An Approach of Short Advertising Video Generation Using Mobile Phone Assisted by Robotic Arm

Jiefeng Li[1], Yingying She[1(✉)], Lin Lin[2(✉)], Yalan Luo[1], Hao He[1,3], Weiyue Lin[1], and Shengjing Hou[2]

[1] Informatics School, Xiamen University, Xiamen, China
jiefengli@stu.xmu.edu.cn, yingyingshe@xmu.edu.cn, {1042181127,501700413}@qq.com, 18960110978@163.com

[2] College of Art, Xiamen University, Xiamen, China
linlinxiamen@xmu.edu.cn, 1403018492@qq.com

[3] Quanzhou Institute of Equipment Manufacturing Haixi Institute, Chinese Academy of Science, Quanzhou, China

Abstract. Recently, Short Advertising Video has become an increasingly dominant form of advertisement on social media. However, making Short Advertising Video is a challenging task for micro and small businesses, since it requires professional skills and years of experience. In this paper, we present a novel approach of Short Advertising Video generation assisted by robotic arms. We analyzed the professional composition and imaging of advertising videos, and transformed them into an automatic shooting process during the production of Short Advertising Video, assisted by a robotic arm. Practically, we applied our approach in two kinds of robotic arms and the results showed that robotic arm assist solution can highly enhance the efficiency and effect of making Short Advertising Video. In addition, our video generation approach can save time and money for novice users from micro and small business who has very limit resources and budget. And, we believe that our approach might overturn the existing production model of the Short Advertising Video propagated in the online business and social media.

Keywords: Graphical human-computer interaction · Robotics and vision

1 Introduction

With the popularity of smart phones and mobile applications, Short Advertising Video on mobile phones has shown potential. Well-made and professionally-edited Short Advertising Video on social media can assist in product presentation and have high conversion rates, which can greatly increase product sales.

In this paper, we mainly consider short commercial advertising videos for micro and small businesses. Instead of branding, the purpose for them to make

N. Magnenat-Thalmann et al. (Eds.): CGI 2020, LNCS 12221, pp. 157–168, 2020.
https://doi.org/10.1007/978-3-030-61864-3_14

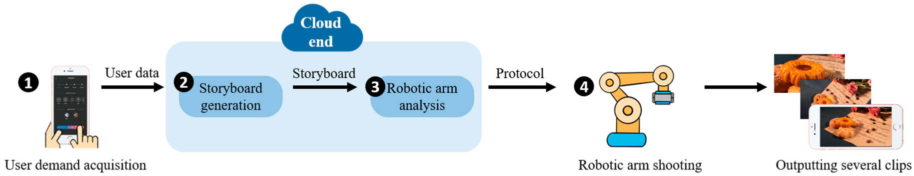


Fig. 1. The Short Advertising Video generation procedure of AD-Designer.

advertising videos is to show the overall appearance and details of the product, which consequently can be able to motivate consumers to buy the product. This kind of Short Advertising Video is usually without actors, and all product shots are filmed in one location. Due to the limit of social media propagation, the length of one video is usually approximately 15 to 30 s.

Though Short Advertising Video on social media has high conversion rates, producing high-quality advertising videos is challenging for novice users from micro and small businesses who can not afford high cost. It not only needs the support of a professional advertising video shooting team, but also requires a long production cycle. Existing mobile applications designed for novice users, such as iMovie and VUE, provide templates that help novices arrange to capture content in a professional and structured way. However, there is no detailed guidance when novice users shoot specific clips. Even though several methods were proposed for post-processing a video to enhance its visual qualities, they are still very inefficient and cannot make up defects of the original video. In addition, several shooting-assisted devices, such as OSMO, solve some problems of manual shooting, but novice users still have to design the motion path of camera by themselves. These problems have created a huge obstacle for novice users to promote their products in online media by Short Advertising Video.

To address the above challenges, we developed AD-Designer, a mobile application coordinated by cloud video processing modules to help novice users make Short Advertising Video. In our work, in order to prevent users' shooting problems mentioned above, we introduced the robotic-arm-based shooting process into our existing script-based interactive advertising video production framework [1]. It is an upgraded version of our previous visual-guided shooting process. Our experiment shows that compared with the manual process, AD-Designer increases the quality of the advertising videos and the cost has been greatly reduced. The whole generation process is shown in Fig. 1.

2 Related Work

2.1 Computational Modeling of Cinematography

Computational modeling has been previously proven effective in a number of situations. Studies have focused on modeling computational cinematography from various aspects. Chen et al. [3] modeled the shooting scene in AR(augmented reality), so that users can plan an aerial video by physically moving their mobile device, as a viewfinder, around a miniature 3D model of the scene. The method presented by Leiva et al. [4] encouraged users' exploration of different contexts for video prototyping by combining video with digital animated sketches. The system proposed by Tien et al. [5] classified shots in basketball game automatically through a GOP-based scene change detection method. Inoue et al. [6,7] proposed a novel concept of actuator-driven, frame-by-frame intermittent tracking for motion-blur-free video shooting of objects which move very fast. Mitarai et al. [8–10] analyzed home-making movies with only one character in the video to assist users. Also, some other studies [11–18] focused on static images, rather than videos, which is different from each other, especially for advertising video.

2.2 Robotics in Video Shooting

Several shooting-assist devices have been used for professional advertising videos. Camera sliders, such as GVM[1], enable users to create smooth sliding image; Camera stabilizers, including the DJI OSMO[2], keep cameras flat no matter how users move the camera. To some extent, these tools can reduce human error such as camera shake. However, novice users still have difficulties in designing path of camera without detailed guidance.

In recent years, the robotic arm has become a widely used tool in various domains. Many studies have shown the stability and flexibility of a robotic arm [19–24]. In order to make the quality of advertising video shooting by novice users close to professional advertising videos and reduce cost and time, we built an automatic shooting system encoding scripting of advertising videos, such as composition and shot type, into the movement of a robotic arm. Therefore, a robotic arm can move automatically to shoot specific shots for novice users, which enhances the quality of Short Advertising Video.

Some robotic arm assisted video capturing devices, such as KIVA[3], have appeared in the market. They can enhance the stabilization of the camera. However, users still have to plan the movement of camera by themselves, which is challenging for novice users. Also, in order to capture one perfect video clip, users may need to adjust the motion of robotic arm over and over again, which is very time-consuming, especially when there are many products needed to be presented.

3 Method

3.1 Overview

The traditional process of making Short Advertising Video can be simplified into three steps. Firstly, the director designs the storyboard, which conveys the overall idea of the advertising video and describes the specifications of every shot.

[1] https://gvmled.com.
[2] https://www.dji.com/osmo.
[3] http://motorizedprecision.com.

Secondly, based on the storyboard, the photographer sets the scene and shoots the clip one-by-one. Finally, the editor organizes all the clips from the photographer and renders the output videos. These procedures require professional knowledge and experience and are costly, which makes Short Advertising Video generation almost impossible for novice users from small and micro businesses. Accordingly, our system, AD-Designer, aims to algorithmically encode the technique of making Short Advertising Video by incorporating it into a mobile phone and a robotic arm.

Previously, users could set their advertising video context and use AD-Designer to shoot the clips by themselves at the beginning [1]. However, we found that it was still difficult for novice users to take high-quality videos with simple guidance. Users had difficulty in moving the camera when shooting a specific clip with a complex composition. Users also could not move the camera in a smooth line and its velocity did not remain constant along that line. These mistakes prevented viewers, customers of the product, from understanding the content. Hence, we introduced the robotic arm to take the place of human to shoot the product. The upgraded process is shown in Fig. 1. In this paper, we mainly investigated how robotic arm can take the place of human to take videos automatically.

3.2 Storyboard Design

Storyboard is a representational and textual description of the creative script of an advertising video. It denotes the overall idea of the video, which then determines the basic structure of the output video. In our previous research, with professional advertising video experts, we have collected and analyzed a large number of excellent advertising videos [1]. After users choose the category of their product and the visual style of the video, storyboard is generated on cloud end. In the storyboard, each block represents a video clip and contains all the data of the visual features of this clip. Some of the video clips need to be taken by robotic arm, which are then transfromed into the movements of the robotic arm mentioned in Sect. 3.3.

3.3 Robotic Arm Shooting

The shooting of advertising video relies highly on years of professional training. In our previous research, text prompts and wireframe shooting guidance still could not help novice users shoot high quality videos [1]. Therefore, our system converts the professional shooting skills for advertising video, such as composition and camera movement, into the continuous movement model of a robotic arm. As is shown in Fig. 2, we modeled the abstract visual effects of the camera frame and map that to the camera's movement in the shooting space. After that, inverse kinematic (IK) algorithms are employed to convert the camera's movement into the movement of the robotic arm. During shooting, the mobile phone is fixed on the gripper of the robotic arm, and its movement is driven by the transformation of the robotic arm as well. The input of the shooting module

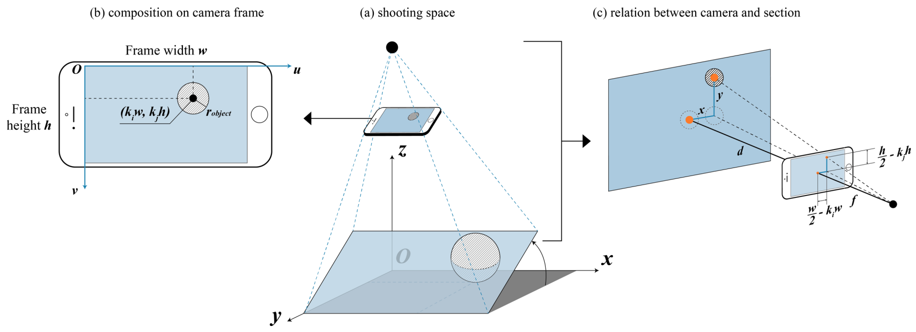


Fig. 2. The modelling of the abstract visual effects of the camera frame and mapping it to the camera's movement in the shooting space.

is the specifications of the camera and storyboard which includes all the visual features of each product clip, while the output is the raw footage captured by the mobile phone carried by the robotic arm. In Sect. 3.3, we describe the process of how abstract visual effects are transformed into movement of the robotic arm.

All the spatial parameters and coordinates shown in Fig. 2 are set to describe the model of the robotic shooting. For any object in the shooting space, assume that its radius is R_{object}. The coordinates of the camera are $C(x, y, z)$. The focal length of camera is f. The distance between the camera and the object is d. Due to the uncertainty of the shape of object, we consider the object as a sphere in this model. The coordinate of the object shown in the video are $O_{x,y}(X_{object}, Y_{object})$ and the radius is r_{object}.

Fig. 3. The Screenshot of Ad-Designer user interface of setting scene guidance.

3.3.1 User Interaction The robotic arm system needs to know where the object is set in the shooting scene. Therefore, an interface for guiding users to set the shooting scene is designed as shown in Fig. 3. The red region with the red dotted line is for the product that users mainly want to represent in the advertising video. The yellow region with yellow dotted line is for the object that serves as the foil in the scene which can create the atmosphere and enhance the quality of the product. The white lines are designed to help users understand the shooting scene and adjust the camera angle. After setting the scene, users can press the button on the right to stimulate the robotic arm to start shooting.

3.3.2 The Composition in the Camera Frame In storyboard generation module, we considered the composition and the shot type of each clip. We set the storyboard as well as the length and width of the camera frame as the input of robotic shooting module. In cinematography, the parameters that affect the composition of an image are: shape and proportion of the object and position/orientation/balance/harmony among the objects. The area of interest, the product, is the most important factor to be considered. Thus, the object's position, size and its relationship with the foil are used to describe the principles of composition within the camera frame. Accordingly, we used the proportion between the object and the camera frame, k_x, k_y and the radius of the object, r_{object}, to characterize the object in the frame. These two features are taken as the initial output of the process. A function F_{2D} is defined to describe the processing:

$$\begin{gathered}(k_x, k_y, r_{object})_{ij} = F_{2D}\left(w, h, Q_i\right) \\ i = 1, 2, 3, ..., n; j = start; end.\end{gathered} \tag{1}$$

Parameters w and h denotes the width and length of the camera frame. Q represents the paradigms of the clip in the storyboard while i is the serial number of the clip. Because we are dealing with videos instead of static images, the output is the composition of both the start point and the end point. F_{2D} can be divided into three parts as follows:

3.3.2.1 Position. In order to make the object more balanced and harmonious in the video, the position of the object should be aligned according to multiple rules. The rule of thirds, golden section and the horizontal line compositions are commonly used. According to these rules we can specify the proper position of object in the camera frame. The movement of camera and shot type in the storyboard determine which rule is applied in the shot. For example, if a clip is a fixed shot and the shot type is a close shot, the golden section is often applied. The mathematical representation of the position coordinates of an object is usually $(\frac{5w}{8}, \frac{5h}{8})$.

3.3.2.2 Size. Based on the study of massive advertising videos and advice from professional advertisers, we summarized the proportion of the area occupied by objects in the camera frame in different compositions. For example, when a clip is a close-up shot, the proportion of the product in the picture is about one-sixth to one-fourth of the camera frame.

3.3.2.3 Relation Between Product and Foil. During the shooting of the advertising video there is often more than one object in the scene. In order to create the overall atmosphere of the video, it is necessary to place a foil beside the product. When considering the relationship between the object and its foil, there are several rules that we should follow to restrict their positions in the coordinate system. The key rules are: 1) the foil should be placed around the product, 2) the center of the two cannot overlap and the edge line cannot be tangent, 3) the overall arrangement of the objects should be interspersed so that the layering of the image is stronger. We define the 2D coordinates of the foil in the camera frame as (X_{foil}, Y_{foil}) with radius r_{foil}. The position of the object is restricted as follows:

I) The edge lines should not be tangent;

$$\sqrt{(x_{object} - x_{foil})^2 + (y_{object} - y_{foil})^2} > |r_{foil} - r_{object}| \tag{2}$$

II) Objects cannot be completely obscured;

$$\sqrt{(x_{object} - x_{foil})^2 + (y_{object} - y_{foil})^2} > r_{foil} + r_{object} \tag{3}$$

III) The bottom line positions of the objects should not be too close.

$$y_{foil} + r_{foil} \neq y_{object} + r_{object} \tag{4}$$

3.3.3 Movement of the Camera In previous section, the features of the objects appearing in the camera frame have been obtained through F_{2D}. The appearances of objects in the camera frame determine the spatial relation between camera and objects, and vice versa. As shown in Fig. 2(C), this one-to-one mapping allows us to deduce the relation between camera and objects in shooting space according to 2D features of objects in the camera frame. In detail, we can obtain the position of camera $C(x, y, z)$ in shooting space. A function F_{3D} is defined to describe the mapping processing:

$$\begin{aligned} (C_{x,y,z})_{ij} = F_{3D}\left(f, (k_x, k_y, r_{object})_i, R_{object}\right) \\ i = 1, 2, 3, ..., n; j = start; end. \end{aligned} \tag{5}$$

R_{object} is the radius of object in shooting scene. F_{3D} can be divided into two parts:

3.3.3.1 Distance Between Camera and Objects. We assume that d is the distance between camera and object. According to the mechanism of 3D perspective projection, the distance between camera and object can be obtained by the ratio between 2D and 3D radius of the object:

$$\frac{f + d}{f} = \frac{R_{object}}{r_{object}} \tag{6}$$

3.3.3.2 Exact Coordinates of Camera. The position of object in the camera frame is corresponding to the X_{camera} and Z_{camera}:

$$k_x w = \frac{w}{2} + \frac{(X_{object} - X_{camera}) f}{f + d} \tag{7}$$

$$k_y h = \frac{h}{2} + \frac{(Z_{object} - Z_{camera}) f}{f + d} \tag{8}$$

3.3.4 Movement of the Robotic Arm As mentioned above, the spatial features of the camera from the start to end are obtained in each clip through F_{3D}. Thus, the movement of camera can be an input for the computation of each angle of joints by the inverse kinematics algorithm. The inverse kinematics (IK) algorithm makes use of the kinematic equations to determine the joint parameters that provide a desired position for the end effector of the robotic arm. The IK constraint continually adjusts the rotation on the parent and child bones, so that the tip of the child bone is at the target bone. The direction the parent and child bones bend can be changed based on the IK constraints. A function $F_{Robotics}$ is defined to describe the processing. n is the degree of freedom of the robotic arm:

$$\begin{gathered} ((\theta_1, \theta_2, ..., \theta_n), v)_{ij} = F_{Robotics}(C_{x,y,z})_{ij} \\ i = 1, 2, 3, ..., n; j = start; end. \end{gathered} \tag{9}$$

n is the number of degrees of freedom and θ_i is the joint angle of the i degree of freedom. The velocity of movement of the robotic arm in each clip can be computed by the duration defined in the storyboard and the movement of the camera:

$$v_i = \frac{|C_{end}(x, y, z) - C_{start}(x, y, z)|}{T_i} \tag{10}$$

T_i is the duration of clip i defined in the storyboard.

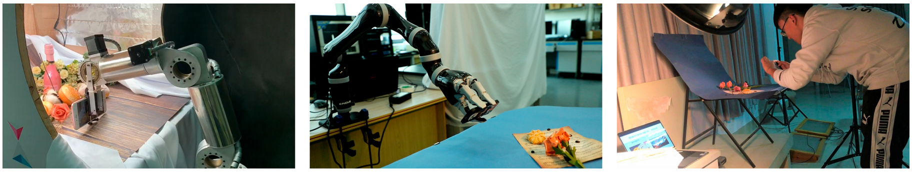
However, there exist redundant parts between clips. For example, the end point of clip i might not be the start point of clip $i+1$, the IK module thus needs to compute the path for robotic arm to transition from i to $i+1$. Accordingly, in order to design a complete continuous motion path, the IK module needs to compute the movement of the robotic arm for not only each clip, but also redundant parts between clips.

4 Experiments

4.1 Implementation

The entire system can be divided into three parts: the mobile front end; the cloud backend and the robotic arm. Users select the style and category of the product on the front-end, which was implemented on iPhoneSE with iOS 10.0.

After users' selecting, the data is sent to storyboard generation module and robotic arm analysis module on the cloud backend. We use Apache Tomcat as the cloud service. Then, the data of motion planning of robotic arm is sent to the control system of robotic arm and robotic arm starts to shoot video clips. Two robotic arms we used in our experiments are shown in Fig. 4(a)(b).



(a) (b) (c)

Fig. 4. (a) Shooting with a laboratory self-made robotic arm. (b) Shooting with an industrial robotic arm, KINOVA Ultra Light Weight Robotic Arm 6DOF. (c) A novice user was taking a set of clips under the guidance in the AD-Designer storyboard.

4.2 Procedure

We conducted two sets of controlled experiments for examining the effectiveness of AD-Designer. In the first set of experiments, we selected two types of robotic arms with iPhoneSE as the shooting device to take 6 shots. In the early stage of the experiment, we utilized a self-made robotic arm to carry out the test. After that, we switched to a more professional industrial robotic arm, KINOVA Ultra-light weight robotic arm 6DOF, to conduct a more accurate quantitative experiment. The practical illustrations of the two tested robotic arms are shown in Fig. 4(a)(b). In the second set of experiments, we selected 8 novice users to take a set of clips under the guidance of the AD-Designer storyboard, as shown in Fig. 4(c). For each shot, novice users watched the video demonstration first, then shot clips by themsleves. They repeated the two steps until they finished 3 video clips. Finally, the cost of time and the quality of the final outcome were compared with the results of the automatic shooting by the robotic arm to distinguish the performances of the two sets of experiments.

4.3 Results

Time. In the two sets of experiments, as shown in Fig. 5(b), the time cost on the shooting module of the 2 sets of experiments was significantly different. In the first set of experiments, robotic arms could shoot at least 6 shots consecutively within 1 min. The captured shots could be rendered based on 10 sets of scripts that existed on the cloud, which finally outputted 10 completed advertising videos for users to select. In the second set of experiments, users could only choose one set of the scripts at the shooting stage and followed the guidance

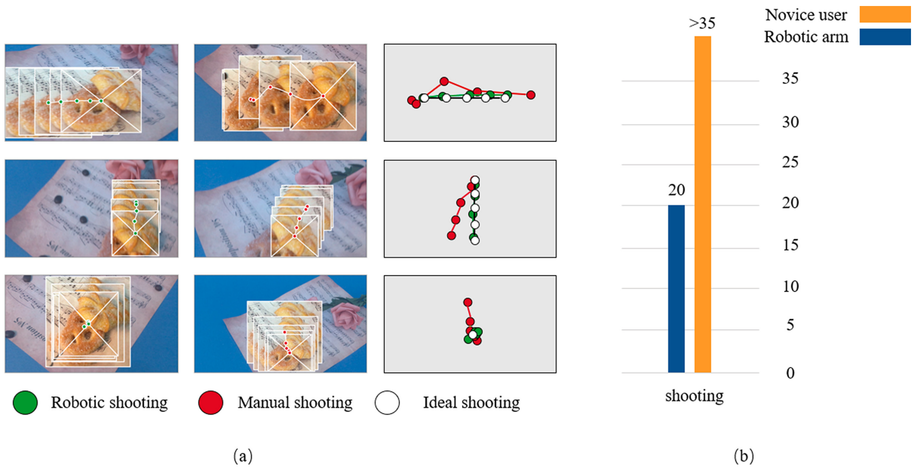


Fig. 5. (a) Comparison of effect of manual shooting and automatic shooting. (b) Comparison of time spent between novice users and robotic arm.

step-by-step. Hence, the robotic shooting assisted system can reduce the time and cost markedly and increase the shooting efficiency significantly.

Quality of Shots. To test whether a robotic arm can perform better than a human, we selected 3 kinds of shots (tracking shots, zoom-in shots, and crane shots) from the output adverting videos of the two sets of experiments. We first extracted keyframes of each shot per 15 frames. After that, we connected the object's center point within the frame to form a sampling curve to compare the final visual results. Figure 5(a) shows the result. From each group of comparisons, we can see that the sampling curve captured by the robotic arm is considerably smoother than that captured by users. The result has proven that our system makes the videos look more stable and enhances the effect of the advertising videos.

4.4 Expert Evaluation

We invited an expert who has many years of professional advertising video production experience to evaluate our system. We showed the working mode of the whole system and then mainly described the process of the automatic robotic arm shooting. The expert approved that the working mode of the whole AD-Designer system conformed with the traditional process of making professional advertising video, and the output videos are also very consistent for the purpose of social media propagation. The effect of the robot arm is similar to the indoor camera dolly, which makes videos look more stable than those taken manually. She proposed that the robot arm can be more flexible when moving along some complex curves. In summary, the expert appreciated the high efficiency and low cost of our approach.

5 Conclusions and Future Work

We proposed a novel appraoch of making Short Advertising Video for novice users from small and micro businesses. In order to minimize human error in the shooting process and enhance the quality of advertising video, we extracted features of professional cinematography and modeled the process of shooting advertising video by a robotic arm. Our testing result confirmed that our automated approach speeds up the process of shooting of Short Advertising Video and removes barriers that novice users shoot videos manually, as well as enhancing the overall quality of Short Advertising Video. As short video becomes an increasingly dominant form of advertisements, Ad-Designer is already used by several small and micro businesses from Internet online sales platform. And, these users really appreciate our approach of Short Advertising Video. It can not only lower the cost in time and money but also increase their product sales on online platform. In summary, our research focuses on exploring new mode of HEC(human-engaged computing), which aims at achieving synergized interactions between human capacities and technological capabilities to help realize progressively developing human potential. In particular, in this paper, we are trying to model the tacit knowledge from experts and apply it into the interactions between novice users, computer and robotic arm, in order to help novice users perform better in creative work.

Notably, even though we used KINOVA in our experiment, it doesn't mean expensive device like that is a necessity. As mentioned in Sect. 2.2, there have been many low-cost devices designed for novice users, like OSMO, which are capable of capturing stable videos flexibly. Our work provides ideas of automated working mode in programmatic creative for making Short Advertising Video, which assists novice users, with no need of professional team, to make professional videos, and reduces human resource cost. In future work, we will expand types of camera movement and composition to improve the flexibility of the system and enhance the quality of the output videos. Furthermore, besides a robotic arm, we believe that our computational model can be applied to other devices such as unmanned aerial vehicles and camera dollies.

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