

## Drones and Drawings - methods of data acquisition, management, and representation

The use of UAVs is increasingly widespread in activities related to the documentation of Cultural Heritage. In recent years we have seen the fast development of methodologies, calculation platforms, and tools aimed at integrating heterogeneous data, especially from survey campaigns that use drones to reach privileged observation points and ensure full coverage of the investigated object. The definition of increasingly specific and reliable photogrammetric acquisition procedures, also thanks to the widespread use of small drones (micro and mini UAVs), has produced significant experiments and interesting results in the archaeological, architectural, and territorial fields. Universities, research centres, and companies are increasingly involved in activities to optimize the related information acquisition and management processes. The common objective of these researches is to arrive at an effective configuration of integrated, verified, and disre-

tized data, from which to structure valid multiscale and multilevel representation systems. Thus, the different categories of drones, UAS (Unmanned Aerial Systems), USV (Unmanned Surface Vehicles), and UUV (Unmanned Underwater Vehicles), today applied for the documentation of heritage, find their specific field of experimentation also in the Design area, integrating systems and measurement tools to contribute to the definition of new and unique databases and systems of representation of the Cultural Heritage. With the editing of this issue, the aim was to promote an interdisciplinary and international discussion on recent experiences on the topic of the use of drones in the field of Surveying and Drawing, providing a moment of reflection between different research realities in the field of architectural and territorial documentation.



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The conversion of the analogical extent of physical space into its virtual configuration has marked, as is well known, an epochal turning point for the field of Design and Representation. The "digital" development and the profound change in manufacturing and society patterns that derives from it entail a transformation both in data acquisition and storage methods and in the quantity and typology of processing and results. These very often unexpected outcomes constantly renew the demand, leading to the development and deployment of new technologies, methodologies and applications. This virtuous circle encourages the testing of innovative documentation, management, and knowledge utilisation processes, as well as leading to the generation of new configurations and new representations versions of the object under investigation. Furthermore, the potential for digital replicas now makes it possible to explore novel approaches to valorisation and conservation, increasingly oriented towards time and cost reduction and aimed at preserving Cultural Heritage, and not only, and preserving its memory.

Developing digital and innovative documentation equipment, especially related to expeditious surveying, leads to reconsidering and defining new acquisition formats and protocols. The several generated outputs can be used as specific tools, in accordance with their own descriptors, to support musealisation projects, material or structural analysis, risk monitoring, and state-of-the-art conservation of a specific piece of historical heritage. In particular, the development of acquisition methodologies based on mobile laser or photogrammetric techniques is gaining relevance when carrying out the development of studies and research on a particularly extensive heritage, i.e., on an urban and territorial scale. In these cases, technology is constantly improving to meet the need for transportability or wearability of the instrument, thus aiding the operator and significantly reducing working time. Hence, traditional fixed scanning systems are combined with rapid survey dynamic approaches and methods, based on LiDAR and/or photogrammetric. This one is able not only to complete the possible missing



data that could not be acquired with Laser Scanner instruments due to location or non-accessibility, but is also becoming the preferred tool for carrying out survey campaigns, - for a never insufficient redundancy of readings, the basis of measurement theory - verified through ad-hoc targeted data provided by static instruments, whenever necessary.

The popularity of Unmanned Aircraft Systems (UAS) for data collection in many technical-scientific fields (survey sciences, topography, engineering, architecture, agronomy, etc.) is attributable to their affordable cost and the speed of obtaining valid outputs in terms of documenting the existing heritage. Combining these two features makes them ideal for implementing new photogrammetric and videogrammetric acquisition protocols. Moreover, the affordability and versatility of drones currently on the market allow for the ongoing development of automatic applications within workflows that concern more than just the documentation of cultural heritage but also, for example, new communicative forms inherent to performance Art: the merging of art and technology, expressed in the exchange of languages and innovative expression forms, elevates drones from mere tools to a possible art form. In this sense, current acquisition methodologies impact the workflows and specialists' work practices and, at the same time, affect the way of new digital representation models are processed and transmitted.



Fig. 1 - Drones as a tools for landscape analysis and representation. By A. Bosino, N. Mengoni, E. Ferrari, C. Lupi, C. Perotti "Art and Drones: Retracting the paths of Torquato Taramelli 100 years later" (Proceedings of the 2nd D-Site conference).

Fig.2 - Use of UAV for inspections and detailed acquisitions of outdoor and indoor environments. Image by P. Becherini, R. Volzone, A. Cottini, "A 3D model for architectural analysis, using aerial photogrammetry, for the digital documentation of the convent of Santa Maria da Insua, on the northern boarder between Portugal and Spain". (Proceedings of the 2nd D-Site conference).





The digitisation of heritage and the range and quality of databases resulting from the application of micro and mini UAVs (Unmanned Aerial Vehicles) are prompting research to focus on their integration and potential purposes. This focus lays the foundations for a reflection on conceivable digital scenarios whereby semi-automated tools depicting our present can shape aspects of our near future.

The call "Drones and Drawings – methods of data acquisition, management, and representation" aimed to trigger a national and international discussion, connecting professionals and research institutes for a shared state-of-the-art definition of the phenomenon of the UAVs' use in the field of Cultural Heritage and, generally speaking, in the field of Drawing and Representation. The call focused on topics concerning data acquisition and management methodologies and processes, also opening up the debate to those research areas that deal with earth sciences and the manufacturing and use of drones.

The 17 selected papers describe national and international research experiences, illustrating the various application and expressive possibilities of UAV technologies through a heterogeneous and multidisciplinary excursus involving in-depth methodological and theoretical insights. The resulting organic overview lays the foundations for developing new possible analysis systems and contributes to the rise of innovative multidisciplinary methodologies related to Architectural and Landscape Design and Representation by gathering the most up-to-date documentation practices in this field.

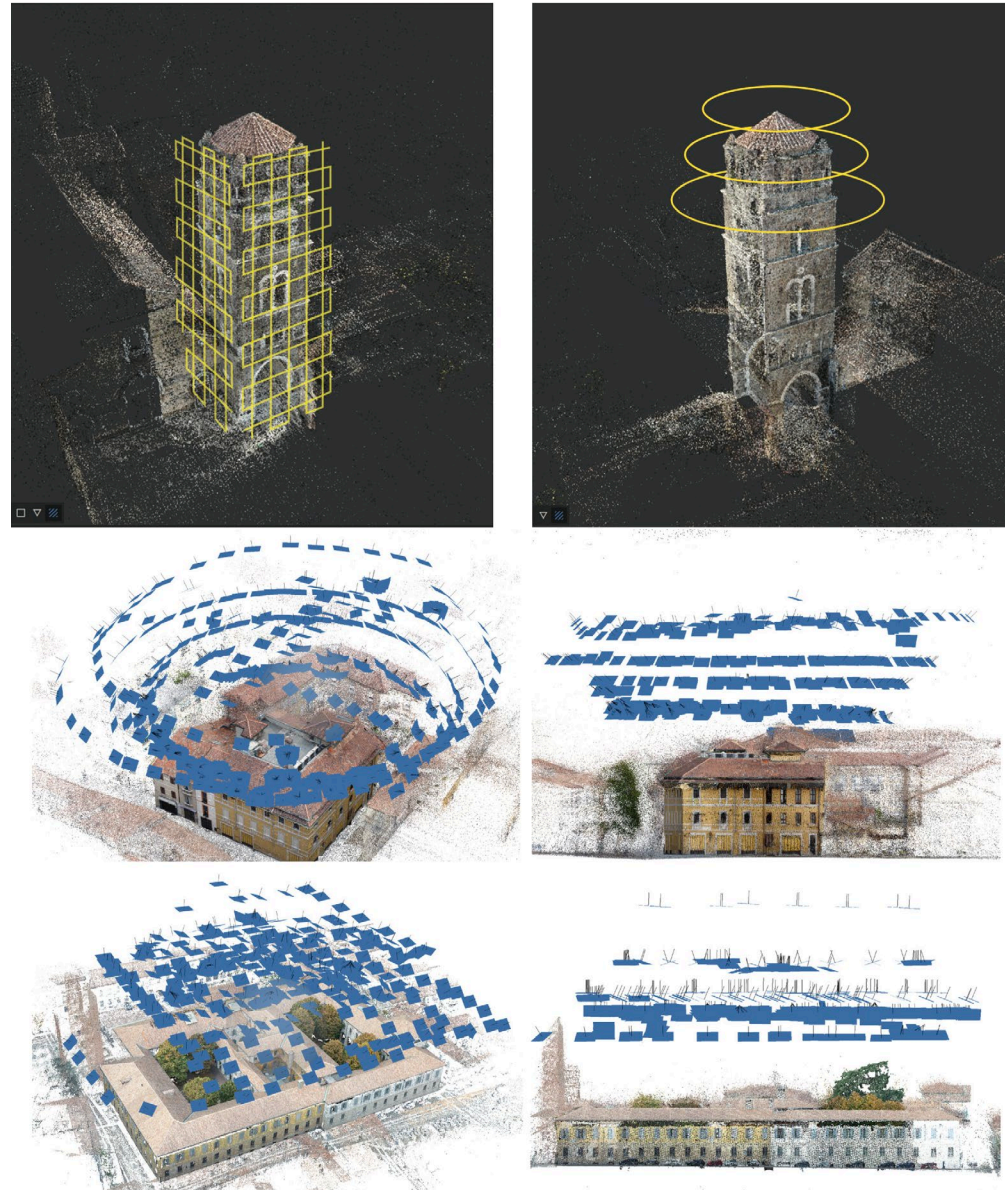


Fig. 3 - Flight plans and acquisition methodologies for the description of horizontal and vertical surfaces. Image above by O. Zerlenga, G. De Matteis, S. Sibilo, G. Ciampi, V. Cirillo, R. Miele, Y. Spanodimitriou, R. Iaderosa "Open source procedure for UAV- based photogrammetry and infrared thermography in the survey of masonry bell towers". Image below by R. De Marco, E. Doria "The processing of UAV 3D models for the recognition of coverages at the technological scale: opportunities for a strategy of conservation monitoring" (Proceedings of the 2nd D-Site conference).

The heterogeneity of the illustrated case studies and research methodologies provides a continuous exchange of perspectives from different experiences and competencies, establishing the technical and theoretical basis for developing innovative methods and representation systems for the built heritage. A macro-thematic critical synthesis of the individual contributions is presented hereinafter, starting from the most generalised topics related to the drones' employment for documentation at a territorial and architectural scale to specific topics regarding the potential of the collected data for different communication purposes.

The present issue sought to initiate this interdisciplinary experience narrative with a piece offering a general, albeit highly topical, outlook on using drones for documenting heritage. Pablo Rodríguez-Navarro, Pedro M. Cabezas-Bernal, Teresa Gil-Piqueras, and Manuel Giménez Ribera present a reflection and performance comparison on using different low-cost drones on the market – all under 250 g – which are, therefore, widely used among surveyors. To verify their limits and potential, the authors test the optics and distortion of a few models upon highly morphologically complex architectural details, evaluating the geometric accuracy of the SfM model thus obtained. Fabrizio Agnello and Mirco Cannella propose a more specific reflection from continuous to the discrete representation of the photogrammetric models. Their study case deals with the complex workflow process of photogrammetric mesh model segmentation of an archaeological excavation, i.e., the Temple G in Selinunte, for information management via web-based systems. The use of drone photogrammetry, in this case, integrates databases obtained from diverse instruments, but it gains its own communicative autonomy during the computerisation stages concerning the texturized model.

Spanning the fields of archaeology and landscape, Michele Russo, Federico Panarotto, Giulia Flenghi, Valentina Russo, and Alberto Pellegrinelli are proposing the implementation of an integrated image-based and range-based methodology on

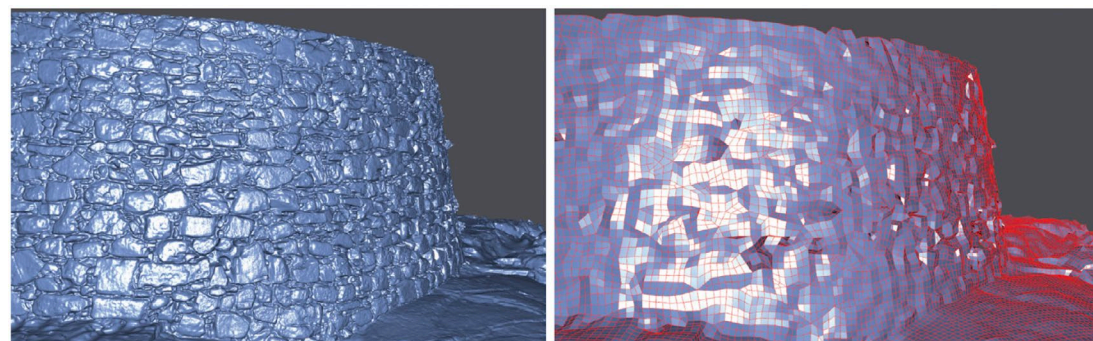
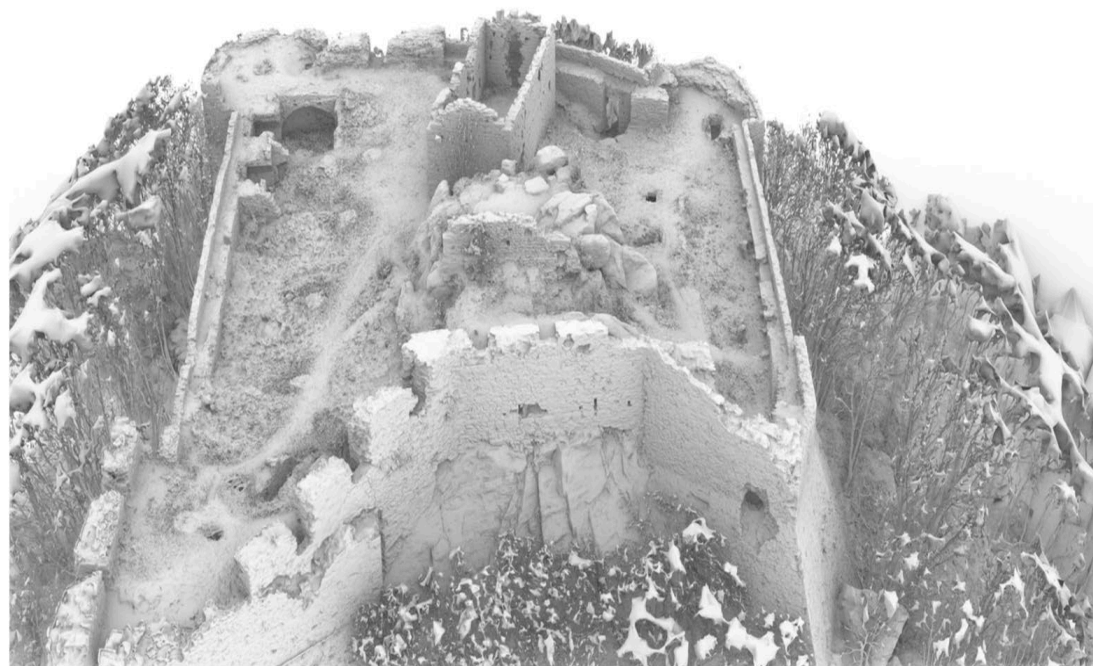


Fig. 4 - 3D modeling process: High-poly and low-poly 3D model comparison. Image above by G. Pancani, M. Bigongiari "The aerial photogrammetric survey for the documentation of the cultural heritage: the Verruca fortress on the Pisan Mountains". Image below by R. Quattrini, R. Angeloni, B. Di Leo "Data integration and optimization for Cultural Heritage fruition. The case study of the Rail-to-Land Project". (Proceedings of the 2nd D-Site conference).





Fig. 5 - Semanticisation and reconstruction of the urban fabric from a drone photogrammetric acquisition. Image above by M. Canciani, M. D'Angelico "A methodology for survey, documentation and virtual reconstruction of historical centers in a seismic area: the case study of Arquata del Tronto". Image below by C. Costantino, A. C. Benedetti, G. Predari, "UAV Photogrammetric survey as a fast and low-cost tool to foster the conservation of small villages. The case study of San Giovanni Lipioni". (Proceedings of the 2nd D-Site conference).

the Castello di Canossa in the Reggio Emilia Apennines. This landscape context is difficult to reach and requires the setting up of a multi-instrumental acquisition campaign. The research aims to achieve a multi-scale geometric information model and verify the metric and overall metric and geometric accuracy obtained. Furthermore, the necessity of using drones for particularly inaccessible environments or those considered fragile due to peculiar morphological or typological conditions is reiterated in the paper written by Adriana Marra, Francesca Savini, Marco Giallonardo, Giovanni Fabbrocino, and Ilaria Trizio. Their thorough methodological experimentation on the damaged area of the Navelli village deals with the theme of integrating a variety of sensor data, particularly SLAM (Simultaneous Localization And Mapping) and photogrammetric technologies, to produce georeferenced models; the accuracy and richness

of the information acquired and processed make it possible to perform multidisciplinary investigations. Saverio D'Auria, Maria Ines Pascariello, Giuseppe Antuono, and Tomás E. Martínez Chao discuss the potential of photogrammetric representation to depict the image of the city. Their case study focuses on a characteristic spot in Naples and addresses the processes of semantic segmentation, discretisation and classification of photogrammetric data for investigations to identify the identity features of both urban aggregates and individual façades. Moving from the historical-urban fabric to the architectural scale, we meet some contributions that report the importance of using the photogrammetric tool in a survey campaign to complement LiDAR data so as to fully understand the geometric and typological structure of a specific architectural complex. This is the case of Mariateresa

Galizia, Graziana D'Agostino, Raissa Garozzo, and Marco Bertolone, who present their experience in the integrated survey of the Massimo Bellini Theatre in Adriano, proposing not only an overview of the building but also a comparative metric and geometric analysis between the LiDAR and the UAV data with respect to their overlapping surfaces. The same idea also emerges from the paper presented by Manuela Piscitelli, who exploits the drone's capabilities to document the external geometry of the Santa Maria della Purità dome in Campania. She integrates the data obtained with the laser database to assess the criticality of the degradation in progress, providing an overall 3D view of the asset. The paper presented by Marta Quintilla-Castán and Luis Agustín-Hernández also addresses the issue of UAV and LiDAR data integration for generating comprehensive databases on an extensive cultural heritage, comprising both

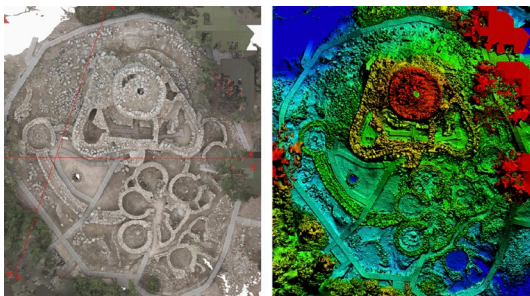


Fig. 6 - Analysis processes on photogrammetric models for heritage knowledge, monitoring and management. From the top, C. Grassi, D. Ronchi, D. Ferdiani, G. F. Pocobelli, R. Manganelli Del Fà, "A 3D Survey in Archaeology. Comparison among Software for Image and Range-Based Data Integration"; in the center, L. Formigari, V. Vona, M. Zuppiroli "Towards an "allround" control of the restoration project: 3D modelling as a real-time monitoring system for the design outcome"; below, F. Fiorillo, L. Perfetti, G. Cardani, "Aerial-photogrammetric survey for supervised classification and mapping of roof damage  
 Workflow of the proposed methodology for damage mapping of roof covering based on supervised image segmentation". (Proceedings of the 2nd D-Site conference).

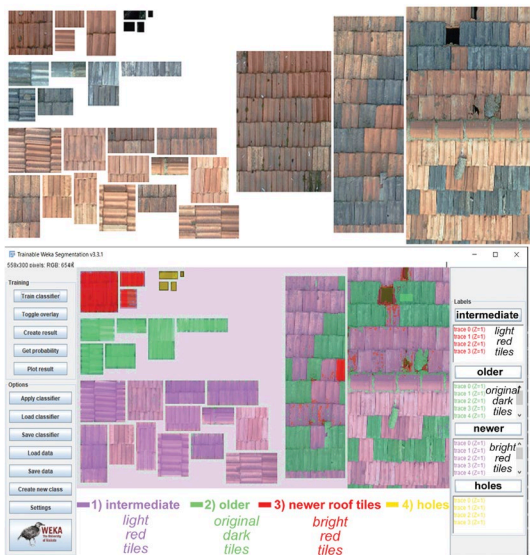
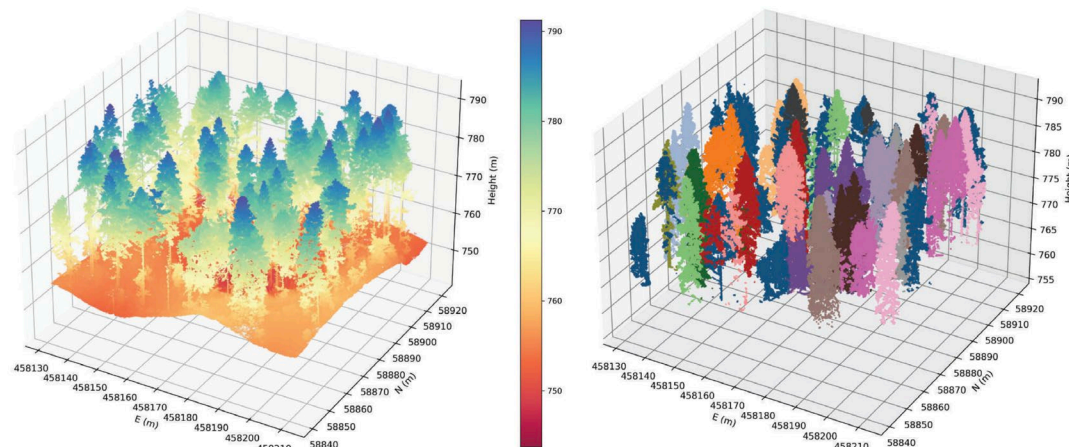


Fig. 7 - Segmented photogrammetric point clouds: matched trees in colors, felled trees in blue. From C. Spadavecchia , E. Belcore , M. Piras , M. Kobal 'Forest change detection using multi-temporal aerial point clouds' (Proceedings of the 2nd D-Site conference).



religious and residential buildings. In this case study, too, visualisation on WEBGIS platforms appears to be one of the privileged choices for the critical and conscious fruition of the heritage. Still in Spain, the authors Luis José García-Pulido, Jonathan Ruiz-Jaramillo, and Sara Peñalver Martín propose an analysis of several fortifications from the Nasrid period, whose detailed photogrammetric models well document diagnostic, technological, and material component status. Here, the 3D restitution and visualisation make it easier to further study the reconstruction of the historical phases in the various buildings. Another interesting topic covered in the call, with several examples, is landscape representation. Sara Colaceci, Emanuela Chiavoni and Maria Grazia Cianci discuss landscape representation and management systems. The authors implement a UAV acquisition methodology to generate models capable of increasing the current levels of landscape awareness and becoming reliable information bases for classifying territorial assets. Andrea Pirinu and Nicola Paba present an interesting investigation of the Sardinian military landscape. Here, the drone is used to produce orthophotos and geographical models useful for



updating the existing cartography, thereby expanding the study towards the historical aspects of the fortified territory. Likewise, their colleagues Jesús Rodríguez-Bulnes, José Antonio Benavides-López, Jorge Rouco Collazo, José María Martín Civantos and Pablo Romero Pellitero analysed a large area in the Espique valley, producing image-based and range-based databases, together with GNSS coordinates, to verify the properties of the different point clouds and assess the quality of the DTM obtained.

Guiye Lin, Andrea Giordano, Luigi Stendardo, Lu Xu, and Xiaochun Yang lead us to the East, presenting a study case in which photogrammetric and LiDAR databases are integrated to provide the basis for an HBIM workflow applied to traditional Chinese architectures, aiming at their scheduled maintenance. The following essay by Emanuela De Feo and Elide Nastri also deals with the topic of surveys for restoration through multidisciplinary approaches and data integration. In particular, the authors report research carried out on the basis of an accurate digital survey whose integrated image-based and range-based data contribute to the set-up of a database to generate highly detailed analysis and drawings representing the state of conservation. In the following contribution, Anna Sanseverino, Marco Limongiello and Fausta Fiorillo experiment with the processing of drone images for structuring a parametric model of a disused industrial plant optimised for advanced visualisation. In particular, the implementation of novel features of the photogrammetric pipeline made it possible to automate the production of so-called maps used for the generation of PBR (Physically Based Rendering) materials that were subsequently imported into the BIM environment.

Andrea Tomalini, Edoardo Pristeri, and Jacopo Bono provide an original consideration on the use of micro-UAS in the field of architectural survey, evaluating - through two tests carried out on the same case study - the limitations and potential in flight planning and the generation of more effective models. Finally, Lima Najjar and Fatma Aycim Turer Baskaya address the topic of spatial video

projection as an expressive medium for public spaces. In an excursus about the possible uses of drones, the authors round off the call by showing us a glimpse into the future of technology, conceived not merely as tools but also as expressive means. In this sense, technological advances and the introduction of rules and regulations will contribute, willingly or not, to shaping the collective system comprising tomorrow's infrastructure of a global civilisation. However, the development and application of technology are not an end in itself. We have seen how in the papers presented, Drawing, and more generally Representation - whose innovation is also based on multi-disciplinary technological development - become the active vehicle for disseminating knowledge, an opportunity for cultural deepening linked to the development of Cultural Heritage promotion.