

Photogrammetric Survey for a Fast Construction of Synthetic Dataset

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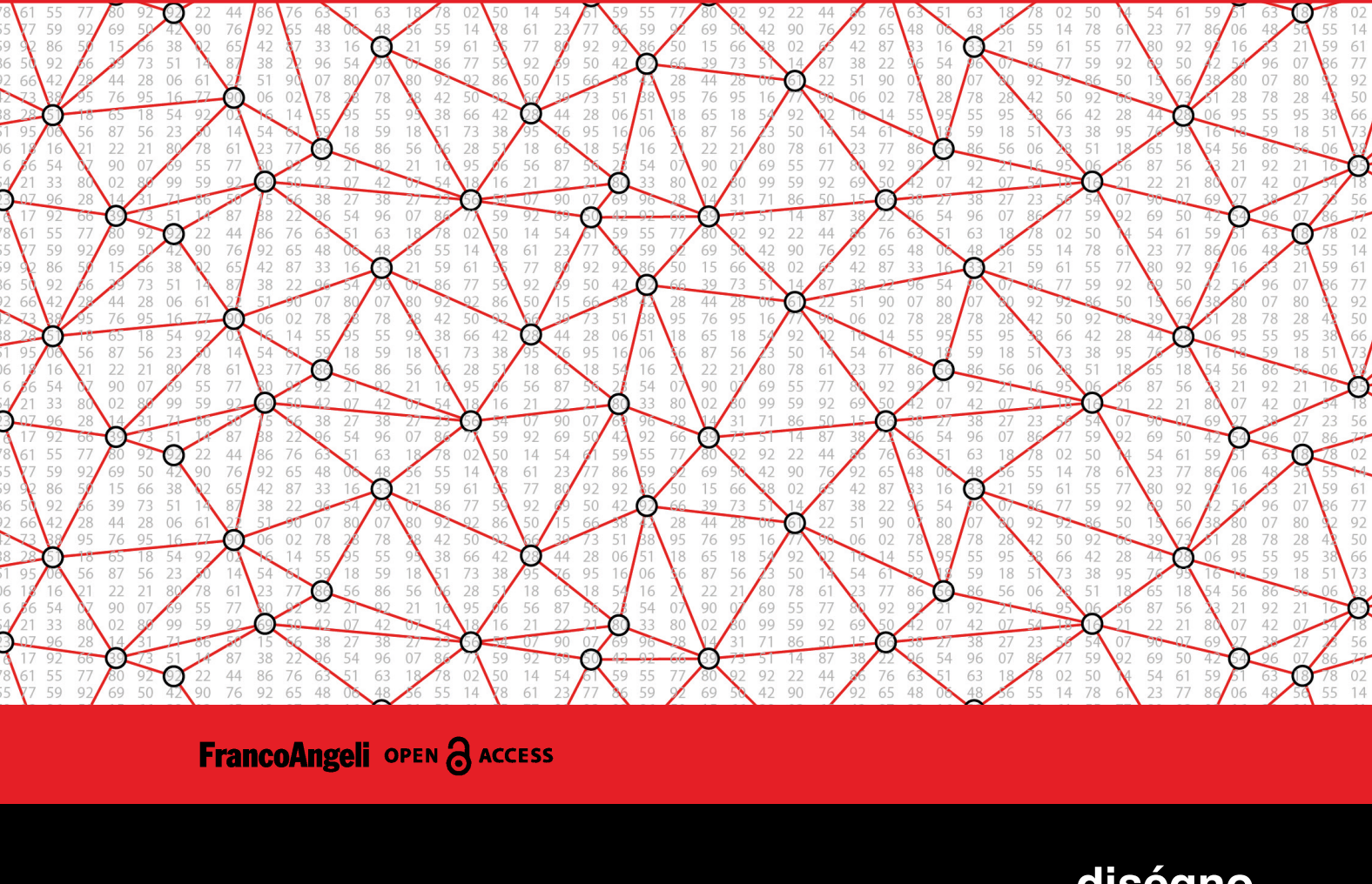
Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain

edited by

Andrea Giordano

Michele Russo

Roberta Spallone



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Augmented Reality and Artificial Intelligence in
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7

Francesca Fatta
Preface

9

Andrea Giordano, Michele Russo, Roberta Spallone
Representation Challenges: The Reasons of the Research

AR&AI theoretical concepts

23

Francesco Bergamo
The Role of Drawing in Data Analysis and Data Representation

29

Giorgio Buratti, Sara Conte, Michela Rossi
Artificial Intelligency, Big Data and Cultural Heritage

35

Marco Ferrari, Lodovica Valetti
Virtual Tours and Representations of Cultural Heritage: Ethical Issues

41

Claudio Marchese, Antonino Nastasi
The Magnificent AI & AR Combinations: Limits? Gorgeous Imperfections!

47

Valerio Palma
Data, Models and Computer Vision: Three Hands—on Projects

53

Alberto Sdegno
Drawing Automata

59

Marco Vitali, Giulia Bertola, Fabrizio Natta, Francesca Ronco
AI+AR: Cultural Heritage, Museum Institutions, Plastic Models and Prototyping.
A State of Art

AR&AI virtual reconstruction

67

Alessio Bortot
Physical and Digital Pop-Ups. An AR Application in the Treatises on Stereotomy

73

Maurizio Marco Bocconcino, Mariapaola Vozzola
The Value of a Dynamic Memory: from Heritage Conservation in Turin

79

Antonio Calandriello
Augmented Reality and the Enhancement of Cultural Heritage: the Case of Palazzo Mocenigo in Padua

85

Cristina Cãndita, Andrea Quartara, Alessandro Meloni
The Appearance of Keplerian Polyhedra in an Illusory Architecture

91

Maria Grazia Cianci, Daniele Calisi, Sara Colaceci, Francesca Paola Mondelli
Digital Tools at the Service of Public Administrations

97

Riccardo Florio, Raffaele Catuogno, Teresa Della Corte, Veronica Marino
Studies for the Virtual Reconstruction of the Terme del Foro of Cumae

103

Maurizio Peticarini, Chiara Callegaro
Making the Invisible Visible: Virtual/Interactive Itineraries in Roman Padua

AR&AI heritage routes

111

Marinella Arena, Gianluca Lax
Saint Nicholas of Myra. Cataloguing, Identification, and Recognition Through AI

117

Stefano Brusaporci, Pamela Maiezza, Alessandra Tata, Fabio Graziosi, Fabio Franchi
Prosthetic Visualizations for a Smart Heritage

123

Gerardo Maria Cennamo
Advanced Practices of Augmented Reality: the Open Air Museum Systems for the Valorisation and Dissemination of Cultural Heritage

129

Serena Fumero, Benedetta Frezzotti
The Use of AR Illustration in the Promotion of Heritage Sites

135

Alessandro Luigini, Stefano Brusaporci, Alessandro Basso, Pamela Maiezza
The Sanctuary BVMA in Pescara: AR Fruition of the Pre-Conciliar Layout

141

Alessandra Pagliano, Greta Attadema, Anna Lisa Pecora
Phyigitalarcheology for the Phlegraean Fields

147

Andrea Rolando, Domenico D'Uva, Alessandro Scandiffio
A Technique to Measure the Spatial Quality of Slow Routes in Fragile Territories Using Image Segmentation

153

Giorgio Verdiani, Ylenia Ricci, Andrea Pasquali, Stéphane Giraudeau
When the Real Really Means: VR and AR Experiences in Real Environments

159

Ornella Zerlenga, Vincenzo Cirillo, Massimiliano Masullo, Aniello Pascale, Luigi Maffei
Drawing, Visualization and Augmented Reality of the 1791 Celebration in Naples

AR&AI classification and 3D analysis

167

Marco Giorgio Bevilacqua, Anthony Fedeli, Federico Caprioli, Antonella Gioli, Cosimo Monteleone, Andrea Piemonte
Immersive Technologies for the Museum of the Charterhouse of Calci

173

Massimiliano Campi, Valeria Cera, Francesco Cutugno, Antonella di Luggo, Domenico Iovane, Antonio Origlia
CHROME Project: Representation and Survey for AI Development

179

Paolo Cini, Roberto Pierdicca, Ramona Quattrini, Emanuele Frontoni, Romina Nespeca
Deep Learning for Point Clouds Classification in the Ducal Palace at Urbino

185

Pierpaolo D'Agostino, Federico Minelli
Automated Modelling of Masonry Walls: a ML and AR Approach

191

Elisabetta Caterina Giovannini
Data Modelling in Architecture: Digital Architectural Representations

197
Marco Limongiello, Lucas Matias Gujski
Image-Based Modelling Restitution: Pipeline for Accuracy Optimisation

203
Federica Maietti, Marco Medici, Ernesto Iadanza
From AI to H-BIM: New Interpretative Scenarios in Data Processing

209
Michele Russo, Eleonora Grilli, Fabio Remondino, Simone Teruggi, Francesco Fassi
Machine Learning for Cultural Heritage Classification

215
Andrea Tomalini, Edoardo Pristeri, Letizia Bergamasco
Photogrammetric Survey for a Fast Construction of Synthetic Dataset

AR&AI urban enhancement

223
Giuseppe Amoruso, Polina Mironenko, Valentina Demarchi
Rebuilding Amatrice. Representation, Experience and Digital Artifice

229
Paolo Belardi, Valeria Menchetelli, Giovanna Ramaccini, Margherita Maria Ristori, Camilla Sorignani
AR+AI = Augmented (Retail + Identity) for Historical Retail Heritage

235
Fabio Bianconi, Marco Filippucci, Marco Seccaroni
New Interpretative Models for the Study of Urban Space

241
Marco Canciani, Giovanna Spadafora, Mauro Saccone, Antonio Camassa
Augmented Reality as a Research Tool, for the Knowledge and Enhancement of Cultural Heritage

247
Alessandra Pagliano
Augmenting Anghi: Murals in AR for Urban Regeneration and Historical Memory

253
Caterina Palestini, Alessandra Basso
Evolutionary Time Lines, Hypothesis of an AI+AR-Based Virtual Museum

259
Daniele Rossi, Federico O. Oppedisano
Marche in Tavola. Augmented Board Game for Enogastronomic Promotion

AR&AI museum heritage

267
Massimo Barilla, Daniele Colistra
An Immersive Room Between Scylla and Charybdis

273
Francesco Borella, Isabella Friso, Ludovica Galeazza, Cosimo Monteleone, Elena Svaldruz
New Cultural Interfaces on the Gallerie dell'Accademia in Venice

279
Laura Carlevaris, Marco Fasolo, Flavia Camagni
Wood Inlays and AR: Considerations Regarding Perspective

285
Giuseppe D'Acunto
Augmented Reality and Museum Exhibition. The Case of the Tribuna of Palazzo Grimani in Venice

291
Giuseppe Di Gregorio
The Rock Church of San Micidario of the Pantalica Site and 3DLAB VR/AR-Project

297
Elena Ippoliti
Understanding to Enhance. Between the Technical and Humanist Approaches

303
Gabiella Liva, Massimiliano Ciammaichella
Illusory Scene and Immersive Space in Tintoretto's Theatre

309
Franco Prampolini, Dina Porpiglia, Antonio Gambino
Medma Touch, Feel, Think: Survey, Catalog and Sensory Limitations

315
Paola Puma, Giuseppe Nicastro
The Emotion Detection Tools in the Museum Education EmoDeM Project

321
Leopoldo Repola, Nicola Scotto di Carlo, Andrea Maioli, Matteo Martignoni
MareXperience. AI/AR for the Recognition and Enhancement of Reality

AR&AI building information modeling and monitoring

329
Vincenzo Bagnolo, Raffaele Argiolas, Nicola Paba
Communicating Architecture. An AR Application in Scan-to-BIM Processes

335
Marcello Balzani, Fabiana Raco, Manlio Montuori
Integrated Technologies for Smart Buildings and PREdictive Maintenance

341
Fabrizio Banfi
Extended Reality (XR) and Cloud-Based BIM Platform Development

347
Carlo Biagini, Ylenia Ricci, Irene Villoresi
H-Bim to Virtual Reality: a New Tool for Historical Heritage

353
Fabio Bianconi, Marco Filippucci, Giulia Pelliccia
Experimental Value of Representative Models in Wooden Constructions

359
David Campagnolo, Paolo Borin
Automatic Recognition Through Deep Learning of Standard Forms in Executive Projects

365
Matteo Del Giudice, Daniela De Luca, Anna Osello
Interactive Information Models and Augmented Reality in the Digital Age

371
Marco Filippucci, Fabio Bianconi, Michela Meschini
Survey and BIM for Energy Upgrading. Two Case Study

377
Raissa Garozzo
A Proposal for Masonry Bridge Health Assessment Using AI and Semantics

383
Federico Mario La Russa
AI for AEC: Open Data and VPL Approach for Urban Seismic Vulnerability

389
Assunta Pelliccio, Marco Saccucci
V.A.I. Reality. A Holistic Approach for Industrial Heritage Enhancement

AR&AI education and shape representation

397
Maria Linda Falcidieno, Maria Elisabetta Ruggiero, Ruggero Torti
Visual Languages: On-Board Communication as a Perception of Customer Care

403
Emanuela Lanzara, Mara Capone
Genetic Algorithms for Polycentric Curves Interpretation

409
Anna Lisa Pecora
The Drawn Space for Inclusion and Communicating Space

415
Marta Salvatore, Leonardo Baglioni, Graziano Mario Valenti, Alessandro Martinelli
Forms in Space. AR Experiences for Geometries of Architectural Form

421
Roberta Spallone, Valerio Palma
AR&AI in the Didactics of the Representation Disciplines

427
Alberto Tono, Meher Shashwat Nigam, Stasya Fedorova, Amirhossein Ahmadian, Cecilia Bolognesi
Limitations and Review of Geometric Deep Learning Algorithms for Monocular 3D Reconstruction in Architecture

Photogrammetric Survey for a Fast Construction of Synthetic Dataset

Andrea Tomalini
Edoardo Pristeri
Letizia Bergamasco

Abstract

In this work we show how Physically Based Rendering (PBR) tools can be used to extend the training image datasets of Machine Learning (ML) algorithms for the recognition of built heritage. In the field of heritage valorization, the combination of Artificial Intelligence (AI) and Augmented Reality (AR) has allowed to recognize built heritage elements with mobile devices, anchoring digital products to the physical environment in real time, thus making the access to information related to real space more intuitive and effective. However, the availability of training data required for these systems is extremely limited and a large-scale image dataset is required to achieve accurate results in image recognition. Manually collecting and annotating images can be very resource and time-consuming. In this contribution we explore the use of PBR tools as a viable alternative to supplement an otherwise inadequate dataset.

Keywords

synthetic dataset, image recognition, visual programming language, physically based render:



Introduction

In the context of built heritage enhancement, the use of mobile computing technologies for its fruition can revolutionize the user experience [Barsanti et al. 2018; Lo Turco et al. 2019]. AR systems, if properly combined with ML algorithms, can expand the level of knowledge that can be accessed while observing the asset [Spallone et al. 2020]. While it is very easy to imagine the database containing the information associated with an architectural asset, it is less immediate to imagine the query needed to access and explore it. Considering that within the same database very different information is stored: referring to the history, the construction technique, the history of the architect, etc.; one can understand how solutions such as audio tours, information panels, or QR codes are not suitable to answer the subjective curiosity of the user [Andrianaivo et al. 2019]. With the help of a mobile device, starting from the recognition of the object itself, one could connect and reorganize all this information according to the user's preferences [Vayanou et al. 2014].

To enable this kind of navigation, one of the first steps is to ensure that the mobile device can recognize the object in the frame. However, while some disciplines already apply Deep Learning for image recognition [Norouzzadeh et al. 2018; Liu et al. 2020], research is not as flourishing for architectural feature recognition.

This research work proposes a methodology to enrich the training dataset needed to build a software capable of recognizing the built heritage from pictures coming from a mobile device with the help of PBRT tools. Once the architectural artifact has been surveyed, its digital twin can be inserted into a modeling environment and used for the creation of possible views, even improbable ones, expeditiously, taking into account different lighting and meteorological settings which could affect the picture taken from the end user.

Case Study Definition and Data Acquisition

Given the still preliminary stage of the work, the Saracen Tower of Spotorno was chosen as a case study by the research team because of its small size and its position visible from different points of the town. For this specific use case, a three-dimensional model has been useful for the creation of photorealistic rendering used to train a ML algorithm. For this reason, and to optimize working time, it was decided to generate a photogrammetric model by carrying out a free-net adjustment with a subsequent assignment of the model scale by applying the method of least squares over 3 known distances, measured using a metric token (fig. 1). The approach of using elements of known length is a cheap, expeditious and well-established procedure, both in the orientation of the photogrammetric block in industrial applications [Luhmann et al. 2010], and in the survey of archaeological heritage [Nocerino et al. 2013]. The important thing is to correctly size the supports taken as reference – they must be proportionate to the object to be surveyed –, the distance of the images, and the degree of precision and accuracy required by the final model.

The aerial photogrammetric shots were taken using a DJI Mavic Mini drone, equipped with a 1/2.3" CMOS sensor. The dataset was integrated with some images taken from the ground with a Sony Alpha 6000 camera equipped with a 23.5x15.6 mm sensor.



Fig. 1. Conceptual scheme of the survey and construction phases of the textured mesh model.

Despite the non-professional tools, it is now known within the scientific community that the processes of generating point clouds from georeferenced photogrammetric blocks provide excellent results even when the starting data is not a set of images acquired with a calibrated photogrammetric camera. [Cardenal et al. 2004]

The Agisoft Metashape software was used for the 3D model generation operations.

The method used has already been tested and considered appropriate for the survey of elements located in the vicinity of the supports used as references but, despite the cost-effectiveness of the process, even at greater distances the uncertainty is within a few centimeters. [Calantropio et al. 2018]

Dataset Construction Workflow

As previously mentioned, the generation of the 3D model, starting from aerial and ground photos, was carried out using the Agisoft Metashape software. Since the final aim was to produce photorealistic renderings in a fast way, it was fundamental to optimize the mesh, firstly, to reduce the calculation time, secondly, to achieve a representation without gaps, without visible polygon edges and with a more homogeneous appearance. A dense cloud of 5,198,304 points was used as input for the mesh calculation, resulting in a mesh of 345,280 faces. Then, to decrease the complexity of the geometry, the coplanar faces were merged and the areas surrounding the tower were decimated. The output of this process was a mesh of 219,269 faces.

An algorithm was written within Rhino's Visual Programming Language (VPL) environment to automatically generate the useful photorealistic views from this last textured mesh. Grasshopper was chosen as the programming environment because of its ability to naturally manage complex geometries. Moreover, being integrated within Rhino, it was possible to easily connect it to different PBR rendering engines (Rhino Render and V-Ray).

In the algorithm, three working phases can be identified:

1. The identification of useful views around the case study. A hypothetical circular path was drawn around the tower. Along this path 26 chambers were positioned, 13 at one elevation and 13 at a slightly higher elevation, with the centre of the tower as the intake point.

2. Through the analysis of the epw weather file of the location, the solar path was imported. The months between the summer solstice and the winter solstice were selected, and for each month 5 moments in the day were selected in order to have a render for each possible significant position of the sun.

3. The last step was to automate the rendering procedure of all the views for each chosen moment during the selected months. We have 26 chambers, for each of them 5 positions of the sun were selected for the 6 chosen months for a total of 780 images (size of each image 480*480 px). The images were exported in .png format with the contour of the architectural object. It was decided on a first hypothesis to include as little context as possible and to avoid representing the sky, in order to prevent the ML algorithm that would be trained on this dataset from identifying features on objects or landscape components (clouds, bushes or other) other than the tower.

A first dataset built in this way was generated in about 3 hours. Many of these steps could be further automated, thus reducing the required time. (fig. 2)

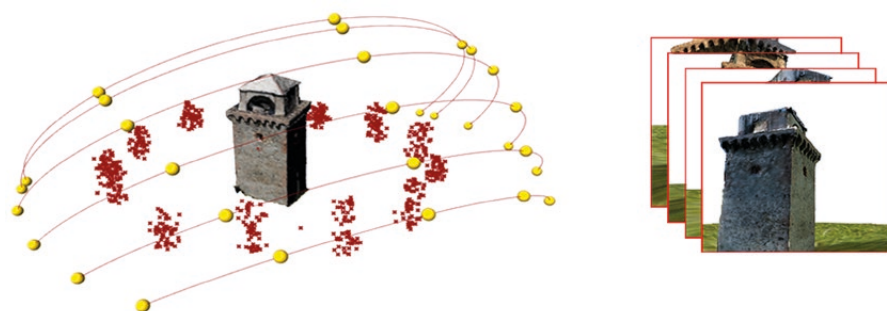


Fig. 2. Selection throughout the year of 30 different lighting conditions and relative camera positions.

Test Classification Pipeline

To test if the data produced by the aforementioned workflow is suitable for training a classification algorithm, a naive image classification pipeline has been created. This has also been useful to identify possible problems with the generated images, such as the issue that will be mentioned in the next paragraph.

The architecture of the pipeline is outlined in Figure 3. The first block is in charge of importing the data as it is. Since in this case we are using a simple binary classifier, we have four different types of data. The two types of data used for training are the pictures generated algorithmically and pictures coming from a public dataset of building facades for the other class. The other two types of pictures used for testing the classifier are real pictures of the tower taken with a camera and other pictures coming from the aforementioned public dataset. The pictures used to train the classifier are then elaborated in the 'Augmentation' and 'Preprocessing' blocks of the script to be ready to be used from the classifier. The test pictures only have to be preprocessed. The classifier is an implementation of a Stochastic Gradient Descent (SGD) [Bottou Leon 2010] classifier which, even if not tuned, allows us to draw some conclusions about whether the data we generated can be useful for image recognition purposes.

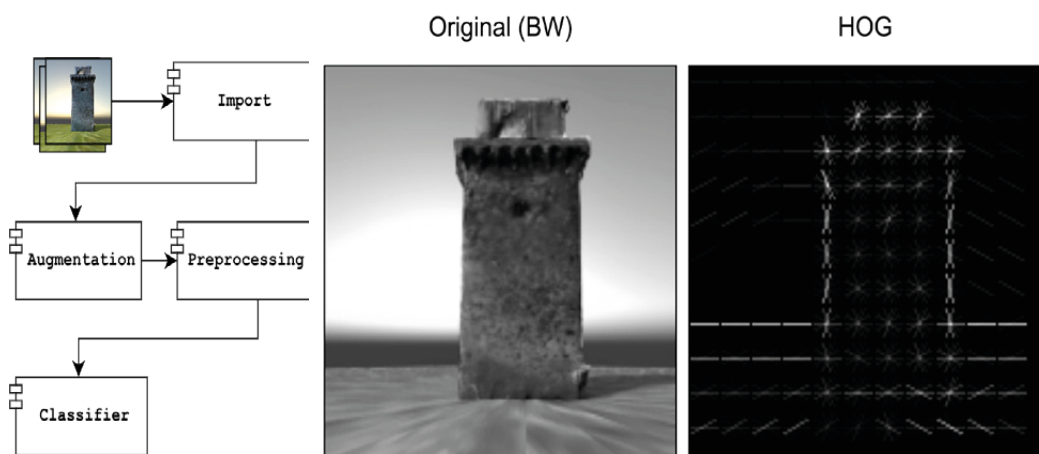


Fig. 3. From the left: Classification pipeline architecture. Two intermediate outputs of the pipeline stages.

Dataset Construction Improvements

After training and testing the classifier on the first dataset, an overfitting problem became immediately apparent. The images, as previously described, were taken with the same camera settings, the same perspective and the tower was always in the center of the picture. As can be seen in Figure 3, to allow the images to be processed by the classifier, they undergo several levels of pre-processing, including the removal of color information. They are then processed by a ML algorithm that calculates the Histogram of Oriented Gradients (HOG), a technique used to select the most interesting features within the image from a software perspective.

If the automatically generated images have a low degree of variability in some regions, which is visible in the HOG data, there is a risk that the classification algorithm will learn to correctly classify only those images with this degree of variability, i.e. the synthetic ones, and misclassify the real images.

To solve this problem, some degree of variability in the relative position of the tower in the image had to be included. The initial VPL algorithm has been modified, spheres have been constructed on the point on which the cameras were initially positioned and for each image the camera has been positioned on a random point belonging to this sphere. A similar solution has also been used for the camera target, with this stratagem the images no longer have the same coordinates and our case study is never in the same position within the image.

Conclusions

Even though it has not been tuned, the classifier scored a ~70% of accuracy in distinguishing images of the tower from images of other buildings.

The benefits of the presented approach versus a more traditional ground survey are clear. In a comparable time we can obtain much more data about the case study allowing to achieve promising results in image recognition with ML algorithms.

With the tested classification algorithm, the background of the rendered 3D object plays an important role as it is processed along with the subject during the pre-processing phase and the resulting information is used during the training of the SGD classifier. The output of the render should in fact have in the background different images which are similar to the true background of the real building, thus adding 'noise' behind the subject and reducing the risk of 'overfitting' the classification model, which would decrease its accuracy.

Including the surrounding scenery into the rendering therefore means providing a more complete context to the subject of the survey. This can be achieved by taking some additional pictures with the drone or by using inexpensive hardware to collect spherical images. This information can be augmented using a 3D rendering engine to include night or dusk settings as well. Moreover this technique also provides the operator a mesh which is useful in the mentioned AR applications.

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