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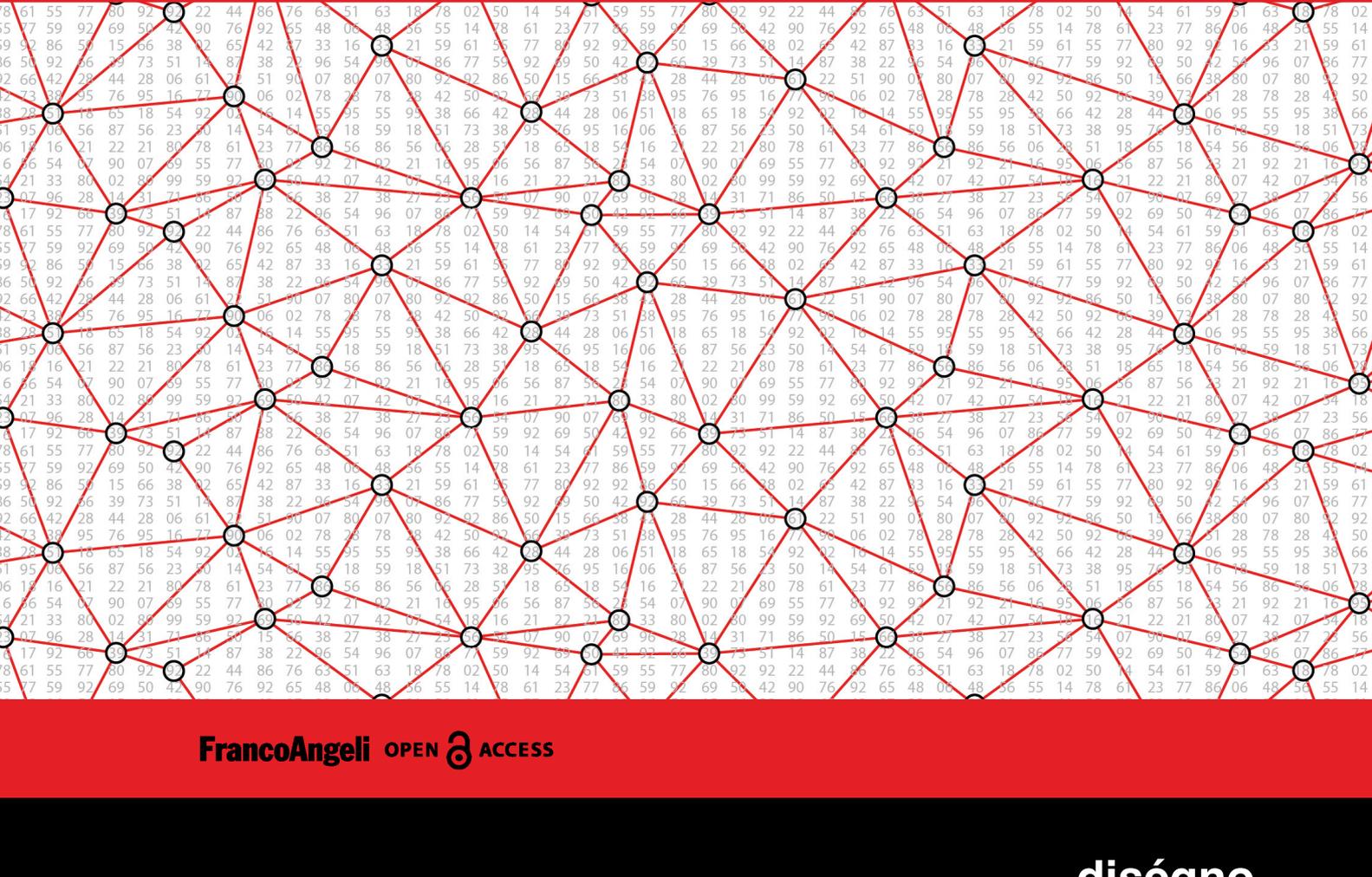
Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain

edited by

Andrea Giordano

Michele Russo

Roberta Spallone



director Francesca Fatta

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Roberta Spallone

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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
Gabriella 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-caring

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

Artificial Intelligency, Big Data and Cultural Heritage

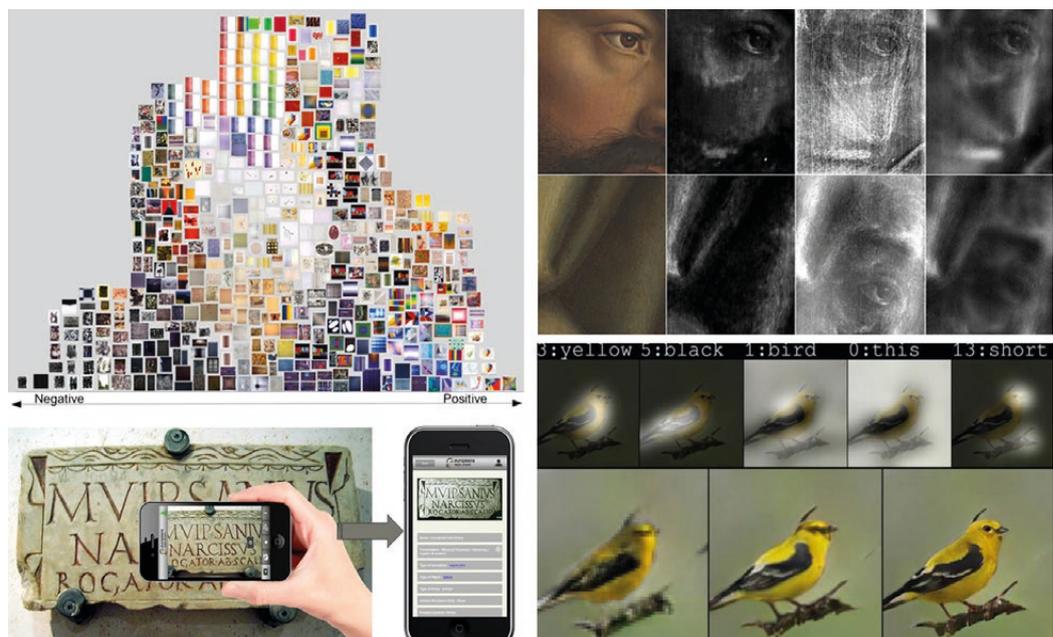
Giorgio Buratti
Sara Conte
Michela Rossi

Abstract

In recent decades, the cultural heritage sector has benefited from solutions offered by ICT for the conservation, management, enhancement and communication of cultural heritage; today this specific sector benefits from the infinite potential of application of AI. The proposed research identifies the three main lines of research that operate in the cultural heritage exploiting the synergy between machine learning, big data and AI, starting from the analysis of the state of the art and a subsequent first taxonomic approximation of artificial intelligence systems. The analysis of some case studies developed in the field of recovery and restoration of cultural heritage, monitoring and prevention of damage, data acquisition and analysis of the same, confirm the real potential of AI: trigger knowledge from knowledge.

Keywords

AI, cultural heritage, interaction, automatic drawing, taxonomy.



Introduction

Since the 2000s, the improvement in microchips' computing performance has made creating, collecting and transmitting data so fast and cheap, to bring the amount of available information to exceed a crucial threshold [1], determining the advent of the so-called Big Data era. Originally, the term "Big Data" referred to the technical ability to collect, store and process increasing amounts of data at decreasing costs. There is nothing innovative about this definition, which could be compared to the advantages of printing over handwriting or any other technical improvement in cultural technologies history. The unprecedented aspect is the ease of accessing more data than it seems possible to handle for the first time in human history data is abundant and cheap and continues to exponentially increase. The information collected in digital form in a delocalized telecommunications network is accessible in real time to various types of electronic devices that allow data re-processing. In this context, any search creates in a few seconds a redundant mass of information that complicates the identification of the most significant content. The quantity and type of information has reached a complexity that transcends a direct management possibility, requiring an adaptation of the taxonomic ordering structures used up to now to understand phenomenal reality and to manage knowledge.

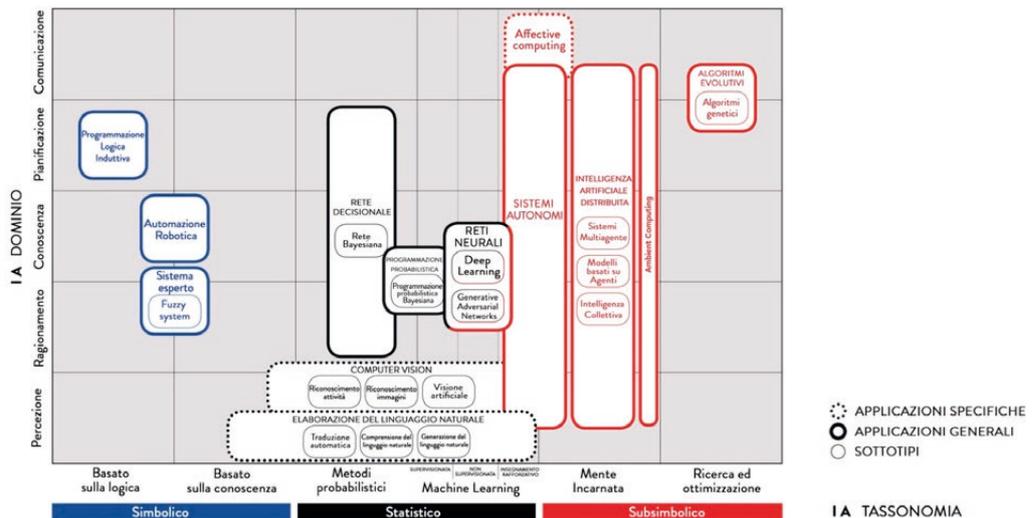


Fig. 1. Taxonomy of AI referred to F. Corea, <https://www.kdnuggets.com>

AI and Big Data: Order Complexity

Unlike humans, computers can use the growing amount of 'disordered' information by defining a new way of producing knowledge, no longer based on reference theories, but on a posteriori identification of recurring patterns within the rough data flow. This abdication of the causal logic linked to reasoning in favor of computational analysis does not imply a 'technological' determinism or that data driven research must guide all cognitive processes, because the data has no intrinsic value but in a defined context. If knowledge's inferential processes start from the informations acquired, it's also true that a simple data accumulation does not generate knowledge without a method capable of identifying the correlations among variables. In this context becomes crucial research on Artificial Intelligence, a definition that includes a differentiated set of techniques and methods with the aim of automating human cognitive abilities. And since computers process data at speeds now close to the speed of light [2], it is possible to analyze increasing amounts of information, generating predictive models based on objective assessments. Since its inception, AI research focuses on the creation of models that simulate the dynamics of human intelligence, based on the comparison and reworking of external stimuli, which can be classified according to the main active research directions. The table (fig. 1) shows on ordinate axis the abilities of human intelligence:

- Perception: skill to transform sensory inputs into useful information);
- Reasoning: skill to connect / solve problems;
- Communication: ability to elaborate a language and transmit concepts;
- Knowledge: skill to understand and represent reality;
- Planning: skill to define and achieve objectives.

The main research lines currently recognized are summarized on the abscissa axis:

- Symbolic Approach: which considers intelligence as that process of transforming perceptual stimuli into symbols to which a meaning can be attributed, according to more or less formal rules;
- Statistical Approach: based on logical–mathematical tools to extract information content useful for transforming information into knowledge starting from Bayesian inference, formalizing the hypothesis that a greater use of a given data increases the probability of its exactness;
- Sub–Symbolic Approach: based on neuronal functioning whereby information is transmitted regardless of meanings: knowledge emerges regardless of previous mental models, but on the basis of structures based on experience.

From these line of research, six subgroups descend which identify the main AI applications:

- Logic–based: tools used for problem solving through the orderly representation of knowledge;
- *Knowledge–based*: tools with extended ontologies and relational databases of notions, information and rules;
- Probabilistic Methods: tools that allow agents to act even in incomplete information scenarios;
- Machine Learning: tools that generate data from other data;
- Embodied Intelligence: engineering toolbox, which assumes that a body (or at least a partial set of functions such as movement, perception, interaction, and visualization) is required for higher intelligence
- Research and Optimization: predictive calculation tools that allow you to optimize possible solutions according to the specific context.

These methods are already used, often unknowingly, on a daily basis: when we ask for directions to our portable device or ask a virtual assistant to turn on the light, we are interacting with natural language interpretation AI and neural networks trained to carry out research and home automation operations.

For some years now, the use of genetic or evolutionary algorithms in form finding studies has consolidated the AI tools also in the drawing discipline. These processes consider the different morphological hypotheses as biological individuals and recombine them, similarly to sexual biological reproduction, introducing elements of disorder that simulate random genetic mutations. Thousands of formal solutions (new individuals) are thus generated, among which those that guarantee the highest level of optimization are chosen, just as selective processes promote the survival of the individuals most suitable for an ecosystem. In this way it is possible to explore solutions hitherto unused due to the lack of description and control tools adequate to the problem complexity.

The New Frontiers of AI Applied to Cultural Heritage

The first one collects all the research characterized by the development of innovative methodologies and systems to monitor and prevent damage to the cultural heritage, helping to increase the offer for the users. The most common example is the biosensor that can prevent damage from biological pests. This is any analog or digital device that works with living organisms (indicators) able to respond to certain environmental stimuli, producing an electro–chemical, optical signal to reach a threshold value. Today automatic biosensors are studied, that work in real time and continuously to signal in indoor environments the achievement of favorable conditions to germinative factors and therefore a constant monitoring of the state of health of the good [Danese et al. 2019]. Significant are the researches based on the use of neural networks in conservative perspective; in particular the one carry on by the researchers of National Gallery, Duke University and University College of London, that used neural networks to analyze complex high–resolution digital X–ray images of the cathedral of Gand “Adoration of the Mystical Lamb” [Van der Snickt et al. 2020]. Convolutional neural networks (CNN) combined with multi–resolution imaging techniques, initially used to determine the

authorship of a work and to distinguish fakes, are now able to reconstruct unfinished or deteriorated drawings from time as demonstrated by the research of the Dutch Technical University of Delft [Zeng et al. 2019]. The goal is the automatic reconstruction, through a pixel wise technology, of Vincent van Gogh's drawings that are deteriorated by time. The team was able to return works now irretrievably lost to the public, using the algorithm inspired by biological neural networks similar to human brain ones and trained on a data set containing reproductions of original drawings of various qualities, sizes, made at different times.

The second area analyses the experiments that focus on automatic data acquisition, such as the application of mobile technologies for three-dimensional surveying and the acquisition of images of monuments, architectures, archaeological sites. The distributed AI is an interesting line of research that is giving the first results in the field of three-dimensional and photogrammetric relief, through drones that are able to direct their flight in strategies similar to the ones of bees and other social insects. Flight trajectories are not pre-programmed for individual units, but depend on the network of interactions given by the continuous communication between the various subjects, and between them and the environment in which they operate, as it is visible in the Aerial Construction project [Willmann et al. 2008]. The project of the DISI of the University of Trento in collaboration with local authorities, such as the MART of Rovereto goes further, developing AI able to analyze the influence on perceptive properties and the emotional level that a work of art arouses in the observer. The AI recognizes the intensity and the type of the emotion through a facial recognition system based on the affective computing and the deep learning, providing useful information for the museum and curators [Sartori et al. 2016]. The work of the CNR-IMATI within the project Horizonte 2020, GRAVITATE provides us an example of automatic extraction of features through the Generative adversarial network. The experimentation allows to identify the ceramic fragments, through the combination of semantic and geometric elements, and to assemble them in a semi-automatic way, simplifying the work of the archaeologist and giving the possibility to virtually reunify a spread archaeological heritage. [Moscoso Thompson, Biasotti 2019].

The third field aims to develop systems for the management of large amounts of data and informations, analog or digital, contained in libraries, archives, museums, and to provide the user with easier and more immediate access to information. There are many apps today that want to meet the needs of the users, who are visiting cities and monuments, by providing in real time useful and richer content and interpretations of our past, mainly using the ambient computing and the deep learning. Time Machine is a European project that aims at 4D digital reconstruction of every historical place of the main European cities, combining them with data of all types accessible with augmented reality interfaces; Monugram allows to give information of a monument based on the recognition of the image taken by the user in real time; Woolyesses is an interactive chatbot for tours enriched with personalized multimedia content and anticipating the needs of the user; Eagle, allows automatic recognition of Greek/Latin epigraphs and dissemination of associated information. The aim of the different methodologies is unambiguous: to orient the technology towards the rediscovery of the knowledge to protect it or make it accessible, putting the digital reality at the service of the material one.

Conclusion

The fields of application of AI are constantly evolving and searching for new contexts in which the application of predictive algorithms allows the extrapolation of finalized solutions from the automatic reprocessing of a large amount of data. The intelligence of the machine is a consequence of the research speed of comparable information in a network that mimics neural connections. The solution is the statistical result of a comparison based on the evidence: a digital reinvention of the empiricism that preceded the development of experimental science, which built knowledge on reasoning aided by intuition. New knowledge is born from the empirical reworking of previous knowledge; the added value is parametric definition of reworking and the relationships between algorithms, controlled by humans. The inventiveness that distinguishes it does not depend only on logical capabilities; in fact the

described context opens to a series of reflections within the transformations taking place in drawing and in the contribution of the machine to design.

For example, the Drawing–Bot is an AI developed by Microsoft in collaboration with three American universities that uses the technology of the antagonistic generative network to create images from its description. A neural generative network creates new images from some keywords, while an antagonistic network compares them with a database of existing images, eliminating the results that differ from it. At present this AI produces good results for short and explanatory expressions; it is able to easily extract the forms and then integrates them autonomously with the absent details from the given description, while the final result is likely to be a confused image for complex descriptions, but it is only a matter of time and speed of calculation. In the example [Zhang et al. 2017] the quality of the representation is close to the photographic one, but the reproduced bird does not exist in the reality, is a representation born from the “imagination” of a computer. This case opens up to a series of reflections on the machine’s learning potential and on how the relationship between the machine and the designer may evolve in the future. Today the machine is able to create a drawing based on the same geometric rules used to trace it by hand, but will it be possible to teach the machine the capacity of autonomous reasoning and to simulate the human creative capacity, through data processing?

Notes

[1] At the time of writing [2021] the amount of data currently engaged in the world each year is about 40 ZB [zettabytes]. One ZB corresponds to 102121 bytes, equivalent to approximately 180 million times the information collected in the records kept in the Library of Congress in Washington, recognized as the largest existing library with over 158 million documents held.

[2] At the time of writing the most powerful computer in the world is Summit, developed by IBM for the ORNL, United States Department of Energy, capable of handling 100 petaflops, equivalent to 100 million billion operations per second. Summit is used in studies ranging from particle physics to weather/climate forecasts, from the creation of new drugs to the simulation of the effects of nuclear explosions.

[3] Although the paper was conceived jointly, Michela Rossi is the author of *Introduction*, Gorgio Buratti is the author of *AI and Big Data: Order complexity* and the related image, Sara Conte is the author of *The new frontiers of AI applied to cultural heritage*. The *Conclusions* are drafted jointly.

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Authors

Giorgio Buratti, Dept. of Design, Politecnico di Milano, giorgio.buratti@polimi.it
Sara Conte, Dept. of Design, Politecnico di Milano, sara.conte@polimi.it
Michela Rossi, Dept. of Design, Politecnico di Milano, michela.rossi@polimi.it

