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AI and Computer Vision in Cultural Heritage Preservation

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***Abstract*— In the recent years, rapid advances in technology, especially in Artificial Intelligence (AI) and Machine Learning (ML), have impacted the way economy functions, as well as society at large. The integration of these technologies in tourism plays a significant role in cultural heritage preservation. This research explores the intersection of artificial intelligence, cultural heritage, and tourism, with a focus on Montenegro's efforts to leverage digital transformation for tourism development. Many monuments are not marked and there is no background information about their historical significance. With four UNESCO World Heritage sites, Montenegro is recognized as country with high touristic potential and rich cultural heritage, which implies that implementation of AI technologies can preserve forgotten monuments and give them a new life, as well as enhance the overall touristic experience and position Montenegro at the forefront of international touristic landscape. Using a well-known framework Flask, we developed web application that allows users to take images of a monument, upload it to our web application and after a few seconds, they get annotated image of a recognized monument, along with a text containing more information about the said monument.**

***Keywords*— artificial intelligence, computer vision; cultural heritage preservation; machine learning**

I. Introduction

People were always fascinated by the question of intelligence and it was a subject of many researches over the past few centuries. It was not until 1955, when John McCarthy, American mathematician and computer scientist, introduced the term Artificial Intelligence (AI) [1]. The birth of AI as a research discipline is considered the Dartmouth Summer Research Project of 1956, organized by John McCarthy himself, along with his colleagues [2]. Today, only 67 years later, artificial intelligence is everywhere around us and we use it for our daily tasks. The rapid pace at which the technology is advancing is fascinating, making even Moore's law inapplicable in the context of modern technology. All of this is feeding into Y. N. Harari's idea of dataism – religion of data as a new religion that we are all believers of, highlighted in his book Homo Deus [3]. In recent years, as AI and machine learning are becoming more powerful and practically useful, different applications of AI in cultural heritage preservation have been proposed [4-6].

There is a strong link between technology, science and what we call cultural heritage. This relationship is not focused only on preservation of cultural heritage, but also it makes a great foundation for inventing new methodologies and techniques that enable further research of traditional disciplines related to cultural heritage [7]. Cultural heritage plays an important role in development of tourism. Some destinations base their touristic offer solely on cultural heritage, or it makes the majority of the offer. Therefore, a special form of tourism is developed, named heritage tourism [7]. Heritage is defined as something we inherit from the past and use as a resource for tourism, education and community development. Cultural history of a country plays a fundamental part of nation's identity, and thus it is important that cultural heritage is represented accurately and that it is available for tourists to explore as a part of their experience. Cultural heritage is integral to global tourism system, with many destinations showcasing art, culture and built patrimony as main parts of their tourist experience. There are new opportunities for AI applications in the context of cultural heritage, but not without the complex challenges [8].

In this paper, we will focus on the use of AI and computer vision and explore the way how a system for recognising monuments and tombstones could be recognised and potentially integrated into digital solutions for tourism. In the paper, we are describing a proof-of-concept of a web application capable to support execution of a computer vision prediction model and serve as a platform for further research and development.

II. Background

A. Montenegro – recognizing tourism potential

Montenegro, a country with rich natural and cultural heritage, recognizes the need for digital transformation in the domain of tourism. "Strategy of Smart Specialization" is an official document issued by the government of Montenegro in 2019 that recognizes development priorities, among which is tourism as a vertical priority and Information Communication Technologies (ICTs) as a horizontal priority that has an impact on tourism [9]. Additionally, "Strategy for the Development of Tourism in Montenegro 2022-2025" is another strategic document issued by the government that states goals of development of tourism in Montenegro,

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including operational objective 6 – development of digital, innovative solutions and new technologies in tourism; and operational objective 7 – Montenegro as globally recognized tourist destination [10].

Montenegro has four properties inscribed on the UNESCO World Heritage List, among which is Stećci Medieval Tombstone Graveyards [11] shown in Fig. 1. This serial property, located mostly in Bosnia and Herzegovina, but also Montenegro, Serbia and Croatia, has never been a subject of holistic preservation and their value remains undiscovered [12][13]. According to Jahić (2017) [14], as many as 20% of total number of stećci in Bosnia and Herzegovina were destroyed, submerged or disappeared.

Figure 1. Medieval tombstone graveyards near Zabljak, Montenegro

This work is motivated by the efforts aimed at heritage preservation and possible applications of digital innovation fir cultural tourism, social innovation and awareness, as well as cultural heritage preservation. The work is in part inspired by the STECCI project as we envision creating a dataset based on images of medieval monuments and stećci – tombstone graveyards in Montenegro that will be used for creating of computer vision models to support digital solutions for cultural heritage both for research and tourism purposes [12]. We also anticipate creating a dataset for the historical monuments that will enable training of computer vision prediction models that will creating applications capable of recognizing unmarked monuments.

B. *Computer vision AI models in tourism*

As technology rapidly changes, new techniques and methods raise as more practical and better than others. That being said, in the recent years, deep learning methods have outperformed machine learning techniques that were used in several fields of artificial intelligence, computer vision being the most advanced of all [15]. Deep learning has improved findings in variety of computer vision problems, such as object detection, motion tracking etc. Object detection is the process of detecting instances of specific class in digital images or video [15]. The use of this technology can improve overall tourist experience and position tourist destination as up-to-date and competitive on the international touristic landscape.

One of the problems that exists in Montenegro is that vast majority of monuments that represent cultural heritage are unmarked or not properly marked, not maintained and left to be demolished or affected by the climate factors. That being said, Montenegro as a popular tourist destination has not valorized cultural heritage to its full potential and that implementation of AI based computer vision could help. Particularly with object detection, e.g. using a phone camera, cultural heritage sites can be recognized and tourists, as well as locals, can gain more information about historical site they just visited.

III. Materials and Methods

A. *Data collection*

Dataset was collected manually. We chose two monuments for first version of this AI model, the ones that were not marked and very little information is available about them at the site. There was a class balance, with each class having 120 photographs taken for annotation.

B. *Dataset Annotation and Preparation*

Using Roboflow, an online tool that provides various free datasets for model training, as well as possibility to make a dataset of your own for computer vision projects, taken images were manually annotated using Smart Polygon and Polygon tool [16] as illustrated in Fig. 2. Annotated photographs were then preprocessed and augmented into a dataset. There was total of 203 source images (annotated) split into 3 classes, where one of the classes is automatically created by Roboflow. Training set consists of 162 images, validation set of 27 images and test set has 14 images. Augmentation step of preparation of the dataset consisted of rotation and saturation of the images, brightness, blur and noise changes. Dataset was augmented 3 times, meaning that final dataset had 517 images for model training.

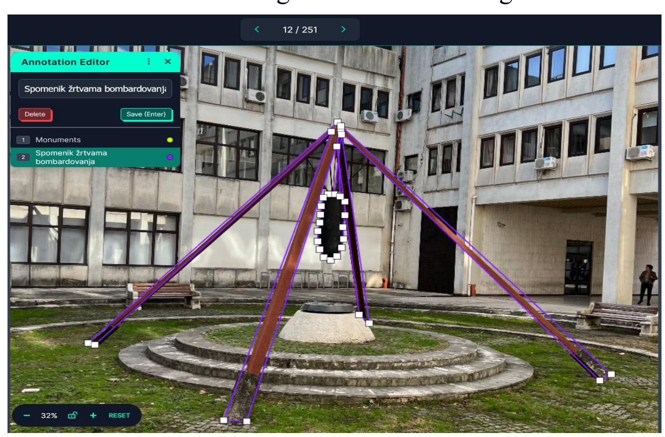

Figure 2. Annotation process in Roboflow

C. *Model training*

For model training, Google Colab platform was used, along with YOLOv8 model. Colaboratory, or “Colab” for short, is a product from Google Research [17]. It is a virtual machine that allows users to run Python code and is suited especially for machine learning and data analysis. The use of Google’s GPU resources is also enabled.

YOLOv8 (You Only Look Once) is a new, state-of-the-art model that contains support for object detection, classification, and segmentation tasks, accessible through a Python package [18].

```
!pip install ultralytics==8.0.20
from IPython import display
display.clear_output()
import ultralytics
ultralytics.checks()
```

This code will install YOLOv8, clear the output, import the Ultralytics library, and run checks to ensure that the installation is successful. This approach is common when setting up dependencies and libraries in a notebook environment.

```
!pip install roboflow
from roboflow import Roboflow
rf = Roboflow(api_key="xxxxxxxxxxxxxxxx")
project = rf.workspace("xxxxx").project("xxxxx")
dataset = project.version(1).download("yolov8")
```

This code installs the Roboflow Python library, imports the required modules, initializes Roboflow with an API key, and then uses Roboflow to access a specific workspace, project, and version to download a dataset named "yolov8." API key here is replaced with random combination, not actual.

```
!yolo task=detect mode=train model=yolov8s.pt
data=data.yaml epochs=70 imgsz=500 plots=True
```

This code initiates training of the model. Task = detect specifies the object detection task, train indicates the training mode, model indicated is pre-trained YOLOv8. Data.yaml points to the YAML configuration file providing dataset information. This training consisted of 70 epochs, with input image size 500 during training. Plots set to “True” enable generation of training progress plots.

D. *Model testing*

The training of the model took about 25 minutes. Overall precision and recall were high, with mean Average Precision (mAP) of 0.945 at 50-95% Intersection over Union (IoU) threshold. Mean Average Precision (mAP) is a metric used for evaluating the performance of object detection model [19]. The AP metric is based on precision and recall metrics: precision measures the accuracy of model’s positive predictions, and recall measures percentage of actual positive cases that the model correctly recognized [19]. Given the testing photos, model recognized monuments at a high precision – *“Spomenik Karađorđu”* and *“Spomenik žrtvama bombardovanja”* with 0.9 accuracy, as shown in Figure 3. This prediction model is used only for demonstration of the overall system integration and as a proof of concept. New models will be created once the more elaborate datasets are developed.

IV. Implementation and Discussion

The final step in training our AI model is the creation of a file called "spomenici.pt," which contains everything that has been learned. However, this model needs to be seamlessly integrated into an application in order to be practically useful. A lightweight Python web framework called Flask acts as the vital interface between user accessibility and cutting-edge AI capabilities [20]. The proposed architecture of the flask based web system for the pilot is depicted in Fig. 4.

Figure 3. Examples of successfully recognized objects

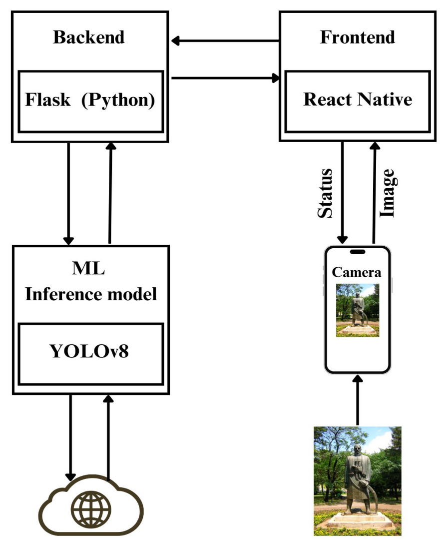

Figure 4. Architecture of the pilot system

The process of training entails a complex synchronization of data and algorithms, reducing knowledge to the end product, "spomenici.pt." This file provides evidence of the many iterations our AI model underwent and represents the intelligence it has since acquired. Flask is used as the integration platform because of its ease of use and adaptability. It simplifies the construction of web applications and makes it easier to integrate our AI model that has been trained. The way that Flask and AI work together is numerous.

By assigning URL patterns to functions, Flask's routing mechanism serves as a perspective for processing incoming requests and controlling data flow. As a result, communication between consumers and the AI model is seamless. Incoming requests are handled by Flask, enabling user input to be received and subsequent interactions with the trained AI model. The essential component of interactive apps' dynamic nature is this feature.

The AI model is now deployable and accessible thanks to this integration. A web interface allows users to engage with the model, making easier the usage of cutting-edge technologies. It is important to mention that this prediction model was made as a mock-up model for the one we intend to make when we gather a big enough dataset. Future model will demonstrate the use of AI and ML, as well as computer vision, for identification of unique medieval tombstones, stećci located in our region. This model could be integrated into other technical solutions containing VR and AR technologies.

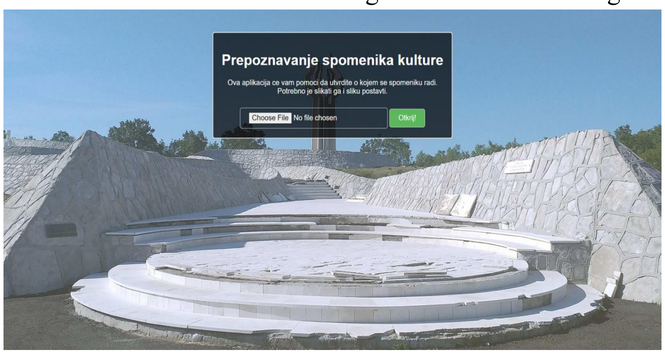

Figure 5. Landing page of the web application : upload picture of monument

Figure 6. Page with recognized monument and it’s description

V. CONCLUSION

For centuries, humans have been inspired by their brain and their fascination with intelligence has led us to the development of AI, a tool nowadays used on daily basis. The implementation of this technology into tourism has a high potential of improving overall tourist experience and further valorize cultural heritage potential that Montenegro as a country possesses. AI, particularly the field of computer vision, has a potential to reveal Montenegro’s forgotten cultural and historical monuments to its visitors, which currently lie dormant, unmarked and uncelebrated. The importance of this project lies in applying digital transformation in tourism department in Montenegro, following many of the strategic documents and achieving objectives set by government of Montenegro.

Future work includes collection of much larger dataset that will include vast majority of monuments from each part of the country, and integration of the model in the mobile application that will be available for use to tourists coming to explore Montenegro’s hidden cultural heritage. As for the medieval tomstones, the main focus will be put on creating an elaborate dataset for medieval tombstone graveyards, such as one near Zabljak in Montenegro, to train computer vision models that can find applications in research of stećci, their cultural heritage and climate change impacts, but also for digital tools and mobile apps for cultural tourism.

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