Final Report

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1 Executive Summary

BRIDGET opens new dimensions for multimedia content creation and consumption by enhancing broadcast programmes with bridgets: links from the programme you are watching to external interactive media elements. Bridgets can be created automatically or manually by service providers or users, using either archive content or internet sources. A bridget could be enjoyed on either the main or second screen allowing for immersive augmented reality experiences. During the project a hybrid broadcast/Internet architecture has been developed and will reach final standardisation as the MPEG Media Linking Application Framework (MLAF) in early 2017. Beyond state-of-the-art results have been achieved in bridget enabling technologies. We have created and trialled prototype applications of a professional Authoring Tool (AT), easy-to-use AT and bridget player to demonstrate project results.

To ensure BRIDGET was in line with industry needs we held 3 workshops for industry. In the first, feedback helped refine the project's plans. In the second the technologies, platform and user trial results were presented to a broad representation of industries. The final workshop was used to get feedback and establish the BRIDGET Alliance, an industry forum to foster the Multimedia Hyperlinking Environment.

We developed techniques for fast video analysis offering keyframe detection for visual search purposes, scene classification, content segmentation, as well as both audio and visual quality assessment enabling broadcasters to leverage their vast archives. The visual scene classification technique was evaluated on benchmark datasets and shown to outperform the existing state of the art techniques, while the visual search-oriented keyframe detection technique has been adopted in an upcoming standard (MPEG CDVA).

Advanced visual search tools, with image-to-video and video-to-video search were developed, based on novel techniques for descriptor extraction, aggregation, indexing and fast geometric verification. Our RVD-W aggregation combined with deep features and indexing with binary sub-strings achieves world class results on ultra-large datasets, contributing to and impacting the latest MPEG visual-search standards.

The work on 3D scene reconstruction has reduced the computational requirements for 3D object reconstruction, introducing a novel representation called SPLASH to combine the modelling flexibility and robustness of SPLAts together with the rendering simplicity and maturity of meSHes. To complement the 3D visual tools a 3D audio engine was developed which includes room-specific acoustic simulations to complete the 3D immersive experience.

These technologies were integrated and trialled in the project prototypes, the first iteration of the authoring tool and player showcased MLAF and early stage research into visual search and media analysis, with a user able to create bridgets and then consume them on the second screen app. The second iteration took on board user feedback to improve the interface and integrate social media while also including the other project technologies including the 3D scene creation and representations. Additionally work was done into making the player standards compliant so that it could play more formats.

This work was tested by users after each prototype iteration. The trials ranged from small focus groups to more wide ranging international approaches. There were RAI content creators and production experts recruited to assess the professional authoring tool and end users of all ages to trial the player. Both sets of users enjoyed using the prototypes and the technologies were well received. Feedback was constructive, enabling improvements to be made and additional ideas were generated for future research directions.

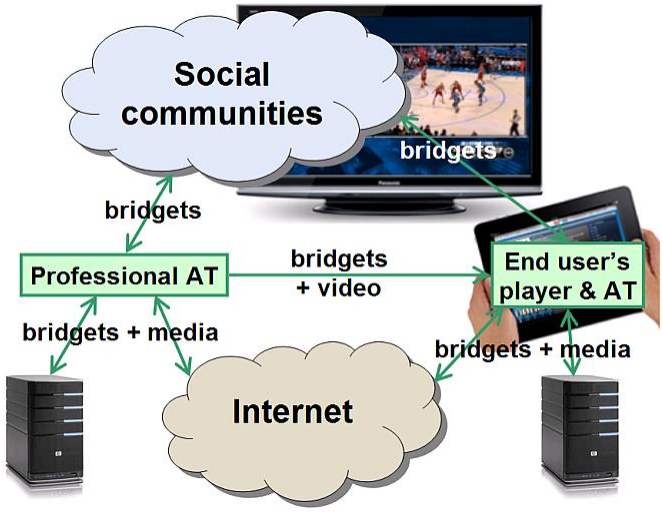
The results of the project have been disseminated to the research community via papers and conferences, to industry via workshops and trade events and to the public via exhibitions and the project website. Several of the technologies created in the project are already being exploited, there are 2 patents, VA are commercialising the media analysis tools, RAI are already planning pilots of this technology and WimTV has launched bridgeted content and applications already. Strong interest is also confirmed by the prestigious "what caught my eye" award at IBC 2015.

The way people relate to visual media has changed. BRIDGET was originally driven both by the arrival of second screen and the advancement of media analysis, search and 3D scene reconstruction for immersive content. However, BRIDGET also delivered powerful media cross-linking, in the form of the MPEG MLAF standard, with much broader applications. Our early user trials with RAI content producers showed that users are excited about this technology. By keeping a core thread of standardisation throughout the project we hope to lower the threshold of such new technologies for a truly horizontal market.

2 Project Description

BRIDGET opens new dimensions for multimedia content creation and consumption by enhancing broadcast programmes with bridgets: links from the programme you are watching to external interactive media elements such as web pages, images, audio clips, different types of video (2D, multi-view, with depth information, free viewpoint) and synthetic 3D models.

Bridgets can be:



- created automatically or manually by service providers, either from their own content (e.g., archives, Internet and other services) or from wider Internet sources;
- created by end users, either from their local archives or from Internet content;
- transmitted in the broadcast stream or independently;
- independently distributed by users e.g. via social networks;
- filtered by a recommendation engine based on user profile, relevance, quality, etc.;
- enjoyed on the common main screen or a private second screen, in a user-centric and immersive manner, e.g., within 3D models allowing users to place themselves inside an Augmented Reality (AR) scene at the exact location from which the linked content was captured.

To deliver the above, BRIDGET has developed:

- a hybrid broadcast/Internet architecture;
- a professional Authoring Tool (AT) to generate bridgets and dynamic AR scenes with spatialised audio;
- an easy-to-use AT for end users;
- a player to select bridgets, and consume and navigate the resulting dynamic AR scenes.

The AT and player use a range of sophisticated and innovative technologies, extending the state-of-the-art in media analysis, visual search, and 3D scene reconstruction. This enables customised and context-adapted hybrid broadcast/Internet services offering enhanced interactive, multi-screen, social and immersive content for new forms of AR experiences. BRIDGET tools are based on and contribute to international standards, thus ensuring the creation of a true horizontal market and ecosystem for connected TV and contributed media applications.

3 Research & Development Areas of Interest

BRIDGET was driven by the change in the way people relate to visual media: digital TV, IPTV, multichannel, user-generated content, interactivity, second screens, etc. There are several specific elements that came together to drive BRIDGET:

- The second screen phenomenon became a powerful complement to existing successful live services, such as TV. However, the use of the second screen, while triggered by the service providers' content, often happened independently of them. BRIDGET aimed to bring the second screen content closer to that of the service providers, offering a mix of their content and content that is semantically linked.
- Sophisticated signal processing technologies that were nearing readiness for consumer use, such as media analysis and visual search, 3D scene reconstruction, and authoring tools for interactive, multi-screen, social and immersive content. BRIDGET improved these technologies and uses them to leverage the most valuable service provider's asset, the broadcast content, by enriching it with **links to audio or visual content or time portions** that we call "bridge points" or ***bridgets***.

- Having developed easy-to-use bridget authoring tools, BRIDGET is stimulating newer forms of creativity for both professional and end-user-generated, immersive and interactive digital media content. Our feedback from our colleagues at RAI has been fantastic and we've enjoyed watching how excited they get about the possibilities for second screen content served via *bridgets*.
- BRIDGET was determined to exploit international standards because they lower the threshold of acceptance of such new technologies and create a true horizontal market and ecosystem for connected TV and interactive media applications. With the consortium being established members of MPEG we created a draft international standard for Media Linking Application Format (MLAF) that is anticipated to be published by ISO in early 2017.

4 Activities and Results

BRIDGET held 3 workshops. In the first industry feedback was used to consolidate the project's plans, develop requirements and functionalities, and define the first set of use scenarios. In the second the results of the first year – technologies, platform and user trial results – were presented to a broad representation of industries potentially affected by BRIDGET, receiving valuable feedback. This and the reviewers' comments were used to revise the requirements and functionalities, and define a new set of use scenarios. The third workshop was used to get final feedback from industry representatives and to sense the interest in the establishment of a BRIDGET Alliance, an industry forum designed to foster industry application of the Multimedia Hyperlinking Environment, of which second screen is the first step.

The project has a strong view towards standardisation and has developed The Media Linking Application Format which has been submitted to ISO/IEC MPEG and it is expected to be published in early 2017 as an International Standard. This standard has been honed throughout the project to incorporate the feedback from both industry and end users.

In addition, to support the MPEG standardisation activity on Compact Descriptors for Video Analysis, we looked at the issue of fast video analysis and keyframe selection for visual search purposes, enabling broadcasters to leverage their vast archives. As part of this work we have developed two techniques, one based on RVD-W and one based on the variation of colour histograms, the latter of which achieved the speed and performance required for adoption by MPEG. Furthermore, we developed a visual scene classification technique based on combination of CNN features with the RVD-W aggregation scheme, achieving beyond state-of-the-art performance on a range of benchmark datasets. We have developed a suite of components for visual quality assessment for triaging archive data and an audio quality assessment architecture to aid evaluation of the robustness of audio fingerprint-based synchronisation during bridget authoring.

We have completed development of visual search tools operating on video databases, with image-to-video and video-to-video search capabilities, including techniques for descriptor encoding, temporal aggregation, descriptor tracking and fast geometric consistency check in video. Furthermore, we extended our RVD-W to work with deep features, showing significant improvement over existing state-of-the art methods such as sum or max-pooling aggregation. A novel indexing method using binary sub-strings of variable length have been proposed and developed, achieving a speedup by a factor of between 10-1000 times when compared with the prior art Multi-Index Hashing method. The work on RVDW and local binary descriptors has been published in IEEE Transactions PAMI and IEEE Transaction on Multimedia, sub-string matching at CVPR-16, while our paper "On Aggregation of Local Binary Descriptors" received the "Best paper award" at the ICME 2016 (3rd IEEE International Mobile Multimedia Computing workshop). 5 contributions were made to the MPEG CVDS/CDVA standardization work with significant impact, and our work on temporal sampling, improvements to temporal localisation of search and speed of the MPEG experimental model were adopted.

For 3D media tools, significant research and implementation progress was made during the project. An overall workflow was established and implemented which covers all 3D media aspects: data acquisition, modelling/representation, processing, encoding, decoding, and rendering. From the research viewpoint, the 3D reconstruction pipeline was significantly improved by developing smart algorithms to effectively reduce computational complexity. Further, a novel hybrid format for 3D objects based on SPLAts and meshes (SPLASH) was developed and evaluated which combines the advantages of both mesh-based and

splat-based formats to improve the 3D models created without significantly increasing the computational power required, a necessary advancement to bring quality 3D models to the second screen. The dense depth-based surface reconstruction was improved by including initial point clouds to launch the 3D estimation process. A 3D audio engine was developed including an algorithm for room-specific acoustics simulations based on implicit representation of its geometry, using 3D audio on the second screen content will improve the immersive experience. For 3D media encoding, a compression method for hybrid SPLASH 3D models was developed to exploit the correlation between the locations of splat centres and mesh vertices making the models easier to store and transmit. Additionally, for surface patch representation, an efficient mesh size reduction was addressed. For rendering, several algorithmic improvements were applied to the video-to-point cloud integration frameworks; the tools for textured mesh and splat models were adapted to support the new features of the hybrid SPLASH models, and the surface patch rendering was improved by developing dedicated refinement strategies in order to obtain smooth surfaces without visible artefacts at surface patch borders. With respect to audio, an algorithm for online rendering has been developed which enables the user to change the "viewing" angle by rotating the scene and thus observing it in full 360°.

For integration into the BRIDGET applications a complete and fully automatic workflow for 3D model acquisition was implemented and tested which covers all 3D media aspects: data acquisition, modelling/representation, processing, encoding, decoding, and rendering. The off-line extraction (and generation, if needed), at the service provider's Authoring Tool (AT) and 3D models from 2D/3D video data for broadcast/internet delivery was addressed. Additionally, free viewpoint scene representation at the user's player, either from a set of pre-defined viewpoints from which the scene was originally recorded, or through free navigation around the scene was developed. At the broadcaster's side, the professional AT enables the content creator to run a semi-automatic extraction of 3D scene information from archived (and, typically, previously broadcast) 2D/3D video content. Further, associated content from the Internet, including images, videos and CG data, if available, can be used as well to complete the 3D scene information. 3D audio source localisation methods based on binaural synthesis were supported for reconstruction purposes. The 3D audio engine also supports "recorded audio bridgets" – bridgets that provide interactive 3D audio reconstruction of a scene recorded with free-field microphone array. Based on this, solutions for an efficient encoding and decoding of 3D media were evaluated and adapted in order to achieve an efficient transmission from the service provider's AT to the end user's device. The projection and rendering of 3D scene data according to the user-selected viewpoint from a set of original viewpoints was investigated. In this context, 3D audio was aimed to be adapted and rendered according to the chosen viewpoint. Additional views for free scene navigation around original viewpoints can also be provided within the limits of the model data.

The BRIDGET applications team had a threefold scope: *i*) designing seamless and effective user interfaces for BRIDGET tools; *ii*) conducting research on innovative media rendering technologies, with particular emphasis on low complexity methods well suited to mobile devices; and *iii*) integrating the results of the state-of-the-art research into a unified software/hardware architecture.

The project provided a two stage prototype development schedule. The first prototypes show cased the media linking application framework developed within the project. It involved a player that responded to the first screen to display bridgets and an Authoring Tool for creating bridgets using the early visual search tools. Within the second development phase the user interface designed in the previous project phase was refined, additional media representations (e.g. 3D models) were added, social network services were integrated and end-user created content was supported. Algorithmic optimisations for real-time rendering of advanced media formats (synthetic 3D models and binaural audio) were implemented and new data formats were supported. The second release of BRIDGET Authoring Tool (AT) and BRIDGET Player also include a number of functionalities like 3D graphics as destination content, 3D object reconstruction, mesh and point cloud WebGL viewers for 3D objects, a dashboard to orchestrate bridget activation during the live TV programs, an extensive layout editor and support for ARAF format.

4.1 Project Applications

BRIDGET combined cutting edge research in several areas and presented it in three applications for use in the creation and consumption of bridgets. There is a multi-screen player, an authoring tool for professional

use and a mini authoring tool for consumer use. The authoring tools integrate the BRIDGET research, which is focussed on making service providers' and personal archives more manageable. They enable the authors to access and create 3D models and point clouds for inclusion in their bridgets. The player in turn allows consumption of bridgets across multiple different environments.

4.1.1 Authoring Tool

By the end of the first year of the project the Professional Authoring tool was already taking shape, with interfaces to many of the tools being developed by the research teams. In the second year that integration continued and new tools were continually being added as they were developed. The authoring tool gained functionalities for managing user-specific content, extended meta-data fields, meta-data based search, a bridget layout editor and bridget reuse for modifying or as bases for new content. We took on board feedback from professional users which has enabled us to improve the interfaces and usability. The final version of the authoring tool contains 3D reconstruction engines and the live programs orchestrator (the dashboard).

4.1.2 BRIDGET Player

Already by the end of the first year the player was capable of displaying bridgets synchronised with the main screen and had been integrated with WimTV to show how it can work in a real life setting. In the second year it brought you immersive media rendering allowing users to explore 3D models on their android device, see Figure 1 for some examples. The team worked hard to keep up with the android releases with each update offering new challenges. They've also added links to facebook and twitter to tie in to the social media-sphere so people can share their favourite bridgets. The final year worked on making the player compatible with more standards so that it would be MPEG-4 compliant and better able to synchronise with the main screen.

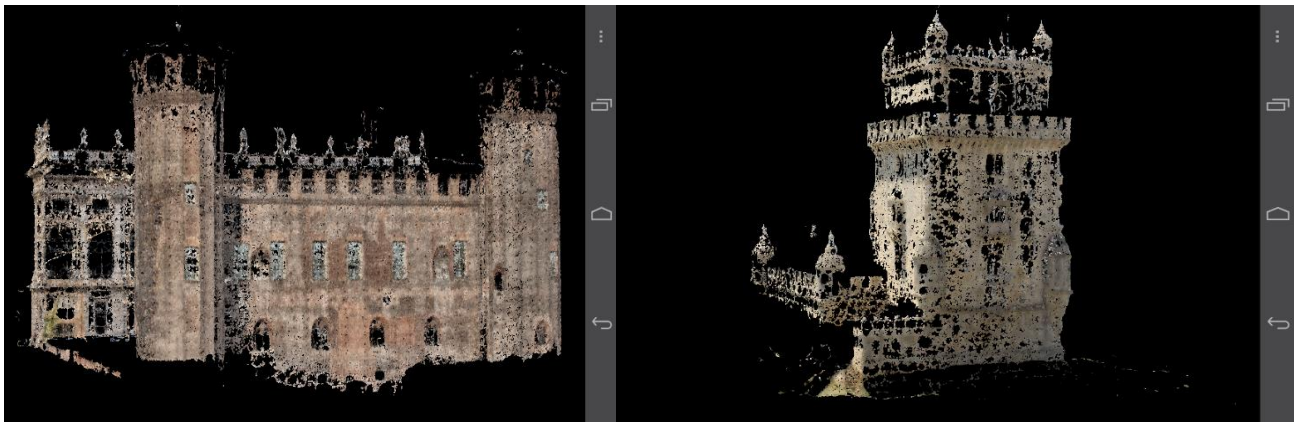


Figure 1 Splats rendering Bridget player on a mobile device running on Android

4.2 User Involvements & Evaluation

The project ran 2 rounds of user trials, the first in the second year had trials for each of the prototypes; the authoring tool was trialled in RAI's Turin Production Centre premises between July and August 2015, the player was trialled by end users at Telecom Italia's Joint Open Laboratory in October 2015.

Figure 2 Example of a BRIDGET player layout for the programme GulpGirl

The second batch of user trials were more intensive and were subdivided into three main activities: a) execution of Professional Authoring Tool user trials; b) execution of End-user Player Application user trials in focus groups; c) execution of End-user Player Application user trials in field trial. The first activity took place at RAI's Turin Production Centre premises between August and September 2016. The second activity tok place at Rai Turin R&D Department in July 2016. The third activity was performed across the Univ. of Surrey, IMT and Univ. Politecnica de Madrid during the first half of October 2016. In total 136 users tested the final prototypes.

The authoring tool trials were well received and many of the users felt they were able to create bridgets with the current provisions. They offered several ideas for future work ranging from content organisation to wysiwyg lay-out editors and integration with existing enterprise services. The second round of trials show no diminishment of the desire to use bridgets and the added functionalities to aid archive management for bridget development were well received. While the quality of the automatically created 3D models was acknowledged not to be sufficient for the main screen the evaluators were excited by the concept and appreciated the fact that the entry requirements were low for programme makers to create basic 3D models.

The BRIDGET player was positively received during both the trials with users finding the prototypes easy to interact with and contained interesting content. They were able to navigate the app without significant problems and liked the 2 layouts we'd designed for the trial, see Figure 2 for an example. From an innovation point of view they enjoyed that the bridgets knew when to start so that relevant information was always available. They also saw it as a great way to extend many different types of programmes. Again it was satisfying that even during the latest user trials which took place in the last month of the project the ideas were still seen as novel and the main comments for improvements were directed at the cosmetic details rather than the underlying paradigms.

5 Impact and Future Exploitation Prospects

5.1 Dissemination Strategy

The dissemination results of the project include:

- its own twenty-six public deliverables (e.g., its website), three workshops and five batches of user trials;
- the publication of seven peer-reviewed research papers in prestigious international journals, plus another fourteen in equally well-known international conferences;
- the filing of three patents;
- the active participation in another six public events (workshops, conventions, etc.);
- the joint establishment, together with another three EU-funded research projects, of the "Second Screen CC Content Convergence" mini-cluster.

Perhaps more important are the standardisation results of the project, which are notable, since all BRIDGET partners are very active in the development of ISs (International Standards), both within ISO and other standardisation fora, and firm believers in their societal impact. The BRIDGET Consortium has

designed its various technological tools and system architecture, together with the corresponding module interfaces, based on previously existing ISs, with the aim of lowering the threshold of their acceptance, and helping create a horizontal market/ecosystem for interactive media applications. What is more, BRIDGET has managed as well to have an impact on future ISs by submitting its tools and system architecture/interfaces to the relevant fora, notably MPEG (Moving Picture Experts Group, formally, ISO/IEC JTC 1/SC 29/WG 11). The most important outcomes of BRIDGET in this respect have been:

- Sixty-eight proposals and technical contributions co-authored by BRIDGET members have been submitted to MPEG, and discussed at its meetings (ten during BRIDGET's lifetime).
- Twenty-six (forty-one counting successively refined versions) output documents co-edited by BRIDGET researchers have been agreed upon and approved at MPEG meetings. In particular, the following document reached the FDIS (Final Draft International Standard) status in August 2016, and should be published by ISO as an IS before the end of January 2017: A. Messina (RAI), T. Lavric, M. Preda (IMT), "Text of **ISO/IEC FDIS 23000-18 Media Linking Application Format**", MPEG output doc. N16184, 115th MPEG mtg., Genève, CH, June 2016.

5.1.1 BRIDGET Web Site

The BRIDGET website (http://ict-bridget.eu) is the project's main public communication tool. It reflects the project's aims, research and scientific impact. This is the place where all information related to BRIDGET is stored and made accessible to interested parties. A full list of papers and copies of public project deliverables are available on the website.

5.1.2 Scientific Community and Industry

Dissemination to scientific community is based on bilateral exchange of information with major scientific institutions as well as communication of project achievements in conferences and through publications. Dissemination of knowledge within the scientific community is done via presentation of research methodologies, strategies and outcomes at conferences pertinent to the key BRIDGET technologies. Ongoing dissemination to the wider academic community has already taken place in several peer reviewed international publications. As part of this BRIDGET project partners have attended the following scientific dissemination venues to present research papers:

- International Conference on 3D web technology.
- International Conference on Interactive Experiences for TV and online Video.
- International Broadcasting Convention.
- International Conference on Image Processing.
- International Conference on Computer Vision and Pattern Recognition

5.1.3 Dissemination in View of Future Exploitation

One of the main strengths of the BRIDGET consortium is their strong ties to industry. This has resulted in BRIDGET attending industry workshops and events, to better disseminate the technologies being developed as part of the project. With the development of the prototypes BRIDGET has been able to take engaging demonstrators to key venues:

- IBC 2015: BRIDGET had a successful exhibition at IBC, where we shared a CC Mini-Cluster stand with 3 companion EU projects (MediaScape, SAM and LinkTV). BRIDGET presented demos including the full delivery chain with bridgets being served from a remote server, with the main TV channel and two 2nd screen devices. We received very positive feedback from the many broadcasters and content providers who visited our stand. We also showed off the Authoring tool to create Bridgets with the underlying 3D reconstruction and the Visual Search Engine for Images and Videos. BRIDGET received the prestigious IBC award *"What Caught my Eye – Blue Sky Thinking"*, together with our colleagues at the CC Mini-Cluster stand.

- The consortium also presented a paper at IBC conference, detailing the forthcoming MLAF MPEG standard, which helped to publicise the work we were doing and send a steady stream of visitors to our booth.
- 67th Prix Italia: BRIDGET partner RAI demonstrated the project's player application at 67th edition of Prix Italia, held in Torino between 19th and 24th September 2015. Prix Italia is an international competition for television, radio and online media which attracts hundreds of visitors from around the world. The event helped the project increase its visibility inside RAI's production department and among the widest audience of international producers and programme makers with an overall good feedback.
- EBU Metadata Developer Network Workshop: During the first day of EBU's Metadata Developer Network Seminar (MDN 2015) BRIDGET presented a contribution about applications of CDVS in media and broadcasting. MDN is an annual workshop presenting technological innovations and new applications in the area of metadata and its audience includes EBU members' technology experts as well as external experts coming from industry and academia.
- IFA 2106: IFA (Internationale FunkAusstellung Berlin, i.e., intl. radio exhibition Berlin) is one of the oldest industrial exhibitions in Germany, and one of world's leading trade shows for consumer electronics and home appliances. It is (currently) an annual event held in Berlin at the beginning of September 2016. FHG had a booth at IFA 2016 and took this opportunity to show the 3D reconstruction tools developed within BRIDGET and to distribute flyers publicising the whole project.
- IBC 2016: IBC (International Broadcasting Convention), held annually in September in Amsterdam, is Europe's largest professional trade show for broadcasters, content creators/providers, equipment manufacturers, professional and technical associations, and other participants in the broadcasting industry. However, in recent years IBC has de-highlighted its broadcasting focus, and instead marketed its exhibition as the world's largest focused on media and entertainment. BRIDGET had already had a successful time at IBC 2015: we not only presented one technical paper, but also shared with SAM and another two companion EU projects the "Second Screen CC (Content Convergence)" mini-cluster stand, which received the "What Caught my Eye – Blue Sky Thinking" award for the most promising technologies. At IBC 2016, as in the case of IFA 2016, FHG had a booth and used it to show the 3D reconstruction tools developed within BRIDGET and to distribute flyers publicising the whole project. Furthermore, UNIS and VA demonstrated BRIDGET's delivery and visual search tools in the IBC Future Zone, where SAM and BRIDGET shared again a booth. This demonstration attracted strong interest and was seen by over 60 visitors, leading to preliminary discussions on commercialisation opportunities.

5.1.4 Key Stakeholders

Following feedback after the first workshop we decided to change the format for our second workshop and instead we held a 'Distributed Workshop' that allowed us to communicate with more Key Stakeholders from industry. We interviewed 28 individuals from Broadcasting, Cable, Commercial, Consulting, Cultural, Education, OTT, Publishing, Research, Technology and Telco companies from 13 countries in Europe, Asia and America. From this we have garnered extremely valuable feedback on our current prototypes and we will be using this to help direct the research during the final year of the project and beyond.

5.2 Collaboration between Consortium Members

The members of the partners have known each other for a long time, they have cooperated for many years in common standardisation bodies, such as MPEG. In addition they have variously teamed up with some of these and other partners in successful European projects, and effected experts' exchanges.

Currently members of the BRIDGET consortium are collaborating within the following projects and standardisation groups: MPEG-CVDS, MPEG-CDVA, MPEG-Requirements, EBU-Automated Metadata Extraction (SCAIE).

5.3 Clustering Activities

BRIDGET is involved in several activities, which encourage knowledge sharing within their domains of expertise:

- The project established direct links with 3 related EU projects: LinkedTV, MediaScape and SAM, creating the so-called 2nd Screen CC (Content Convergence) mini-cluster. It is a collaborative initiative focused on developing innovative solutions for production, delivery, consumption and ecosystems for monetisation of 2nd Screen content. We held join meetings, presentations, and exchanges.
- The project co-organised the MPEG CVDS Awareness Event in June 2015. We contributed presentations on "CDVS vision, applications and opportunities" and "CDVS standard, technologies and resources" and demos including "Authoring for second screen applications using CDVS", "CDVS in media postproduction applications", and "CDVS on mobile GPUs".

6 Useful Links

BRIDGET Project main site: http://ict-bridget.eu

Centre For Vision Speech and Signal Processing
University of Surrey
www.surrey.ac.uk/CVSSP

CEDEO SAS di Chiariglione Leonardo e C.
www.cedeo.net/

Heinrich Hertz Institute
Fraunhofer Gesellschaft zur
Foerderung der Angewandten Forschung E.V.
www.fraunhofer.de/

Huawei Technologies Düsseldorf GmbH
www.huawei.com/

Institut Mines-Télécom
www.mines-telecom.fr/

RAI – Radiotelevisione Italiana
www.rai.it/

Telecom Italia S.p.A.
www.telecomitalia.com/

Grupo de Tratamiento de Imágenes
Universidad Politécnica de Madrid
www.gti.ssr.upm.es/

Visual Atoms
visualatoms.com/