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OBJECT DETECTION IN ORDER TO DETERMINE LOCATIONS FOR WILDLIFE CROSSINGS

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Abstract: The intensive construction of road infrastructure due to urbanization and industrialization around the world carries with it negative environmental impacts, primarily due to increased emissions of gases, but also due to the separation of natural habitats and ecosystems. In order to overcome this problem, without affecting the mobility of the population, it is necessary to allow wild animals to cross over or below the roads, i.e. to create wildlife crossings, which requires knowledge of the locations where the corridors of animal movements intersect with existing or planned roads. This paper analysis the establishment of a camera system and the application of a deep learning methodology for the automatic identification of animals by species and number, in order to determine locations for the construction of crossings for large wildlife. Also, the paper presents the possibility of using geographic information systems to analyze information obtained by monitoring built wildlife crossings.

Keywords: deep learning, GIS, object detection, wildlife crossings.

Introduction

Throughout recent history, people's lifestyles have changed rapidly. Modern world trends bring a huge risk of degradation of environment in which people live (Vagić, 2018). A great deal of scientific research shows that life on Earth depends on maintaining much fragile equilibrium with a series

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of complex processes between them (Milinčić et al., 2015). The cities are growing, the industry is diversifying, there are more and more vehicles on the roads, resulting in intense degradation of environment in which we live, but also that we share with other living beings. There are constant changes in the environment that have a direct impact and consequences on species, their communities and ecosystems as a whole (Đurđić et al., 2015). Due to modern activities and modern lifestyles, the mobility of the population is constantly increasing. With a production trend of 50 million vehicles per year, it is estimated that there will be around one billion passenger cars in the world in two decades (Mihajlović & Marinković, 2016). In order for a society with so many vehicles to function optimally, the existence of an extensive network of transport infrastructure is necessary. Just in period of 2015-2019, 320 kilometers of highways were built in Serbia (Srna, 2019), which can certainly represent the progress of our society, but only if implemented properly.

By building transport infrastructure, we think first of all of our needs, and only later on, of the needs of other living beings, and often we neglect them. As new roads emerge, many animal migration corridors are being intersected. It is very important for healthy ecosystem that large mammals have possibilities for free movement through the large areas. The migrations are essential for keeping the balance between animal populations, maintaining sufficient genetic diversity or preventing the temporary lack of food (Matuska et al., 2018). It is only when the survival of a certain species is called into question that we begin to think about the possible consequences and steps needed to repair the damage, but in many cases it is too late.

As already indicated, the modern way of life carries with it many negative consequences for our society as a whole. However, relevant elements of modern society can also be used to mitigate or even eliminate harmful anthropogenic environmental impacts. The development and expansion of computer systems has reached a level that could not have been imagined since the beginning of the 20th century. The development of artificial intelligence is growing exponentially, and this trend should, among other things, be directed towards preserving a healthy or, in difficult circumstances, towards healing the damaged environment.

In order not to limit the mobility of the population, while preserving healthy ecosystems of large wildlife, it is necessary to allow the crossing of the human movement corridors with the animal migration corridors, but in such a way that both humans and animals do not interfere with each other in these constant processes. The simplest solution to this problem is construction of wildlife crossings. Wildlife crossing structures help wildlife move between habitats by connecting fragmented habitats (Seo et al., 2021). The number of wildlife crossings built in North America and worldwide has increased during the last decade and their design and performance as mitigation measures has received considerable attention (Clevenger, 2005).

Many large wildlife such as chamois, mouflon, roe deer, deer, wild boar, fox, jackal, wolf, lynx and bear are found on the territory of Serbia (Službeni glasnik RS, 2010a). However, although in Serbia the law and project documentation stipulate the existence of such structures (Službeni glasnik RS, 2010b; JP Putevi Srbije, 2012), so far none have been built. One of the positive examples that things are beginning to change is the international project for the revitalization and management of the ecological corridors of large mammals in the Carpathian region and in the Republic of Serbia named "Connect grin" (RTS, 2019). According to this project, in the future, we should have a map of a clearly defined ecological corridor that will help planners to identify places where wildlife crossings will be over, for example, the Đerdap highway. On the other hand, in some states, such structures are an integral part of the roads design, and so, currently in California (USA), it is planned to construct a wildlife crossing over a 10-lane highway that will be 60 meters long, and as such will be the largest in the world (Aleksić, 2019).

The main goal of this paper is to represent possibilities of a deep learning methodology application on images obtained from camera systems, for the automatic identification of animals by species and number, in order to determine locations for the construction of crossings for large wildlife.

Research methodology

Wildlife crossings can provide linkages, improve connectivity, and mitigate the incidence of road kills, and it can generally be divided into overpasses and underpasses (Ernst, 2014; Pierik et al., 2016). Overpasses or "green bridges" provide open views and sufficient space for animals, which is generally more suitable for species that instinctively avoid narrow and dim spaces. On the other hand, underpasses are intended for small mammals, amphibians, and reptiles, often taking the form of tunnels or small culverts (Zhang et al., 2019).

However, the problem that arises is how to determine the locations where these crossings should be built and what type they should be, because we cannot just place a crossing over a road in a place that seems appropriate to us or that is the easiest or most convenient for construction and that afterwards we hope that some animals will use it. Due to their costs, wildlife crossing structures are usually installed sparsely and at strategic locations along transportation networks (Bhardwaj et al., 2020). An important fact to keep in mind is that making adequate decisions regarding the protection, preservation and improvement of the environment depends in part on quality information and their expert interpretation (Sredojev et al., 2011). With the use of computer vision technology, we can efficiently and accurately monitor wildlife (Lu & Lu, 2022).

This paper proposes the monitoring of roads through the establishment of a camera system that will cover all parts of roads where it is possible to build wildlife crossings, as well as the surrounding area, in order to detect the movement of different species of large wildlife. Cameras can be installed on the pillars of existing energy, telecommunication, or traffic signalization infrastructure where possible, and where such a possibility does not exist, special pillars should be placed for the installation of cameras.

The next question that arises here is how to review hours and hours of videos in order to find the ones which captured certain animals moving near roads or even on the roadway, thus endangering the safety of road users as well as their own safety. Manual detection relies on observers, and observers can be subject to biases and other factors, including fatigue, interest, skill level, training, eyesight etc. (Ulhaq et al., 2021). Fortunately, with the proper use of technology and software engineering, those hours of footage do not even have to be viewed in their entirety, but different deep learning methods can be used to identify objects in videos, where it is very easy to get information at what location, at what time, how much, and which animals were recorded.

Object detection is an important technology that enables computers to have object detection ability such as human vision by recognizing each object in an image (Lee & Hwang, 2021). One methodology that can be used for this purpose is YOLO (You Only Look Once) (Redmon et al., 2016). Processing images with YOLO is simple and straightforward. System resizes the input image runs a single convolutional network on the image, and thresholds the resulting detections by the model’s confidence (Figure 1).

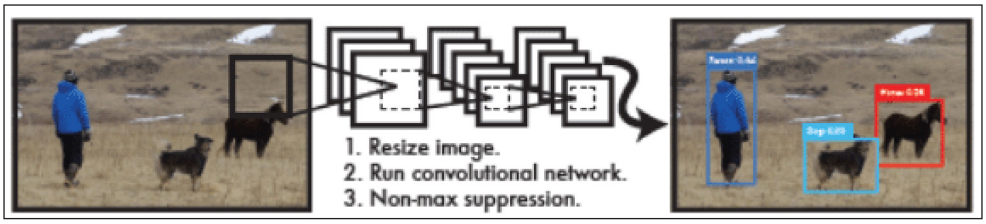

Figure 1. YOLO processing images (Redmon et al., 2016)

A single convolutional network simultaneously predicts multiple bounding boxes and class probabilities for those boxes. YOLO trains on full images and directly optimizes detection performance. This unified model has several benefits over traditional methods of object detection (Figure 2).

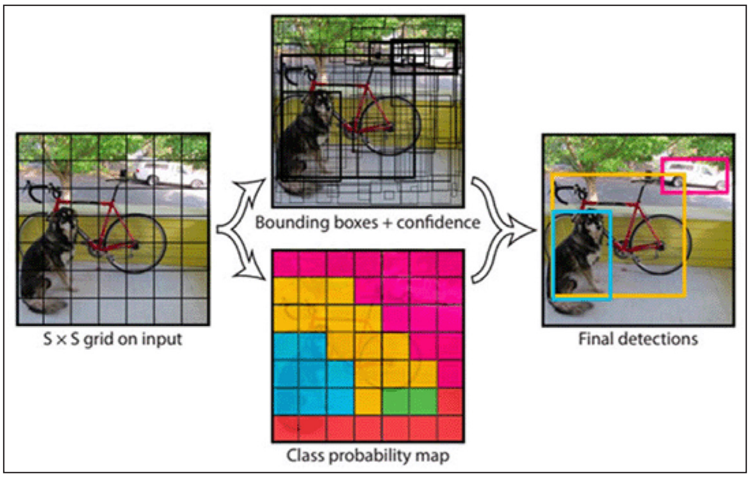

Figure 2. A simplified illustration of the YOLO object detector pipeline (Redmon et al., 2016)

Object detection is reframed as a single regression problem, straight from image pixels to bounding box coordinates and class probabilities. Using YOLO, you only look once (YOLO) at an image to predict what objects are present and where they are. YOLO trains on full images and directly optimizes detection performance. YOLO models detection as a regression problem divides the image into an *SxS* grid and for each grid cell predicts *B* bounding boxes, confidence for those boxes, and *C* class probabilities. These predictions are encoded as an $S \times S \times (B * 5 + C)$ tensor. YOLO is extremely fast. Since frame detection is performed as a regression problem it doesn't need a complex pipeline, simply run neural network on a new image at test time to predict detections.

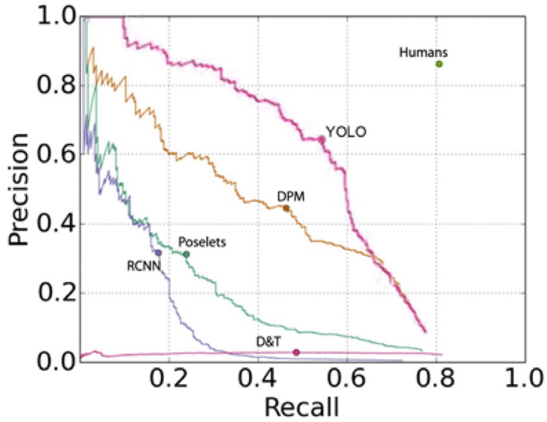

Figure 3. The precision-response relationship of the YOLO method for detecting objects and other methods on a Picasso image set (Ginosar et al., 2014)

In Figure 3 curves showing the precision-response relationship of the YOLO method for detecting objects and other methods on a Picasso image set, and it can be seen that the YOLO object detection method displays the best results on this test (Ginosar et al., 2014).

An alternative way of collecting data on animal movement locations which is not requiring large financial investments as a previously explained method in terms of the purchase of surveillance equipment, its placement, power, maintenance, etc., involves incorporating the presented algorithm into advanced smart systems in vehicles.

The automotive industry has undergone significant changes in the last ten years. The level of vehicle autonomy is increasing every day and autonomous vehicles are becoming a daily reality. Also, there are systems in place to minimize human errors while driving, reduce road accidents, and thus provide people with greater safety. The name of such systems is ADAS (Advanced Driver Assistance System). Autonomous vehicles need to perform their functions without the need for driver intervention, and in order to be able to do so, they need to incorporate some form of artificial intelligence. Therefore, it is necessary to have different sensors that provide information from the environment and a computer system that based on that information and appropriate algorithms make decisions when driving autonomously. One of the basic functions that autonomous vehicles need to perform is the detection of objects in front of the vehicle. There should be information at all times about the objects in front of them. This function can be achieved by using the information obtained from the camera image on the front of the vehicle (Ciberlin, 2018).

Cars have been equipped with camera systems for several years now that cover the entire vehicle environment. The capabilities of such systems are best illustrated with a bird's eye view and a 360° view, where in both cases the vehicle itself is shown in real time and space, based on the merging of different images from cameras on the vehicle which are working as a single system (Figure 4).

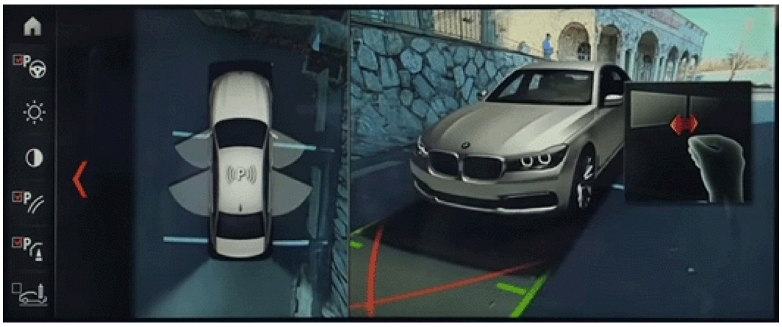

Figure 4. A bird's-eye view of the car and an outline of the car's environment with 360° rotation (DeMuro, 2018)

If automakers include the object detection algorithm presented in this paper in their smart systems, it would open wide opportunities for collecting animal movement data near or even on the roadway. In the case of an animal detection, the system could send data about the time, location, type and number of animals detected to the central base of each state with a video clip from the cameras that detected the animals, which could help verifying whether the detection is correct or some errors may have occurred. Of course, there are no such vehicles on the Serbian roads in enviable numbers, so initially, most of the time the roads will be unmonitored. However, in the future, their numbers will grow very fast, and with them the opportunities for putting this system into practice will grow too.

The locations of the so collected data can be mapped and analyzed in the geographic information system (GIS) with a goal to propose the best sites for wildlife crossings. In contemporary literature, many authors emphasize the importance of GIS application for locating and monitoring wildlife crossings (Alexander, 2008; Aquino & Nkomo, 2021; Clevenger et al., 2002; Karlson et al., 2017; Leoniak et al., 2012). By finally constructing wildlife crossings at locations that would be best according to the presented methodology, the same camera system can monitor them, which gives an insight into whether animals use a placed overpass or underpass and, if so, to what extent. Such monitoring can collect data from a network of all crossings in the country, and even more broadly if the system is established at regional or even continental level.

Further, such results can be linked so the movements of animals across large areas can be tracked through geographical information systems. For example, if a certain number of animals of one species is detected at one crossing, and after a certain time, the same number of animals of the same species is detected at another crossing, and by checking the recordings we find that they are identical animals, their path and speed of movement can be counted by GIS and generally predict their further migratory movements, which is essential for understanding the functioning of ecosystems and determining measures for their conservation and protection.

Research results

For real-time deep learning-based object detection in this paper we used OpenCV and Python. YOLO trained on the COCO dataset consists of 80 labels, including animals, cats, dogs, birds, horses, cows, and sheep. The YOLO object detector divides an input image into an *SxS* grid where each cell in the grid predicts only a single object (Figure 5).

Figure 5. Animal detection using YOLO

The research of the possibility of using the presented methodology for the detection of roadside animals was conducted on February 22, 2020, where a fixed camera simulation on the front of a moving vehicle was done. The camera from a Xiaomi Mi 8 Lite mobile device with 4K resolution at 30 FPS (frames per second) was used. Certainly, the quality of the camera can significantly affect the final results of object detection, especially when it comes to shooting from a moving vehicle, because as the speed of the vehicle increases, the quality of the shot decreases, more precisely the objects are more and more difficult to recognize. Therefore, the higher resolution of the camera and the number of frames per second of the video implies the greater possibilities for obtaining high quality results of object detection in poor shooting conditions and circumstances.

To demonstrate the possibility of using the YOLO object detection algorithm, stray dogs were taken as an example, as the only realistic option that doesn't require significant financial investment and high risk exposure, both for humans and animals that can potentially be recorded roadside and on the pavements in Serbia.

Figure 6. Detection of dogs on the road from the moving vehicle using YOLO

The result of the survey is shown here in the form of the image obtained from the processed video, which shows dogs running on the roadway in front of the moving vehicle from which the shooting was made. Using the object recognition algorithm, it is clearly marked that there are two dogs, but also other objects that the algorithm is "trained" to recognize can be marked, such as in this case a parked car (Figure 6).

Conclusion

Modern lifestyle patterns are causing the need for increasing population mobility, sometimes to such an extent that it looks as the planet we live on is getting smaller. If we already can't give up many aspects of our lifestyle today, we can at least try not to be negligent on the environment in which we live and give the next generations at least the same chance we had, if we could not already provide them the better one. One of the essential elements of preserving a healthy environment is non-interference of wildlife ecosystems with anthropogenic activities. Nevertheless, the construction of each road opens the possibility of a detrimental effect on the freedom of steady movement of wildlife.

This paper offers a simple solution for determining the appropriate locations where it is necessary to build wildlife crossings so that humans and animals can navigate even with crossing their paths, but without interfering with and mutually affecting each other. The solutions presented can be of great importance for the conservation and advancement of different animal species under the conditions of expansive road construction in Serbia in recent years and show how the application of different algorithms through geographic information systems can be a powerful and affordable tool to protect many animal species as well as the environment as a whole.

The great advantage of using the YOLO object recognition algorithm in general is that, in addition to standard objects (humans, animals, vehicles, etc.) the algorithm can be "trained" to recognize anything that can be isolated as an object in a particular image or video. Therefore, the algorithm can be shaped to the user's specific needs. The training of the algorithm can be done by using images with different variations (by types, recording angles, etc.) of the object that we want to recognize in different videos in perspective. According to that, if much more different images are entered into the algorithm, the better quality and accuracy of object recognition will be later, and recommended minimum is 1000 images. This is precisely the biggest obstacle to improving and designing this methodology for our own needs, as it is necessary to provide and process more than 1000 images on the same topic.

However, this is certainly not an insurmountable obstacle, and the degree of engagement to overcome it will depend primarily on the subject matter for which the algorithm is designed, that is, the availability of images on the chosen topic and the ability to collect them. In future, it is plan to create our own training model and demonstrate object detection based on it, as the next research step in this area.

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