Sustainable Smart Advertisement Display using Deep Age and Gender Recognition

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***Abstract*—We propose an innovative and sustainable advertisement display system tailored to bystanders' liking based on age and gender using Convolutional Neural Networks. The bystander's face is detected using a webcam attached to the advertising screen and fed into the trained Convolutional Neural Network to identify the age and gender. The classification results are stored in a real-time database server and retrieved on a website that enables the client to customize advertisements to the targeted groups. The website provides an easy-to-use interface to control the system contents and report daily statistics. This loop, starting from detecting bystanders' faces until the targeting advertisements are displayed, takes place daily every two seconds. Moreover, a motion sensor is connected to the advertising screen for sleep mode to ensure the system's sustainability. The proposed system serves as an intelligent advertisement platform that guarantees the proper content delivery to the right people. The proposed system achieved accuracy is of 91.7% and 95.5% for age and gender, respectively. This developed system could also display pieces of advice and news in populated public places, which will increase awareness and knowledge in society.**

***Index Terms*—Advertisement display system; decision making; deep learning; age classification; gender recognition**

I. Introduction

Effective advertising is key to successful businesses. Relevant and engaging advertisements are essential to reaching potential customers. Personalized and customized advertising approaches are needed to address different customers' needs. Although smart displays for ads are present, the market demands enhanced targeted advertisement approaches that can be displayed on smart screens in public places and upcoming smart cities [1], [2].

Multiple solutions already exist in the market. The mirror advertising screen, for example, works as a mirror and digital advertising screen simultaneously. Its advertising content appears on-screen, reverting to a mirror when no content is displayed [1]. This solution is useful in retail stores, beauty salons, and restrooms. However, the displayed content is random, and the system's operation is non-stop.

A mobile-programmable smart mirror [2] is a mirror with customized displays based on user preferences. This implementation enables the users to customize the content to their liking through a mobile application. This electronic information is then displayed on the smart mirror, allowing users access and interaction while performing their daily tasks. Even though this platform has proven efficiency, the customization in this framework is one-to-one, meaning that it needs to be done by each user.

Artificial intelligence (AI) and deep machine learning approaches are growing significantly with an expected compound growth rate of 33.1% in the upcoming 15 years [3]. Various industries such as healthcare, education, and marketing deploy AI techniques to enhance and optimize their applications. One of the common use cases for AI in marketing is in advertisement [4]. For example, Facebook collects and analyzes users' data to model their interests and adapt advertisements' content accordingly [5]. Similar approaches match user profiles on social media platforms to recommend the most suitable users for advertisement campaigns [6]. A study conducted in [7] applies AI on Instagram profile pictures to determine the gender of the user for targeted advertising. Deep Neural Network (DNN) algorithms are also used for effective advertisement recommendations [8]. The use of machine learning and deep learning techniques improves the quality of advertising, hence, increases clientele.

A smart advertisement display board [9] is proposed to identify and assess users' intention and interest in the advertised items. The captured frames are processed to detect the face and eyes of the customer. This framework identifies intent and interest by calculating the appearance rate when the user's face and eyes are seen. The developed system was able to identify the user's intention with an accuracy of 68.57%. The major limitation of such framework is that it does not implement face recognition; this means that the appearance score of a potential customer can be calculated from different users.

Facial recognition has a lot of applications ranging from attendance taking [10] to advertisement [11], [12]. It is deployed in display systems to improve the services. In 2015, children's charities in the united kingdom (UK) created bus billboards that scanned the bystander's face before displaying an ad depending on the bystander's gender. The purpose of the campaign was to increase awareness about women who are denied rights worldwide based on their gender [11]. This system used facial recognition to recognize gender only for a specific purpose.

A responsive advertising system based on facial recognition is proposed for customizing advertisements in [12]. The system captures, identifies, and processes facial features with an 86% accuracy towards determining the gender, which helps

avoid irrelevant ads. The developed system focuses on gender since age can impact the perception of a person's gender. The research was concluded as an open-ended solution toward age detection due to the low accuracy for that category [12].

Convolution Neural Networks (CNNs) have been demonstrated to have superior gender classification performance [7]. In 2016, a study reported in [13] employed CNN to classify gender and came up with an effective real-time gender recognition system. In 2018, authors in [14] used CNN for gender classification and found a 2% boost in accuracy over state-of-the-art approaches. These studies, among several others, show that CNN, a deep learning technique, can correctly estimate the gender of a face object in a picture [7], [13], [14].

Although these implementations have proven acceptable performance, some issues remain unaddressed. The advertisement content of some of these implementations was random, reducing the reach to the potential customers. Moreover, the continuous operation of such systems increases power consumption, affecting the sustainability of the system. Furthermore, individual users need to customize their displays. In addition, these approaches require continuous data collection during operation.

In this work, we propose a system that adapts its content based on a bystander's age and gender to address these limitations. The adaptability makes advertising more efficient, attractive, and intelligent compared to other implementations. In addition, the system is supplied with a user-friendly website to control the content and report back daily statistics. This website allows the client to make the customization selections in a one-to-many manner to target specific groups. Moreover, the screen reverts to sleep mode when there are no people in the area to ensure sustainable operation and thus saving energy and reducing costs. Furthermore, the proposed system is trained on pre-collected data to classify bystanders based on age and gender. This guarantees efficient delivery of the right content to the targeted customers. It could also be used to display pieces of advice and news in populated public places, which will increase awareness and knowledge in society. By conducting this research work, we aim to construct an accurate, highly customized, smart, and sustainable advertisement display system that utilizes deep machine learning algorithms and CNNs.

The remainder of the paper is as follows: Section II presents our proposed system, while Section III analyzes and discusses our results. We finally conclude our work in Section IV.

II. Methods

A. System Overview

We propose an innovative and sustainable advertisement display system to attract bystanders' attention. The system is designed to display appropriate content based on age and gender. Figure 1 shows the overall system of our proposed advertisement solution. Firstly, an invisible webcam attached to the screen is programmed to take images continuously. The program detects the bystander's face and feeds it into the trained CNN. This architecture classifies and recognizes its age and gender class. Then, the classification results are stored in a real-time online database. Finally, the screen displays the advertisements based on the classifications retrieved from the database. This loop starts from the camera until it displays ads on the screen; it will repeat all day, every two seconds. In short, the camera detects the bystander's face and classifies its age and gender; thus, ads will be displayed on the screen based on the classification results.

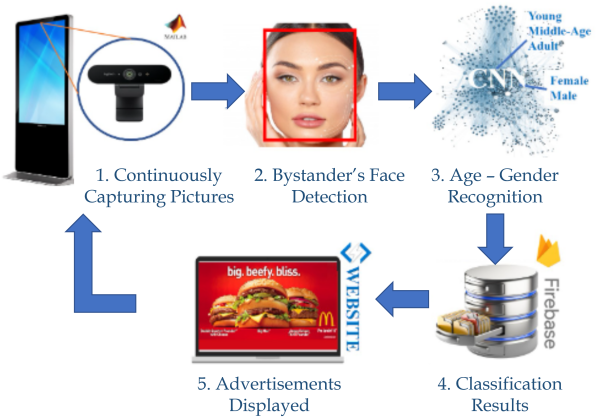


Fig. 1: System overview

Figure 2 shows the setup of the smart advertisement display system. The mirror's frame has an embedded camera, which continuously captures images. Once a bystander is identified, the specified advertisement will be displayed.

Fig. 2: Advertisement display system setup

B. System Flowchart

Figure 3 shows the system flowchart of the smart and sustainable advertisement display. We use a MATLAB computing server in this process. In the first loop, we test and train our CNN using ResNet50 architecture. We first train and test the Age CNN, check its cross-validation score, and do the same for the Gender CNN. The loop breaks and moves to the next if both CNNs yield a cross-validation score greater than 90%. Otherwise, even if one CNN got a cross-validation score lower than 90%, the process of testing and training remains for the CNN that does not meet the desired score. We proceed with the

second loop once we get a cross-validation score greater than 90% for age and gender CNNs. We detect the bystander's face in this loop and feed it to the trained age and gender CNNs. The networks return the bystander's age and gender classes. These results are sent to our real-time online database, which is retrieved in the website as shown in Figure 3. Lastly, the website displays Ads based on the classification results. During operation, this loop executes infinitely every two seconds.

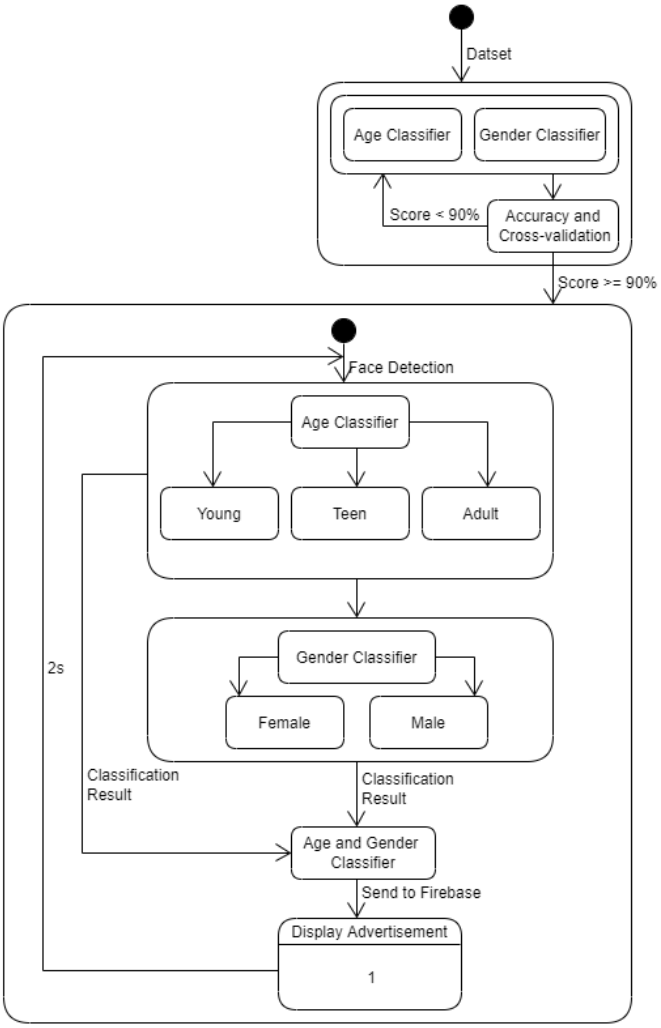


Fig. 3: Systems flowchart

C. Proposed User Interface

We design and implement a smart ads display system website to accompany the system for the clients' use. The simple and convenient User Interface (UI) of the website allows the client to make choices, monitor the interaction, and get real-time feedback, as shown in Figure 4. Clients can add advertisements and choose their targeted age and gender easily. This information is stored in a real-time database. The website retrieves the data from the database and classifies the advertisements based on their targeted age and gender group. Thus, the website classifies it accordingly whenever users add ads and choose the targeted age and gender. Then, the website displays the ads in the watching ads section based on the classification results. Furthermore, the user can find a detailed report with statistical visualizations. These visualizations represent the number of people from each category who pass in front of the screen in real-time. These real-time statistics show interactions and empower the client to make decisions related to appropriate locations and spots for their ads.

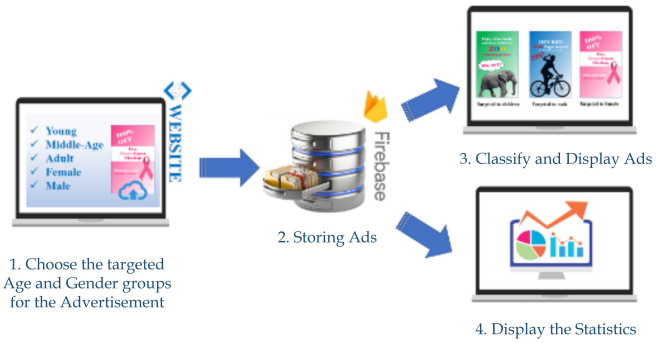


Fig. 4: User interface overview

III. Results

A. Dataset Evaluation

To train and test our system, images from IMDB Wiki Faces [15] and UTKFace [16] datasets were used and optimized for usage in facial recognition. We classify the images into five classes: young, middle-aged, adult, female, and male. It is essential to note that these online datasets were collected in western regions; therefore, these datasets might not yield the best results in Arab regions (such as United Arab Emirates) due to the bias of certain appearances and facial features. Although high accuracy was accomplished in some of the tests, this system might not perform ideally in other settings with other appearances and facial features. Better classification performance can be obtained by using more generic datasets from Arab, Western, and other societies. Additional work, including collecting our own dataset, is being done to address this limitation. This would minimize the time needed for classifying the age and labeling the ground truth. Overall, the system's performance was not significantly affected by the bias in this dataset.

B. CNN Architecture Evaluation

In our proposed system, we use two CNNs for age and gender classification. After pre-processing, cleaning, and classifying the images obtained from the two datasets, the CNNs were trained on a MATLAB computing server. Each of the model's accuracy was evaluated against 10-fold cross-validation. In most tests, the tabulated accuracies were less than 90% due to mis-classifications and quality issues. After several iterations of filtering the images, reclassifying, and fine-tuning, the highest obtained accuracies were 91.7% and 95.5% for age and

gender, respectively. These accuracies reflect the acceptable and generalized performance of the networks.

C. Website Evaluation

We designed a user-friendly website to import ads, monitor statistics in real-time, and display the advertisements based on the classification results. We evaluate the website's performance in real-time.

Figure 5 shows the four main sections of the website: "Home" section (Figure 5a), "Import Advertisements" section (Figure 5b), "Statistic and Reports" section (Figures 5c and 5d), and "Watch Advertisements" section. The "Import Advertisements" allows the client to make the age and gender selections and add the appropriate Ad for the targets. For monitoring and feedback, the "Statistic and Reports" section displays the statistic with visuals, and the detailed report as the number of bystanders varies in real-time.

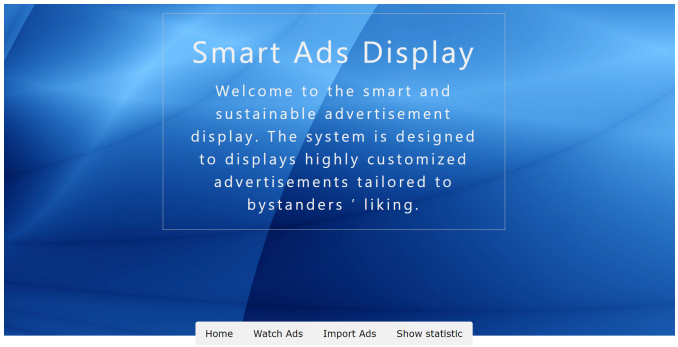
The statistics of each category change in real-time in the statistics display and the detailed report. Figure 6 shows the change of the values for female, male, young, middle age, and adults as the number of bystanders change in real-time.

D. Sustainable Smart Advertisement Display System Performance

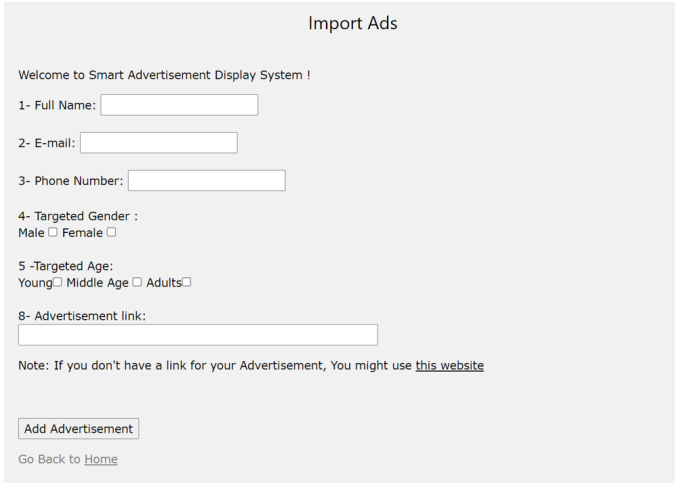
The performance of the smart advertisement display system was tested through different experiments. The desired advertisements was uploaded on the website and the targeted customers were defined as an adult female for the first experiment and an adult male for the second. People from different age and gender groups were asked to pass by the Smart advertisement's display. Figure 7 shows two of the obtained results of successful identification and display for both the adult female, Figure 7a, and male, Figure 7b, respectively, from left to right. After further evaluation, we observe that almost all the results we got match the expectations. The other results are not reported here for brevity. Therefore, we can deduce that the system can successfully identify the targeted customers and display the suitable content specified in the website.

IV. Conclusion

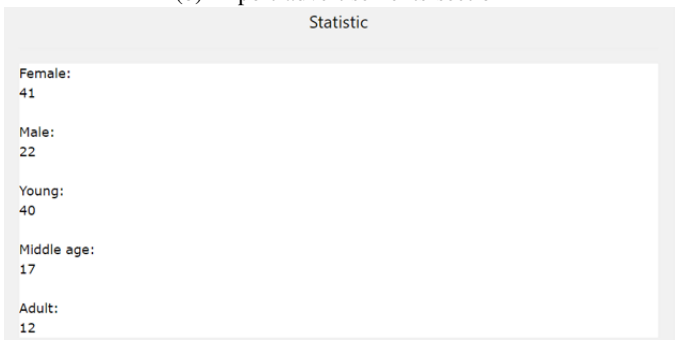
This work has proposed a sustainable smart advertisement display system that tailors advertisements' content to bystanders' liking based on their age and gender. The employed deep learning Convolution Neural Networks (CNNs) are firstly trained on IMDB Wiki Faces [15] and UTKFace [16] datasets. The trained optimized CNN is then used to classify the detected bystander's age and gender. The achieved clarification accuracy of trained network was 91.7% and 95.5% for age and gender respectively. Moreover, this system is accompanied by a user-friendly website that allows clients to customize the content for the target customers. This website also provides the client with real-time statistics retrieved from a real-time database. Besides the demonstrated application of the developed system in marketing, this system could also be used to educate and raise awareness among the public through



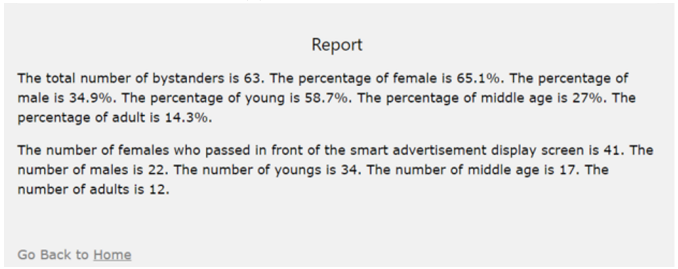
(a) Homepage



(b) Import advertisements section



(c) Statistics section



(d) Reports section

Fig. 5: Sustainable Smart Advertisement Display Website

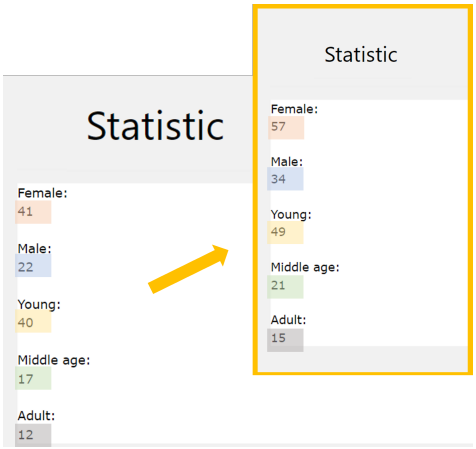
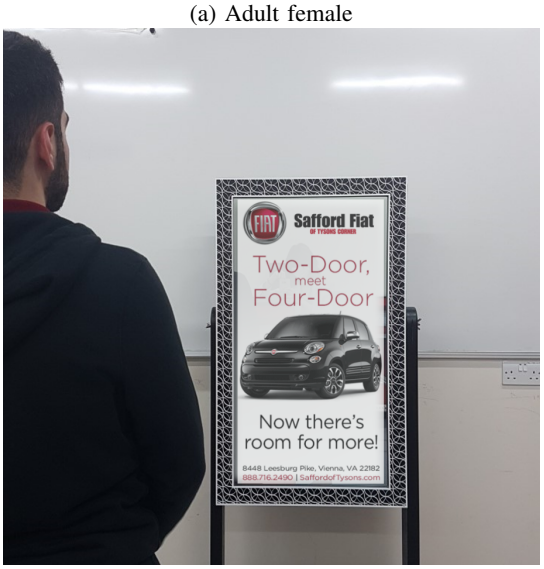


Fig. 6: Statistics are changing in real-time

(a) Adult female



(b) Adult male

Fig. 7: Sustainable smart advertisement display results for a an adult female versus an adult male

displaying pieces of advice and news in populated public places. The developed system performance can be further improved by collecting a local dataset to better represent the appearances and facial features of the targeted customers in regions like the Arab countries.

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