Abstract

With the increase of single-use packaging and the different types of materials, there has been a massive growth in waste. An inappropiate managed of these wastes have caused a huge environmental impact. To deal with this problem, a simple but effective action is to separate the waste at the source point. However, with the diversity of materials available today it can be difficult to know how to dispose correctly all of them. This final degree project seeks to offer help to solve the doubts through a mobile application.

To do so, we wanted to take advantage of the great progress that has been made in computer vision in recent years and develop an application that identifies objects. To achieve this it has been used TensorFlow Lite, whose libraries provides an easy way for training the neural network and generate the model, as well as its import into mobile applications. Likewise, to ease the task of obtaining the necessary datasets for training, an application that generates synthetic images from three-dimensional models has been developed. This images are subsequently used for the neuronal network training.

Key words: recycling, object identification, neuronal network, TensorFlow Lite, image generation, computer vision, dataset, mobile application.

Capítulo 2

Introduction

2.1. Motivation

The waste generation is linked to the current development model of society and constitutes one of the main environmental problems the world is facing [47]. Waste can be classified into two types: those produced by industrial activity, called industrial waste, and those generated by human activity itself, called urban waste.

A large part of the pollution and emissions of CO_2 come from large companies, for example in 2018 25 % of the emissions in Spain were generated by only ten companies [?]. Even though, this coursework will focus on urban waste, which is where the population can be aware of and take measures in this regard.

The problem of urban solid waste comes from recent years increment use of non-return packaging. These packages can be made of different materials such as cellulose, glass, plastic or mixed (laminated paper, laminated fabrics, etc.) which complicates their treatment, since a previous selection and separation must be done.[12].

Poor waste management can cause irreversible environmental impacts. Nowadays it can already be see many of the effects that seemed to come in the future [33]. Among them it can be highlighted the increasing temperatures around the globe, the disappearance of glaciers (both in the mountains and in the polar ice caps [7]) or the decrease in 68 % of the population of vertebrates [?].

In Spain, the temperatures have increase throughout the national territory and the Mediterranean, among its sea level increment. As well the dilation of summer around 9 days per decade, which means that currently it's 5 weeks longer than at the beginning of the eighties. Other effects are the disappearance of more than half of the spanish glaciers and changes in the distribution, behavior and nutrition of biodiversity, among other factors [?].

But proper waste management is something within the reach of any ci-

tizen.

Mixing materials is not only polluting because it makes their recovery and recycling difficult. Waste separation is a costly and polluting process which not always have satisfactory results. This is due to the fact that sometimes the recovered materials are low quality and with a high level of non-recyclable particles because they have been combined with others. Therefore, to facilitate this process we find special containers for each type of waste.

Separating waste properly is a great contribution to take care of the environment. As discussed above, there are a lot of different materials and types of waste, which sometimes can be difficult and confusing knowing how they should be separated correctly. Due to this difficulty arises the motivation for this final degree project. The main objective is to develop an object identification application that, using the camera of a mobile phone, indicates the appropriate way to dispose an identified waste. With this application, it would be easy for citizen to solve in a comfortable way any doubts about recycling that may arise, promoting this way eco-friendly attitudes.

2.2. Objetives

The main objective of the project is the development of a mobile application focused on recycling. This app identifies objects and gives information about the material and the appropriate way to recycle them. Through it, users will be able to identify different wastes to solve quickly and easily any doubts about how dispose them correctly.

To achieve its correct behaviour it is necessary to use artificial vision techniques, which currently involve the use of trained neural networks. To do so, it is necessary to have a large number of correctly labeled waste images (known as dataset) that are used to "teach" (train) the neural network. Obtaining said dataset becomes one of the main sub-objectives of the project. In order to facilitate the process of obtaining the images, is decided to develop a second application. The objective of this one is to avoid the tedious and slow process that obtaining images can be. This one is a computer application that generates synthetic images from three-dimensional models. This application generates as many synthetic images, from the available models, as desired to train the neural network.

2.3. Tools

Android Studio it has been used to develop the identification mobile application. To train and obtain the model necessary for the application performance, it was created a script in Python using Numpy and Tensorflow

Lite libraries and PyScripter as the editor. This first part has been based on the examples and recomendations of TensorFlow Lite, availables on its website[1].

The image generator application was developed using the video game engine Unity. The three-dimensional models used in this application have been sourced from CGTrader[2], Free3D[3], TurboSquid[4], 3DModelHeaven[5] and Unity Asset Store[6].

Lastly, for the project's version control it has been used GitHub and for the project report development the TEXIStemplate in TexMaker editor.

The entire process has been developed with a Windows device and the aplication tests with an Android mobile device.

2.4. Work plan

The workcourse is divided into three different parts: the image generation, training the neural network and development the mobile object identification application.

The first one is focus on the develop of an application that loads 3D models and makes numerous images to each one, changing their position, rotation and background to obtain diversity in the images. The models are organised by their material so the images generated must be arranged the same way. The development of the application is divided into two iterations, the first one is where all the main functionalities are developed and simultaneously verified its performance. Meanwhile, in the second iteration takes place the generation of the dataset.

Once the images are generated it is time for the neural network traning, which is the second part of the project. To develop this it's necessary to investigate the different types of neural networks and choose the most appropriate option to be used in a mobile application. In addition, it will be necessary to obtain some datasets of real images of the materials selected in order to make tests and comparisons of the accuracy in different cases.

Lastly, takes place the development of the mobile devices application, which uses the trained model to identify the material of the object that is being focused on with the camera. Among the material, it's also indicated how it must be recycled. At this point in the coursework various tests must be done to verify the performance of the application. To do so, the application accuracy of different trained models will be compared using diverse everyday

[1] https://www.tensorflow.org/lite/?hl=es_419
[2] https://www.cgtrader.com/
[3] https://free3d.com/es/
[4] https://www.turbosquid.com/
[5] https://3dmodelhaven.com/
[6] https://assetstore.unity.com/

objects.

Capítulo 8

Conclusions and future work

8.1. Summary

The result of the project is the prototype of a recycling help application for Android devices. It shows what is pointed at with the device's camera, identifying and offering information about the material of the object, as well as indicating the proper way to dispose it. As has been commented throughout the document, it's necessary to use artificial vision techniques, which currently involve the generation of a model trained by a neural network. This implies the need to establish several subgoals.

The first sub-objective proposed is to obtain a wide, clear and varied dataset with images of all the materials that will be available. In order to facilitate the obtaining of the datasets, an application for generating synthetic images from three-dimensional models has been developed. To do so, it has been used Unity, a multiplatform video game engine created by Unity Technologies. The application flow consists of loading the different 3D models available, separated by material in the resources, and taking numerous captures of each one. In each capture, both the position and rotation of the object, as well as the background, are established randomly. This is required in order to compile a high diversity in the images. Due to the inconveniences that arose during the obtaining of the models, the final dataset was composed of three different materials (metal, glass and plastic), in which real images are mixed with synthetic images for metal material.

Once the dataset was generated, it was proceed to the second subgoal. This is divided into two different steps. The first one, is the the neural network training and the trained model generation using the previously obtained dataset. The result of the training will be later incorporated into Android Studio to be used in the final mobile application. For this section, it has been used a TensorFlow Lite library, which allows transfer training using the EfficentNet network and provides tools to perform easily and intuitively the model training.

The second step, was to carried out several tests and comparisons in order to find the ratio between synthetic and real images that offer the best balance between the ease of obtaining the dataset and the accuracy of the trained model. The conclusion of the tests was that from 30 % onward of real images, the precision barely changes staying above 90 % confidence. Which means that the accuracy of the model when all the images are real and when only 30 % of these are used in one of the materials, is really similar. With this results it was decided to use the model which metal material data was composed of 70 % generated images and 30 % real images with a 93 % of accuracy.

Lastly, the development of the Android application takes place, using the Andorid Studio tool and TensorFlow Lite's libraries. The application receives images of the framse captured by the camera and, consulting the imported model, tries to identify the object that appears in the image. As a result, it orders the available labels depending the confidence for each material. This way it's informing the user about the material of the object, the container where to dispose it and the confidence of the identified materials.

In order to test its performance, several tests were carried out on real world objects. To do so some changes were made to the application leading the creation of a sencond one, cosidered the test application. Using this application the performance of four models is compared simultaneously. With the data obtained from this tests it was corroborated the correct performance of the trained model selected .

8.2. Conclusions

During the development, various difficulties and conclusions that affected it were observed, which should be taken into account in possible future extensions or in the development of similar and related projects.

It was experieced the real difficulty of obtaining large datasets of specific objects not may resources are available. This has caused limiting ourselves to have just three materials. A solution to this problem can be the use of synthetic images to complete the dataset. This work has shown that, at least in the proposed context, this option has highly positive results, because even though an important part of the dataset was formed by synthetic images, the accuracy was barely affected. After conducting tests in a real environment, as a result of the accurate identification with positive confidence obtained the correct performance of the application is corroborated. For this reason, the image generator application is considered a useful support to many out-of-the-box projects in the field of image and object recognition.

However, in order for this application to be used, it's necessary that getting synthetic images is easier than getting real photographs, since there is still some difficulty generating the dataset. This is caused by the difficulty

to obtain three-dimensional models with high level of realism in textures and materials. This is importante because otherwise the way the light falls and reflects on them can be unrealistic and cause problems in the training of the neural network. Wich makes the problem of generating datasets not entirely solved.

Lighting is another important element, despite the facilities that Unity offers to create different types of lighting, without enough knowledge and experience the results can end up being poor and unrealistic. This is a problem since the application is going to be used on real objects, and if there is no balance between that and what is used for training, the precision of the application would noticeably decrease. This could be observed when the dataset had more than 80 % of synthetic images, where the training images differ form the object in reality, the results were worse in comparison with the rest of the percentages.

With the results obtained during the coursework and the outcome of other synthetic datasets based projects, it can be stated that the correct performance of a synthetic images dataset deppends whether it has been mixed with real images. This happens because virtual and real cameras are different sensors.

Lastly, it has to be taken in consideration that the performance mixing real and sythetic on just one material also influence the outcome of the others which only contained real images in the dataset.

8.3. Future work

The project has several scalable features. The first one is obtaining a larger dataset, which would add more variety of materials and objects to identify. This can be done from real images by themselves, or mixing them with synthetic images. In the case of the second option it is necessary to obtain or generate high quality three-dimensional models of all the materials and objects required. Another expandable characteristic to allow greater diversity of the generated images is to extent the number of images available for the background.

In order to generate more realistic images, it would be necessary to review the lighting in the scene, making it alike to how the objects are later seen in a real environment. Also, it is necessary to acquire a real image dataset of the materials added. The amount of images this would require depends whether it is to be combined with synthetic images or not.

Once the dataset has been obtained just trainning and generate the model is left to finally import it into the application using Android Studio. All added materials also must be related to its appropriate container or disposal site, which is the information the user is looking for.

To improve the network and expand the dataset, it could be developed

a feature where users can send their own tagged photographs allowing the continuous growth of the application and a better service to users.

Another interesting additional improvement is to convert the images generator into an executable application independent of Unity, in which users can generate datasets for their projects using their own models imported into it, or use some ones offered by default, for example those used in this coursework. Although the runtime import of models is not very widespread in video games, due to the number and diversity of users that Unity has, this functionality has been widely discussed and explored. It can be find packages to do so, for example " TriLib 2 - Model Loading Package " by Ricardo Reis footnote url https://assetstore.unity.com/packages/tools/modeling/trilib-2-model-loading-package-157548, " Runtime OBJ Importer " from Dummiesman footnote url https://assetstore.unity.com/packages/tools/modeling/runtime-obj-importer-49547 u " OBJReader " from Starscene Software footnote url https://starscenesoftware.com/objreader.html#ObjReader, as well as numerous forum discussions on the subject.

The Android application itself has also several properties expandable in future work. One of them is to personalized more the user interface so it can offer information about the different containers available or the recycling process. Another option is to develop the application for iOS devices, allowing it to be used by more users. In addition, a necessary extension of the application is the incorporation of accessibility in order to allow its use to all types of users. This improvements correspond, among others, to the introduction of a voice option, customization of the font size, colors and contrasts.