP/PIC were developed and gained success in CA. In MultiFluid, a hybrid enhancement approach has a great potential to enhance the accuracy while maintain the efficiency. Recent advance in this direction includes the Laplacian Eigenfunction method[7] to scale the simulation and the post process[8] using style transfer to add turbulence, and learning-based methods to accelerate computation with fine details[9].

Fig2: An example of existing grid-based solution[10]. From left to right: simulated on coarse grids, after enhancement, simulated with fine grids. The enhanced fluid is not consistent to the fine grid simulation, which the ER will address.

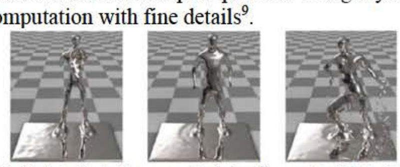

Fig 3: Art effect enhancement technique[11] example. It is hard to maintain the shape of object in a very dynamic scene

Art effect enhancement allows fluid natural movement when it is tracing fast-moving objects. An example is shown in Fig 3, where the fluid appearance may become unnatural when fine details are maintained or too chaotic when the control is too hard. In animation, the control of flow can be achieved via space time optimisation[12] and interpolation, which is less physically plausible. Detailed preserving force and control particle groups are to be used in our development to preserve the target shape and offer fine tune function for artists. This is a more suitable solution and behaves more stable than the recent reported learning-based control methods[13 14]. Machine learning models often encountered processing bottleneck to handle 3D fluid data because the data set is far too large.

Physical modelling enhancement is in line with improvement of capacity of physics model to incorporate multi-phase simulation of interaction among phases and transition between phases. Phase transition like melting and freezing effects can be controlled with the temperature field (either simulated or pre-set) and simulated with particles. The consistency and smoothness in such transition is problematic when the particle resolution is not high enough (the melting may become discontinuous). By adopting the concept of volume fraction[15], particle based

2 [redacted] et. al. (2015). Surface turbulence for particle-based liquid simulations. ACM TOG, 34(6).
3 [redacted] et. al. (2015). Position-based fluid control. In Proceedings of the 19th Symposium on Interactive 3D Graphics and Games (pp. 61-68). ACM.
4 [redacted] et. al. (2015). Fast multiple-fluid simulation using Helmholtz free energy. ACM TOG, 34(6), 201.
5 [redacted] (2017). Fluxed animated boundary method. ACM TOG, 36(4), p. 68.
6 [redacted]., et. al. (2017). An efficient heat-based model for solid-liquid-gas phase transition and dynamic interaction. Graphical Models, 94, 14-24.
7 [redacted]., et. al. (2018). Scalable laplacian eigenfluids. ACM TOG, 37(4), p.87.
8 [redacted] et. al. (2018). Example-based turbulence style transfer. ACM TOG, 37(4), p.84.
9 [redacted]., et. al. (2019). A CNN-based Flow Correction Method for Fast Preview. Computer Graphics Forum. 38(2).
10 [redacted] (2014). Detailed water with coarse grids: combining surface meshes and adaptive discontinuous Galerkin. ACM TOG, 33(4).
11 [redacted] et. al. (2015). Position-based fluid control. In Proceedings of the 19th Symposium on Interactive 3D Graphics and Games (pp. 61-68). ACM.
12 [redacted] (2017). Efficient solver for space time control of smoke. ACM Transactions on Graphics (TOG), 36(5).
13 [redacted]. al. (2018). Fluid directed rigid body control using deep reinforcement learning. ACM TOG, 37(4), p.96.
14 [redacted]. (2019) Deep fluids: A generative network for parameterized fluid simulations, Computer Graphics Forum, 38(2), pp. 59-70.
15 [redacted]. al. (2005). Particle-based fluid-fluid interaction. In Proceedings of SCA (pp. 237-244). ACM.

approaches[5] [16]are developed to produce a wide range of multi-fluid flow phenomena with rich visual effects. [redacted] (the supervisor)'s group also proposed a unified particle framework[17] which integrated the phase-field method with multi-material simulation. In MultiFluid, the convection-diffusion theory will be incorporated and a grid-refined hybrid phase transition can add necessary details in low resolution simulation. Development and validation of our model for such complex phenomena is challenging and we will seek support from the[redacted] to forge multi-disciplinary efforts to address the challenges (see **interdisciplinary aspects** in Section 1.1.4 for details). This will add value to animation production from research in physics and chemistry [redacted]).

Why EU should invest MultiFluid and who will benefit from the action? The research is timely to address the immediate challenges in CA and serves the digital creation community with new fluid animation theory and tools. The advance of technology will bring sizeable return to the stakeholders, e.g. if only a fraction of time can be saved in fluid animation scenes in film production using the developed tool, this will bring down the high cost in production and release the human power for other creative tasks. The target is ambitious but achievable with the following arrangement(also see Sect. 1.1.2): we address the major technical challenges with an innovative hybrid-particle framework; we take advantage of the multi-disciplinary research capacities from the [redacted] (computer animation) and the [redacted](water research); and by proposing enhancement rather than solving a complex full-resolution model, we scale down the problem into a solvable level. The FAETs will add value to the state of the art, hence benefiting animators' creation. The mobility and knowledge transfer are organically integrated in the training and research to deliver the target and tangible outputs. The supervisory team [redacted]) and the fellow have excellent track records in conducting/leading research in fluid modelling and CA. The fellow has led and participated in 5 funded research projects (for fluid simulation and visualisation) and contributed to 6 cross-sectoral knowledge exchange collaborations. Existing experience and competencies in the team is extremely valued in the project execution and exploitation to maximise the outputs and impacts. Training and international working experience in MultiFluid will help the fellow to open new career opportunities and broaden his knowledge and research ability in CA (on fluid dynamics and numerical calculation as well as controllable art animation design). Resources/facilities (software and hardware) and knowledge deposition (codes, previous published paper and research on fluid animation) at the [redacted] are essential, which are not available at other places. The network and connection of the [redacted] with animation companies helps exploit and communicate the research findings widely. Through effective knowledge transfer and development of excellent research, MultiFluid will promote EU's technical competitiveness in VFX and CA through multi-disciplinary research that competing with strong opponents from [redacted].

1.1.2 Research methodology

Fig.4 summarizes the overall framework and methodology. The original simulated fluid can be post-processed with these three tools: *detail, art and physics enhancement tools* as shown in Fig. 4. The resolution, art effect and complex physics will be enhanced simultaneously via separate channel but under the same hybrid theory framework.

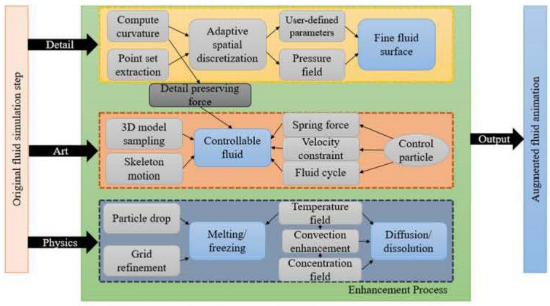

Fig.4 Technological framework and outline of methodology

Develop a fine surface detail enhancement method under coarse grid (O1, WP3**):** Using his previous adaptively asynchronous time integration technique [18], the ER will develop a post-processing approach that creates high resolution surface details for fluid animation. This novel approach will draw coarse blocks and fine surfaces respectively using multi-scale methods, acquiring a more detailed fluid surface under limited computing resources. **Challenge for O1:** In the recent research of detail enhancement, researchers tried to improve the fluid surface detail based on the surface information of the fluid. It may cause issues when the local velocity field is not smooth. For example, a small collapsing air bubble requires a velocity field that quickly switches directions from one side of the bubble to the other, and these sometimes appear to have a 'numerical pressure' slowing the collapse in the enhanced fluid.

Methodology: To improve efficiency, fine grid post-processing steps and adaptive spatial discretization will be used to generate high resolution details. the ER proposes a high precision surface detail generation method for low resolution simulation, which simulates coarse three-dimensional fluid volume and fine two-dimensional fluid surface when adding fluctuation according to surface curvature. To ensure fidelity and reduce time consumption, multiple resolution levels are used to describe different refinements. Three-dimensional fluid blocks are simulated at low resolution, and the original free surface point set around each coarse particle is extracted to obtain a detailed,

[16] [redacted]2014). Multiple-fluid SPH simulation using a mixture model. ACM TOG, 33(5), p.171.
[17] [redacted] et. al. (2017). A unified particle system framework for multi-phase, multi-material visual simulations. ACM TOG, 36(6), p.224.
[18] [redacted]*, et. al. (2018) Adaptively Stepped SPH for Fluid Animation …, Neural Computing and Applications, 2018, 29(1), 33-42.

high-resolution liquid surface. Many studies have suggested a method for improving the fine surface detail under the Euler grid, but further research is needed on the particle method[11]. With user-defined parameters, synthesising the surface wave will be controllable. Different parameters will generate different fluid surfaces, so that the fluid animation can remain diverse. As to refining or smoothing the surface details, we can add or delete the fine surface area dynamically according to the density field, where fluid structural feature analysis based on statistical models of dynamic characteristics and local/global optimisation at multi-scales will be carried. The method can be integrated into existing fluid solver, balancing the computing resources with capacity to animate the surface details with high precision at a limited resolution level.

Develop a fluid animation art effect enhancement method (O2, WP4): Under the guidance of [redacted], the ER will develop a sketch-based manually-intervening approach to sculpt fluids shape, where the animation of fluid is controlled by particle groups and curved skeletons. This project will employ an artistic friendly way to drive fluids simulation to match users' specified changing targets. It provides an analogy to the rigging process in character animation, which is a standard technical in animation production. The controllability and efficiency are enhanced in this way. **The ER will gain knowledge in target-driven animation** (i.e. rigging, fluid control, art-direction, etc.), which will greatly broaden ER's research field and future career. **Challenge for O2:** It is not practical to directly control the movement of each fluid element manually due to the high degrees of freedom. Control particles and skeletons may cause "over-control with hard binding" as shown in Fig 3. Knowing how to regulate the constrain force with an optimisation approach is the key to improve the quality and efficient. The fidelity and control accuracy is set as the optimisation target.

Methodology: To match users' specified shape accurately and effectively, the basic motion skeleton will be extracted from input model to generate control particles. Constraints will be enforced to control particles to ensure incompressibility. To enhance the stability and fidelity for fluid movement and follow a fast deformation target, the ER will employ a particle-mesh hybrid method[19] to impose nonlinear force to control particles and improve fluid shape matching through curvature model of grids. To further enhance the fidelity and avoid the static glass-like effect, this method will create consistent fluid flow inside the target model based on pressure gradient, which also considers the shape of target model and the skeleton structure. This approach is efficient, which has strong application potential that can be adapted to movies, games and other interactive applications.

Develop physics modelling enhancement for fluid animation (O3, WP5): Based on the advances in hydrodynamics (including [redacted] and the ER's previous work), a physical model for the enhancement of fluid physical effects will combine temperature field and concentration field to describe phase transition process and dissolved-diffusion, where features of turbulence are to be studied. This will greatly compensate the inadequacy of fluid VFX modelling to enhance the diversity and fidelity of animation. The ER will strengthen his skills in the physics based animation (i.e. the knowledge of numerical calculation and hydrodynamics, the problem-solving capability of fluid simulation). Such skills will benefit ER's future research by opening new research themes. **Challenge for O3:** Phase transition requires particles to track their position and phase information. However the particles are inadequate to prevent numerical energy compensation. The latest hybrid method ignores the compressibility of the fluid to simplify the solving process. The key issue is to find out how to utilize a hybrid particle and grid framework to remove the inaccuracy in the phase transition. Macroscopic particles in simulation don't possess the same attributes as molecules in real world. Measuring the temperature and concentration field in physical experiments is an intuitive way to build up distinct relations for multiphase interactions.

Methodology: The ER will develop a comprehensive solid-liquid phase transition and convection-diffusion model (in collaboration with th[redacted] and [redacted]teams), making the phase transition and diffusion process more real. The ER will use Lagrangian-Eulerian hybrid method to simulate and reduce granular sensation in particle-simulated process. Heat conduction can be calculated based on temperature field in grid level to avoid the error of surface area calculation in particle level. Based on ER's work[20], the ER will design a convection-diffusion model derived from the change of temperature and concentration, so that the process of dissolving and diffusion can present a more detailed result, avoiding the thick appearance inside the fluid due to energy dissipation, and compensating the energy loss of the grid-particle transformation. To push the boundary of fidelity, the ER will use fluid diffusion features based on vortex to capture fine fluid structures. On the premise of ensuring efficiency, this model can overcome the traditional problems that require extremely high precision and small time-steps to simulate. The implementation and validation will use experimental and high performance computing facilities at th[redacted].

1.1.3 Originality and innovative nature of the project

Fine surface detail enhancement: Synthesis of high precision surface details over low resolution fluids is of great interest and value. Because traditional high-precision fluid simulation is time-consuming, researchers must repeat tedious and time-consuming experiments to obtain reliable parameters and exact dynamics. Our approach tackles the simulation problem with an innovative angle to resolve high-fidelity fluid details. The outputs will be appealing over simple low-resolution resolution and the process will be controllable and efficient over high-resolution

[redacted], et. al. (2015). Efficient Extracting Surfaces Approach Employing Anisotropic Kernels for SPH Fluids. Journal of Visualization, 19(2).

20 [redacted], et. al. (2019) Convergent turbulence refinement toward irrotational vortex. In Proceedings of ACM SIGGRAPH 2019 Posters, No.80.

simulation. It is innovative to solve a high resolution details at fine 2D layers and add these on top of the low resolution simulation, where the visual effects shall match up to the high quality provided in full high-resolution 3D simulation. It is innovative to develop fluid feature analysis based on statistical models of dynamic characteristics and implement local/global optimisation at multi-scales. The user can set parameters interactively to control/refine the simulation results to achieve desired art effects instantly (thinking of a full scale simulation in common practice would take hours or even days to get the intermediate results before any changes can applied, this is efficient).

Art effect enhancement: In the current study on controllability, the main problem need to be resolved is to maintain the shape during fast movement and to pursue the reality of fluid simulation. However, these two goals contradict each other. Excessive maintenance of the shape will lead to the unnatural fluid flow. In the current way of realizing the controllability, the degree of nature gets lost because of the need for maintaining shape of the body, especially when the model is in large motion. The ER will apply particle-grid hybrid method to control the fluid from two computing layers, to solve this issue. For instance, a non-flowing static state (glass-like effect) may present in many cases of controlled fluid animation. To improve the fidelity and remove such artefact, we will apply nonlinear forces by controlling not only particles but also surface curvature of the model as a novel implementation. The sketch based user interaction will be innovative as well.

Physics modelling enhancement: The complexity in physics of multi-phase and multi interaction makes it is hard to model. Often radical simplification must be made and the controllability is not satisfactory for production needs. Conventional thinking of applying pure physical theories and then discretizing them cannot meet the demands of the efficiency and fidelity we pursuit. So the ER will construct animation model directly from real experiments and open up a new thinking for fluid animation. Enhancement technology proposed will address the issues with heat conduction and convection-diffusion model to enhance the overall fidelity in animation. We will effectively solve the incompressibility of the fluid where the popular phase transition method based on the FLIP fails.

1.1.4 Interdisciplinary aspects

Comprehensive development in MultiFluid requires not only good knowledge on computer graphics but utilizes the in-depth knowledge of traditional physics and engineering studies. To maximise the ER's research capacity and sharpen his hydrodynamics knowledge, the [redacted] will offer complementary training (D2.1) on engineering simulation of multi-phase flow, use of high performance computing (HPC) facilities and advanced skills of using professional simulation software, ANSYS, which will provide a benchmark of full scale simulation to validate the animation produced with lower resolution. The ER will collaborate with [redacted] and his team to forge multidisciplinary research, where cases from water processing (aeration, multiphase simulation and biochemical analysis) will use experimental data as well as full scale simulation to validate the new FAETs development and animation. This will catalyse and inspire novel solutions in both fields, e.g. animation will enhance the visualisation of water innovation at the [redacted]. The interdisciplinary collaboration will add value to theoretical development of novel physical model and hybrid framework (particles and grids), and contribute to practical enhancement tools (FAETs) of three channels [redacted] will offer industrial insight and assist the ER to prompt cross-sector exploitation (WP7). The multi-disciplinary aspect in the research will enable the ER with engineering background to collaborate with artists (the [redacted] water scientists [redacted]) and industrial practitioners (collaboration with companies in VFX) for various tasks (WP1-7). The host will provide networking to artists and industrial connections in additional to supervisor's expertise (on physically based modelling, multifluid, user interaction, VR/AR applications) to benefit the implementation of this multidisciplinary research.

Gender dimension: Only over 20% of workforce in CA is female. The [redacted] contact, [redacted] is a talented female researcher (with papers on "particle sampling techniques" and "fluid dissolving" published at TOG and other top journals) who will collaborate and contribute to the research, this helps bring exposure of her excellent work in STEM subjects and CA. Communication strategy will include aspects to encourage female researchers and stakeholders to participate in the activities, for both art creation and science exploitation elements in this inter-disciplinary research. The host is a member of the ATHEA SWAN charter scheme to support equal opportunity for women in the sciences. It holds the ATHEA SWAN bronze award.

1.2 Quality and appropriateness of the training and of the two way transfer of knowledge

The outcomes of this project will help to enhance Europe's competitiveness in the CA industry. Both the ER and the host institution (BU) will benefit from the knowledge transfer simultaneously. The ER will receive comprehensive high-quality research training from the BU (and the [redacted]) according to a *Career Development Plan* (CDP) to open up new career opportunities. The research will benefit from the ER's novel developments and networking with China institutions.

Training and knowledge transfer (KT) is the main drive in this mobility to deliver excellent science and enable new research capacity. Three main training sessions are scheduled as follows to focus on critical training elements and targets: **Session 1**(month 1), an induction week will integrate the ER to the team members, get him familiar with the working environment, offer training on rules and codes of practice, interpersonal skills, library and literature research skills, ethics and data policy and essential IT trainings; **Session 2**(month 1-5) on specific techniques, e.g. master lectures on animation software skills (MAYA,HOUDINI, UNITY), hands-on training of using VR/AR equipment (Oculus, Vive, HoloLens) for fluid visualisation, data handling to develop Data Management Plan to support open data strategy (by library staff), parallel coding on GPUs, using of render servers (render farm), and complementary training at the [redacted] on multi-flow theory, professional simulation software and use of HPC facilities; **Session 3** (month 6-24), this is a serial focus seminars at BU on visualisation and fluid modelling, contributed by the supervisor, members of host research group, ER, external expertise of leading universities and companies(e.g. [redacted] of [redacted], [redacted] of the [redacted], a world famous VFX company) on various topics, including talks on cutting edge technologies on SPH, MPM, PBM, Peridynamics, Data-driven simulation, CA production. This provides networking and the training is open to students (undergraduate, postgraduate and PhD students at the host) and public as well.

Day-to-day training-through-research is implemented in the execution of the well-aligned WPs with supervisory and mentor support ([redacted]) to develop concept, theory, art creation and tools. The ER will shadow and participate in the project management to gain skills on research & financial management, IPR management, coordination of cross sectoral activities, second supervising research students, networking with peers and stakeholders. He will manage and lead research dissemination to peers and industrial users (including seminars and a workshop) and public engagement events (2 outreach activities) to gain horizontal skills and capacity of organising scientific events. The fellow will benefit from career development (coaching and mentoring) and research skill workshops/events (11 available short courses to cover funding bids, writing skills, data and IPR, legal matters, ethics and research methodologies), which will be an amazingly invaluable curriculum for an academic. More details will be explained in the CDP, which is in line with EU Charter for Researchers to widen the competency/capacity of the fellow with new multi-disciplinary knowledge and intersectoral experience.

The fellow will also bring in abundant knowledge and skills of related subjects (with 20 publications and research deposit from a number of research projects) to the host. **Two-way transfer of knowledge** is outlined as below:

Host and [redacted]=>ER: computer animation techniques and software skills, multi-fluid modelling (theory and numerical implementation), art creation principles and practices, animation production pipeline, parallel coding on GPU, advanced rendering and visualisation techniques, image-based enhancing techniques and style transfer in animation, data handling, HPC, professional simulation tools, promoting research via various media, project management and organising public engagement/dissemination/networking events;
ER => host and EU: high-fidelity fluid modelling, fluid surface rendering, fluid simulation software development, new enhancement techniques in details, art effect and physics, in-depth understanding and experience of particle based simulation (adaptively stepped SPH based on asynchronous time integration, divergence-free SPH for small-scale surface details), theory framework of hybrid method, non-linear non-Newtonian fluid modelling, multi-interaction, mass control and energy control in fluid simulation, maintaining incompressibility in fluid simulation, heat transfer and phase transition model in multi-phase. (Key knowledge deposits come from his research projects and publications in *Fluid interactive phenomena simulation for multiphase flow scenario, Non-Newtonian fluid simulation using particle-based method, Multiphase interaction simulation for incompressible SPH Fluids.* One of his techniques has been successfully used to create a commercial software system for urban planning)

The ER will develop new understanding around the two supporting stems of knowledge: 1) a coherent multi-level simulation approach to provide refinement and offer controls in animation, 2) a multi-phase interaction and phase-transition model. This supports the development of new enhancements in CA and open new research themes beyond this project for his future research, e.g. offer immersive fluid experience for VR/AR applications in industrial simulator. Markets demanding of such novel solution is identified in manufacturing, oil industry, water processing, chemistry and medical use in addition to the contribution claimed in this project to VFX sector.

1.3 Quality of the supervision and of the integration in the team/institution

The supervisor, Prof [redacted] has profound knowledge (17 years research) in physics-based animation (in particular, with work pinioned in multi-fluid and meshfree modelling), novel HCI to serve modern simulator design, data management system for CA, and VR/AR applications. He has published over 90 peer-reviewed papers (including high-impact TOG, IEEE TVCG & CGF), edited 2 books and has been the programme committee member for over 20 International conferences. His research has contributed to a number of prestigious research projects (FP7 MC-IIF "AniM"-623883 (PI) on smart data management for CA and FP7 MC-IRSES project "AniNex" – 612627 (chief scientist) on next generation animation technologies involving international efforts of 5 leading research institutions. He has led the digital content and immersive experience development in VISTA AR (co-I), which was reported in BBC news and French newspaper, to support heritage sites and local tourism section. His research has contributed to digital innovation at the UK largest charity [redacted] to save lives at seas. His experience of supervising Marie Curie (MC) actions will provide firm support to this fellowship and the smooth delivery of the research plan. He has supervised 1 MC Fellow, 2 exchanged ERs and 9 ESRs, as well as 8 PhDs and 11 RAs. His competencies, research and management experience will ensure smooth execution and tangible deliverables, provide effective communication and dissemination, and help coordinate practical training. [redacted] also contributes to the faculty management and research policy making in several executive committees, leading BU's preparation for the national research assessment for "*Art and Design*" (REF).

Hosting arrangements: The [redacted] is a renowned centre for CA research and its 90% research environment was rated as world-leading (highest) in the REF 2014 (national research assessment). It has led 1 IRSES(FP7) and 2 RISE(H2020) schemes which integrated a handful international researchers within the team. It has hosted 2 MCA fellows and many research visitors (other funding sources). Office&IT facilities, labs and supporting staff are in position to ensure new arrivals to embark on their research tasks instantly. Supervision team is experienced to cope

with the cultural difference and diversity. Networking and conference attending opportunities are offered (Sect. 2.2) to benefit the training and project dissemination. The host has a EURAXESS Local Contact Point to support the fellow and holds the EC HR Excellence award. The host will support coordination a dissemination workshop and outreach activities with venues, facilities and supporting staff. The importance of the fellow's personal and career development, and lifelong learning, is clearly recognised and promoted at all stages. The host offers specific RKEDF programme for research staff training. BU operates a formal annual Appraisal scheme enables staff to deliver their best possible contribution, unambiguously aligned in support of the university's strategic aspirations.
A mentor, Prof [redacted] (PhD), [redacted] research will be assigned. He will offer mentor support and steer the research as a gate-keeper of quality and standard. [redacted] has secured over €8million in research grants from the EPSRC, AHRC, the Wellcome Trust, EU FP7 and other funding organisations. He is a co-founder of the [redacted]), as a UK flag of industrial doctor training. He will mentor the ER to develop his comprehensive skills and leadership though the research execution.

1.4 Potential of the researcher to reach or re-enforce professional maturity/independence during the fellowship

The ER has built up profound knowledge, expertise and skills (see research track of record in section B2) through PhD training and leading (participating in) government-funded research projects on computer graphics and 3D visualization, e.g. particle based SPH and non-Newtonian fluid. This research will add new expertise on hybrid framework, fluid enhancement tools and multi-fluid/multi-phase interaction through cross-centre collaboration.
The CDP will list the training needs and plan (knowledge, skills, networking) to boost up the ER's career. Multidisciplinary training and development to merge scientific simulation and art creation will broaden his knowledge base and skill profile (Sect 1.2). Developing leadership, independency and mutuality in this project will benefit his career in long term. **The fellowship is a magnifier and incubator** to grow his capacity in conduct world leading research and create cross-sectoral influence. The existing maturity in research will be further re-enforced with new knowledge and skills in complementary areas (fluid enhancement and muli-fluid models), managing experience, international and multi-sectoral cooperation and an expanded personal network and research connections (Sect 1.2). Outreach networking events and research dissemination will build up recognition among peers and international reputation, bringing in future collaborations.
Open up the best career possibilities and new collaboration opportunities: Conducting this multi-disciplinary research (in the [redacted] and the [redacted]) will strengthen his competencies and open new research themes (see 1.1.3), with the new knowledge gain through the well-aligned comprehensive training programme and WPs. The experience of working in both world leading centres (animation and water research) and gaining inside-out knowledge in animation production and hydrodynamics which is not available in another way will open new career possibilities, with related hand-on experience and research excellence. The ER will draft the CDP with discussion with the supervisor and mentor to support his moving up on the career ladder from a lecture towards a professor and becoming an academic leader in 5-10 years.

2. Impact

2.1 Enhancing the future career prospects of the researcher after the fellowship

Pioneering the innovation in CA, the ER will develop close relationship with leading EU scientists [redacted]). After the project completion, joint patent application and IPR exploitation can be taken with support from both BU and [redacted] ([redacted], ER's home institution). Collaborations on research training and developments of novel technology will disseminate at top peer-reviewed publications and impact at the industry will continue using ER's connection with industry from previous projects and MultiFluid (supported by networking and mobility funds, e.g. post-grant Open Access funds, CSC, TRS, and NSFC). BU and [redacted] will jointly run training workshops and networking activities/conferences to support MultiFluid communities in the future. The ER wants to continue the research and use the knowledge developed in MultiFluid to secure funding from NSFC, e.g. develop fluid visualisation and VR application for industry outside CA (e.g. metal forging), supporting further **interdisciplinary and cross-sectoral exploitation**. BU's team will continue the excellence of MultiFluid to conduct commercial exploitation where the ER will contribute as an external consultant, hence diversifying his career path. This will be detailed in a 3 years **post-project actions** in his CDP to specify strategy and activities/tasks to promote research/impact and help develop/diverse career prospects.
Research collaboration. The ER will continue to co-author papers with BU team and other parties for follow-up publications based on mutual interests on fluid animation and other area. BU will benefit from his experience and knowledge through a partnership with his home institution on research and education collaboration (e.g. to coordinate summer school). Deeper long-term research collaborations will emerge with [redacted] and other China institutions with the research quality and nexus build up in this project. This will enhance EU's competitiveness in reaching research collaboration with China and a big market in China. Funding sources (The Royal Society, British Council, NSFC) to support networking, exchange, research and innovation will be sought and secured.

Related post-project research and activities will bring more recognition of peers, strengthen the ER's research profile, and re-enforce/diversify his research competence towards a world leading academic, delivering profound cross-sectoral influence with the wide links and connection developed in MultiFluid. The ER has gained many successes in his previous exploitation of cross-sectoral knowledge transfer with a number of industrial partners. He will continue to lead cross-sectoral development and exploitation, where all research outputs (deliverables) and an integrated research team from MultiFluid are put as valuable and irreplaceable resources. This will **contribute to the EU research agenda to tackle associated challenges in digital creation and smart manufacturing**. The post-project activities may also benefit from Chinese massive investment of "One Belt One Road", connecting China and the world, to open up and create new markets for technologies developed in EU.

2.2 Quality of the proposed measures to exploit and disseminate the project results

Dissemination of the research results: This aims to maximize the visibility of the project, including project website, YouTube and Twitter account for the project (D6.2). Research outputs will be disseminated and exploited at least 3 top conferences like SIGGRAPH, EG, CASA, CGI and SCA, journals of TOG; IEEE TVCG, CG&A (DS2 and DS3). SIGGRAPH 2018 attracted more than 16,000 attendees around the world. Attending such conferences will not only engage the peer scientists but also share the information and knowledge among a broader audience. A workshop will maximise the potential of dissemination by inviting leading academics, animators, artists and other stakeholders. Both the conference attendance (WP6) and **workshop organisation** (M7.1) will nest a large network of the society and foster interests/collaboration into developing research and science in CA, simulation, fluid physics and chemistry. The ER is experienced in presenting his work at international conferences and other occasion. In training session 3 (Sect 1.2), a number of seminars will be organised at the university to engage academics and students to share knowledge on various complex fluid animation and enhancement techniques (external experts are invited). A fair portion of such seminars will cover the research content in this project and provide a platform to form discussion and knowledge exchange. **Industrial exploitation** will be coordinated at BFX (hold at BU), the UK largest VFX festival involving world leading animation companies, to invite industrial representatives to form a focus discussion group on innovation for fluid animation. A specially tailored workshop, meetings and seminars will invite guests from companies to inject research ideas and catalyse cross-sectoral collaborations. In the **exploitation phase** (WP7), artists and technician will form an interest group of leading VFX companies (such as, the [redacted]) to exploit and validate the tangible measurement of saving in staff training time and cost in fluid animation production. Long term commercial exploitation (Sect 2.1) will be carried to maximise the impact and attracts post-project collaboration in cross sectors. **IPR issues** will be dealt with in project setting. A list of background IP (all parties), including software codes from the fellow and the host, and term of use/licensing will be in place at start. The foreground IP will be owned by BU and a royalty free license will be offered to all participates (ER and the research teams) for research and commercial exploitation within and beyond the project life. A post-project patent application is planned. BU legal teams will involve the fellow to draft an IPR agreement, which refers and complies with the "MSCA rules".

2.3 Quality of the proposed measures to communicate the project activities to different target audiences

Communication strategy and actions have been explicitly identified through the project. **A communication plan** will be drafted with the complete details of the actions at the start. The target audiences (researchers, industrial employers, potential customers and the general public) were identified and effective routes to reaching them are clearly planned and organized. Useful details on communication are included in the work plan. It will create public awareness of the project and represent EU image as a big investor for the next generation technology, leading innovations to serve the community and answer societal challenges. A project website provides free access to various contents and heritage objects related to this project. **Outreach activities include** active public participation (posters, open workshop) at **BU's Festival of Learning** and the **BFX.** In 2018, the Festival of Learning has attracted 4,000 local people at different event locations across Dorset. And the BFX provides a networking with industrial stakeholders and general publics. **Other Activities** (throughout Fellowship) will make the outcomes publicly available via social Media (twitter and facebook), including magazines, popular press. The fellow will receive training on use of social media to promote research. The [redacted] has its own YouTube Channels. BU Research Blog won 'Best Research Website'. Resources and supporting staff are available to make the content attractive to public (including fun VR/AR fluid experience), open people's imagination, inspire young generation and promote public awareness of H2020 and related research. The research will benefit from the public views via the open discussion and debates.

3. Quality and Efficiency of the Implementation

3.1 Coherence and effectiveness of the WP, including appropriateness of the allocation of tasks and resources

This work plan consists of well aligned work packages (WP). The implementation is divided into several steps as coherent tasks, and these tasks produce inline deliverables.

3.1.1 Work Package Tables

WP1: Management	Mo. 1- 24	BU
Tasks: T1.1 Project meetings (weekly supervisory meeting, quarterly steering meetings) to resolve issues and track the progress within the research team to ensure the delivery of KPIs. **T1.2** Financial management with support from research administrator monthly. **T1.3** Draft the CDP and agreement on IPR management (Mo. 1, D1.1). The CDP will be reviewed and a post-project plan section will be finalized in Mo. 24. **T1.5** Projects reports to summarise the project achievement and disseminate the outputs which will be submitted to EU research portal (M1.1, M1.2).		
Training components: Project management, leadership, communication and transferable skills through shadowing and hand-on execution.		

Deliverables: D1.1 CDP and IPR management plan;		
Milestones: M1.1 Mid-term report to review the progress in first year and make a plan for next year (revise the project plan and make suitable adjustment to ensure the quality delivery); **M1.2** Final report to conclude MultiFluid		
WP2: Research visits	Mo. 4, Mo.12 and Mo. 18 - 20	[redacted]
Tasks: T2.1 Research collaboration with the [redacted] (Mo.4, Mo.18-20, D2.1, 2.3); **T2.2** Visiting industrial practitioners for validation of concepts and period outputs and steering research (Mo.12, D2.2). **Training components:** Hydrodynamics and multiphase modelling; HPC; professional software (ANSYS); CA pipeline; industrial insight; research data handling; communication skills; focus group organization; interview skills; networking		
Deliverables: D2.1 External research training report; **D2.2** A report containing facts sheets, interview summaries and research strategy review on fluid animation; **D2.3** Validation data and case (experiments and full scale simulation) for multi-phase model, that will feed in WP6.		
Milestones: N/A		
WP3: Details enhancement	Mo. 1-6	BU
Tasks: T3.1 Build multi-scale simulation framework with multi-scale space and time adaptive function and support hybrid particle and grids simulation(Mo. 1-3, D3.1); **T3.2** Develop fine fluid surface modelling from coarse sample and add Lagrange wave feature simulation (Mo. 4-5, M3.1); **T3.3** User interface, design and implementation for toolset on surface detail enhancement (Mo 6, M3.1). **Training components:** Fluid animation; cutting edge CA software; parallel coding; advanced rendering/visualisation; image based enhancing techniques and style transfer in animation;		
Deliverables: D3.1 Design of multi-scale simulation framework and its implementation (source codes and design documents);		
Milestones: M3.1 Fluid Animation Enhancement Techniques (FAETs) for surface details enhancement and related tools (design documentation, experiment report, demos and source codes). Key outcomes will be disseminated with D6.3. This will enable the consequential development in WP4, 5.		
WP4: Art effects enhancement	Mo. 7-15	BU
Tasks: T4.1 Point sampling method of 3D model and optimization with curvature, fluid motion constraint and control (Mo. 7-10, D4.1); **T4.2** Development of automatic/semi-automatic constructing skeleton through motion analysis; generation of control particles with various support radius to guide the fluid using nonlinear constraint forces; (Mo. 11-13, M4.1) **T4.3** User interface, design and implementation for toolset on art effects enhancement, where glass-like fluid artifact will be dealt with providing natural flow guided by pressure difference and controllers (particles and skeletons). (Mo. 14-15, M4.1) **Training components:** CA software skills; animation rigging techniques; fluid animation knowledge;; art creation principles and practices; advanced rendering and visualisation techniques; image based enhancing techniques and style transfer in animation;		
Deliverables: D4.1 (related to T4.1, 4.2) Fluid motion control using control particle systems (source codes and design documents);		
Milestones: M4.1 FAETs for art effects enhancement and fluid control and related tool sets (design documentation, experiment report, demos and source codes), this will be disseminated with D6.5. This will enable the consequential development in WP5.		
WP5: Physics enhancement	Mo. 16-24	BU
Tasks: T5.1 Theoretical development for heat conduction and phase transition of multi-phase fluid animation, simulating Rayleigh Taylor instability using pressure-based approach (Mo. 16-19, D5.1); **T5.2** Numerical implementation of dissolution-diffusion effect based on density field and vortex refinement, where turbulence features/structures will be studied (Mo. 20, 21, M5.1); **T5.3** User interface, design and implementation for toolset on physics enhancement supporting multiple-phase fluid with validation (using data from D2.3). (Mo. 22-24, M5.1) **Training components:** Multi-fluid modelling (theory and numerical implementation); fluid animation knowledge; cutting edge CA software; data handling;		
Deliverables: D5.1 Multi-phase fluid animation theory, formulas and case study (technical report);		
Milestones: M5.1 FAETs for physics enhancement to handle complexity in multi-phase animation and related tool sets (design documentation, experiment report, demos and source codes), this will be disseminated with D6.7. M3.1, M.4.1 and M5.1 will form a complete toolset of FAETs.		
WP6: Dissemination and communication	Mo. 1-6, 10,11, 13-15, 17,18, 22-24	BU
Tasks: T6.1 Draft communication plan to outline the communication strategy and key actions (Mo. 1,2, D6.1); **T6.2** Launch project website and set up social media accounts (Mo. 1-3, D6.2), which will be updated frequently through the project; **T6.3** Writing papers and presenting at international conferences or publishing at top journals (Mo. 4-6, 13-15, 21-24, D6.3, 6.5, 6.7); **T6.4** Public engagement activities at BU festivals (Mo. 10,11,17,18, D6.4, D6.6). **Training components:** Communication via internet/social media; academic writing; research presentation; public event organisation; public engagement; other skills;		
Deliverables: D6.1 Communication plan; **D6.2** Project website; **D6.3, 6.5, 6.7** Respective top journal publication and conference presentation; **D6.4** BFX festival public engagement activity; **D6.6** BU learning festival public engagement activity.		
Milestones: N/A		
WP7: Workshop and commercial exploitation	Mo. 12,13, 20-22	BU
Tasks: T7.1 follow up the industrial visit (T2.2) and network with key industrial stakeholders to form an interest group to exploit period research outcomes (Mo.12,13, D7.1); **T7.2** prepare and organize a workshop to deliver key research findings and outcomes to academics and industrial practitioners (Mo.20-22, M7.1). **Training components:** Industrial exploitation; networking skills; workshop organization; research dissemination;		
Deliverables: D7.1 Industrial exploitation report on fluid animation and related development;		
Milestones: M7.1 A workshop to summarise the research and invite industrial parties to exploit innovation and FAETs tools for three channels enhancement.		

3.1.2 Gantt Chat

Work Package	Year 1												Year 2											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP1: Management	D1 1											M1 1												M1 2
WP2: Research visits				D2 1								D2 2								D2 3				
WP3: Details enhancement			D3 1			M3 1																		
WP4: Art effects enhancement										D4 1					M4 1									
WP5: Physics enhancement																			D5 1					M5 1
WP6: Dissemination and communication		D6 1	D6 2			D6 3					D6 4				D6 5			D6 6						D6 7
WP7: Workshop and comecial exploitation													D7 1									M7 1		

3.1.3 Appropriateness of the allocation of tasks and resources

WP 3-5 deal with the research development and challenges associated to the three key objectives (Sect. 1.1.2). The research tasks and deliverables are consistent with the related research methods (Sect. 1.1.2). For WP 6 and 7, implementation details (such as journals, conferences, targeted audience) are listed in Sect. 2.2.

The ER, supervisor, external expertise ([redacted] and research office at BU has carefully reviewed and approved all tasks and allocated person-months, which are justified by the related deliverables/milestones. It has allocated personal months in an efficient manner to deliver the outcomes and fuse collaborations among parties. For months shared by two or more WPs, the ER will allocate his time in accordance to the priority of tasks and volume of work. The ambitious research targets are achieved by putting multi-disciplinary and cross-sectoral research expertise and resources together: the [redacted] (physics based animation; animation software and skills), the [redacted](water research and simulation), the [redacted] and other industrial stakeholders (industrial insight and knowhows). For instance, T2.1, T2.2 and T2.3 has support the inter-disciplinary research in WP3-5 to provide necessary training, ensure the steering of research and offer validation data. Resources and contacts are shared in T2.2 and T7.1. Previous publications and codes (by the ER, supervisor and peers) have lay valuable deposit to ensure the implementation will complete as scheduled. WP6 and 7 then disseminate and exploit the research to generate impacts. The supervisory and the host will ensure resources for related tasks and trainings needs are in place, such as foreground IP, IT facilities (including workstations, CA software, VR devices, scanners and other data acquisition devices), laboratory equipment, library and courses. Given the talent and track records of the fellow and the team, 24 months fellowship is appropriate to complete all the work in WPs.

Professional animation software, Houdini with simulation packs, is used to mitigate the complexity in software tool development. Fluid rendering will use existing pipeline to save development time. To accelerate the research development and maximise the ER capacity, additional human resources from a PhD student [redacted] specialised on hybrid material point method) and a part-time research assistant (RA) (up to 6 personal-months) are allocated to help with the software development, i.e. T3.3, 4.3, 5.3, which is under the supervision and guidance of the ER.

3.2 Appropriateness of the management structure and procedures, including risk management

HR, PR, RDS, Finance and Legal departments in BU will offer support for the project administration and management, including drafting legal documents, advising on IPR matters, arranging travel and site visits, co-organising workshop/outreach/communication events, purchasing, spending claim and financial audit to ensure EU policies & rules are followed. RDO's experienced team has firmly supported most research activities and exploitation. [redacted] experienced supervisor and PI of many projects, will be the main contact and take responsibility to overlook and manage the project execution. The fellow will share and shadow project management roles to coordinate meetings, supervise RA and participate in decision making. If lack of progress or other issue/risk is identified, immediate meeting will be called ([redacted]) and tangible measures will be taken in 5 working days. This will deal with issues hindering the research plan promptly. If a problem/issue cannot be resolved at this stage, it will be referred to Faculty Research Committee or higher management of BU to take an action. If in the very unlikely case, alternation to WPs and deliverables will happen, [redacted] will seek advices and support from EU REA. Deliverables, annual (intermediate) report and final project report will be submitted as scheduled to summarise achievement. [redacted] will provide supervision support when the ER visits the [redacted]

BU has secured the European Commission HR Excellence in Research Award and hosted many MSCA fellows successfully. The ER will use both BU and EURAXESS services for country-specific information, practical advice on mobility and career development to be fully integrated within the host for the duration of the fellowship.

Project Risks and Contingency Plans		
Risk	WP	Contingency
HR change	All	(Risk level - Low) In case staff (supervisor) won't be able to contribute to the project, a notice normally will be given so proper arrangement will be in place. A cover and replacement will be provided by the host.
Equipment failure and data lose	WP2-5	(Low) Data management training will be offered and cloud backup (at least weekly) is mandatary to minimise the impact of any data lose. Supporting services (IT) will arrange replacement of failure devices. New equipment will be purchased if it is in need.
Industrial advisor fails to commit	WP2,7	(Low) External industrial advisors will steer the research and conduct potential industrial exploitation. If the key contact of [redacted] might not be able to commit in a very unlikely case, replacement from [redacted] and others will be sought.
Multi-phase fluid doesn't converge with validation	WP5	(Low) In this case, investigation will be carried to identify possible cause or flaws in the models with help from supervisor and external expertise. If the problem can't be resolved, a simplified approach based on particles will be used as a contingency plan to provide useful tools and an alternative solution. Extra resources will be placed to complete the task.
Delay in key research delivery	WP3-5	(Low) Reasons of delay will be investigated. Close monitoring is in place (meetings/reports). Extra resources will be allocated to ensure the delivery in time. Alternative research strategy/method will be explored, e.g. in control enhancement, various weighting methods will be tested to provide natural fluid appearance. In the contingency plans, other tasks will start as scheduled in parallel with the delayed task and additional development plan will be added to reduce time for remaining tasks. A provisional report and tools will be elaborated to contain necessary information for carrying works that depend on it.

3.3 Appropriateness of the institutional environment (infrastructure)

MultiFluid is in line with BU's vision and 2025 strategy to support the digital creation sector with priority. **BU**(the [redacted] will fully commit into the successful delivery of the research, supporting the training, research development and use of facilities, including CA software suites, computing hardware/software (including GPU servers for fast computing and parallel processing), VR/AR device (VIVE & Hololens), meeting venue/lecture facilities, general office and IT facilities/supports and on-site library. The fellow and the project will benefit from recent €7 million investments in ICT (including new CA labs and building available in Jan, 2020). BU will ensure the supervision, supporting resources and financial management following REA's rules and guidance. BU will offer training, short courses and workshops in multiple dimensions. BU has cross-sectoral collaborations and will support this mobility with its experience in FP6, FP7 & H2020 projects. BU undertook and is currently undertaking Research and Knowledge Exchange work with 372 Organisations. It will support project events (seminars & workshop) and dissemination/public engagement activities. BU will organise influential events like Learning Festival and BFX festival, which offers networking and public engagement platform for this project. BU's previous research (AniM, AniNex) lays the knowledge deposit.

The [redacted] will offer complementary training, data and access to its facility and software (ANSYS; HPC). The [redacted] representative will join the research discussion and meetings with industrial insight.