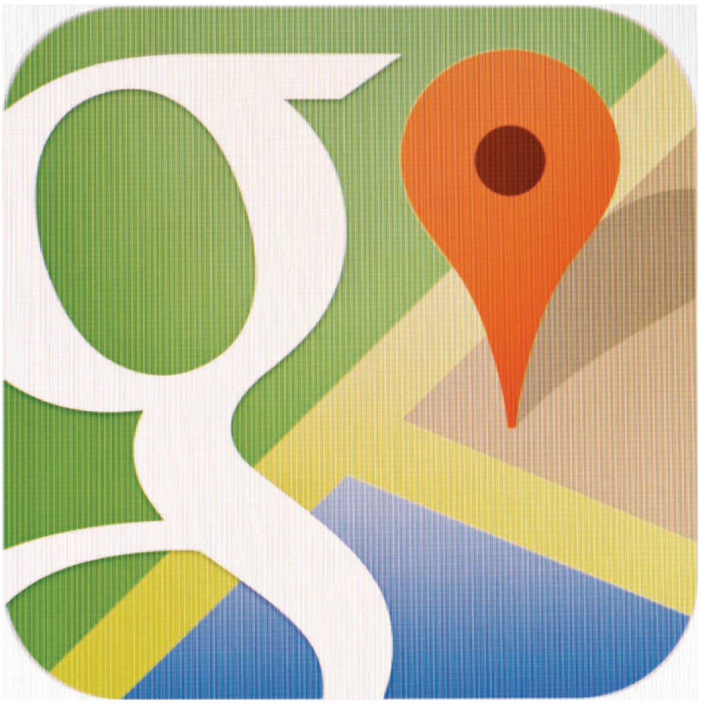
CANavi: Synthesizing Cartoon-Like Animation for Street Navigation Based on Google Maps



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***Abstract*—Today, Google Maps has become one of the most important tools for exploring maps. In addition, Google Street View further provides images for improving users' cognition of new smart cities. Many route recommendation services are available online, but most provide recommended routes on a 2D planar map. This can create a gap between a user's perception and reality. It is not easy for users to understand an unfamiliar place through linked line-segments on a 2D map only. Many users find themselves lost while they attempt to virtually walkthrough an area in Google Street View via a mouse. Moreover, these street images are static and do not depict current weather conditions. Therefore, in this paper, we propose a novel approach for synthesizing cartoon-like animation for street navigation (CANavi). To achieve our goal, we utilized the abundant resources from Google Maps and Google Street View. The results show that our street-navigation animations create interesting and vivid sceneries that can successfully improve a user's cognition and experience when exploring new smart cities.

1. Introduction

Emerging services offered by smart cities aim to improve their citizens' quality of life through innovative technologies, such as open-data platforms, crowdsourced navigation, visualization 3D, etc. [1]. With advances in computing and communication technologies, navigation systems have become fundamental service paradigms which bring convenience and benefits to our daily lives [2]. Before visiting an unfamiliar place, we often utilize route recommendation services to explore and find our destination accordingly [3], [4].

Existing navigation systems intend to not only offer route recommendation services [5] but also other customized services to meet user needs. These services include travel information such as itinerary and expenditure or suggestions for places to visit and scheduling assistance [6], [7]. However, too much information may cause user distraction. It is also important to concentrate users' attention on navigation behavior itself, by merging information from different sources in a more intuitive and natural way.

Moreover, the recommended routes themselves are generally described partially via text and partially by linked edges on 2D planar maps. Even in Google Street View, subscribers only have some captured pictures. In fact, many visitors may still spend a great amount of time and effort [8] or even get lost when navigating unfamiliar real-world places, even though they have already virtually explored the maps.

We therefore made the following assumptions and corresponding effort: by simply concentrating on watching a continuous navigation animation, users can better receive recommended route information, instead of tracking connected lines on a 2D map or repeatedly clicking the Google Street View icon [9].

When users are virtually walking through in Google Street View, they need to keep clicking on the arrow icons for moving forward or changing direction along the recommended routes step by step. In contrast, through our system, users only need to select the start point and the destination on the map, then a continuously navigation video is created. The advantage of using navigation videos is that it allows users to concentrate on the route itself, and therefore enhance their perceptions of distance and spatial coherence. These perceptions are then helpful for reducing the gaps between imagination and real world. Furthermore, to provide other useful information, such as weather conditions, without causing distraction, we integrate this information into the street images by adopting NPR and cartoonizing methods.

According to K. Lynch's "The image of the city" [10], paths and landmarks are significant parts of a cognitive map. A cognitive map can help people adapt to the environment, find paths, and improve mobility in their environment.

There is another important motivation driving this project. Knowing the sadness that the Japan 311 earthquake victims experienced because they were forced to leave their hometowns, L.H. Chen et al began developing a prototype system in 2012. The original idea was to provide a service for users to easily compose a navigation animation of their hometown utilizing images from Google Street View, but much work remained to be completed at the conceptual and preliminary stage [11]–[13].

Advanced smart, green, and integrated transport services are designed to offer environmentally friendly, efficient, and safe benefits to inhabitants and travelers in smart cities [14]. Recently, new generation navigation systems have leveraged crowdsourcing for service updates and maintenance [15]. With the advances of crowd intelligence, we present an authentic street navigation system that aims to provide users with a precise and rapid preview experience of a city, including current weather, appearance, and environment of the recommended routes through a fluent and vivid walkthrough animation. In Figure 1, we demonstrate Taiwan 101 as the visiting target. The proposed solution improves users' cognition and experiences toward exploring new smart cities through these street navigation animations. The abundant and live navigation functions bring an innovative mobility experience to citizens in smart cities, enabling them to react appropriately to distinct weather and climate scenarios (such as Sunny Tokyo City, Rainy Taipei City, etc.).

To synthesize the animation, our system first extracts a sequence of real-world street images from Google Street View by using a Google API (Figure 2). Because the images are taken by Google Street View, with cars during daylight in ideal weather conditions, these street view images are basically static and monotonous.

In addition to an improved mobility experience and safety benefits, another user-centric feature of smart cities is to help citizens and visitors augment deeper impressions and a better sense of the city. To further enhance a users' emotion toward a location's ambiance, the proposed system then retouches images and offers a semi-realistic, visual, and tactile demonstration of the city to be visited [16]. Specifically, users can manually select the playback speed and the visual or cartoon-like effects to be applied in animation through the GUI functions of the proposed *CANavi* system as in Figure 3.

The rest of this paper is organized as follows: in Section 2, related works are introduced; in Section 3, the architecture of our prototype system is described; in Section 4, the current results are shown; and finally, in Section 5, the conclusion and future are discussed.

FIG 1 *CANavi* Taipei 101: The recommended route and street navigation animation of Taipei 101 area.

2. Related Works

2.1. Route Recommendation

Route recommendation is the primary function of a navigation system. When a traveler visits an unfamiliar environment, the route recommendation function is one of the most useful tools to find the destination. A number of research results and commercial applications have been developed for route recommendations. For example, T. Kurashima et al provided users with a

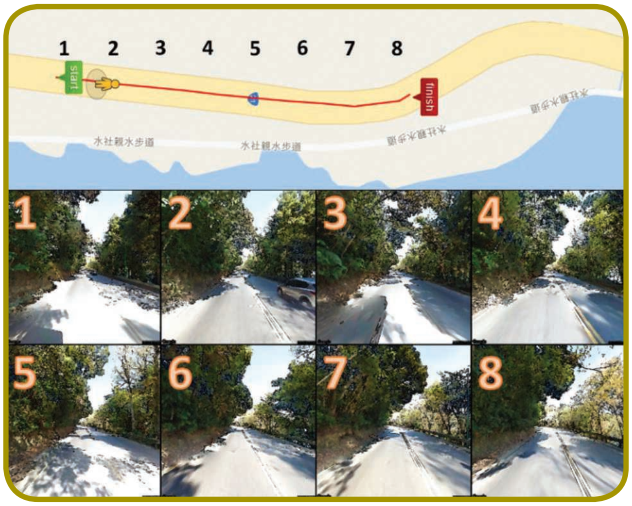

FIG 2 *CANavi* Sun Moon Lake: The recommended route and Google Street View images along the lakeside of Sun Moon Lake in Taiwan.

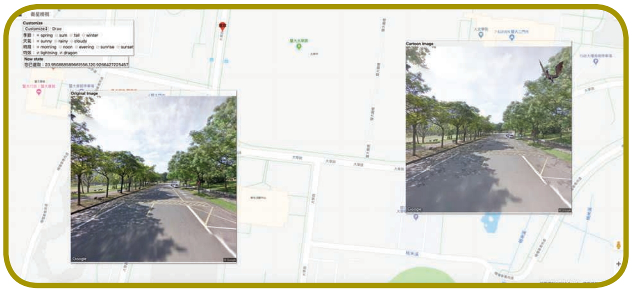

FIG 3 *CANavi*: cartoon-like effects.

recommended route by analyzing the traveling photographers on Flickr based on geotag information [17]. J. Dai et al personalized the route-recommended service using big trajectory data. S. Nakajima et al produced recommended routes by estimating the driver's intention [18].

Currently, driving and route planning information provided by existing route recommendation engines are usually presented and incorporated in 2D or discontinuous street photographs only. It is preferable for new, advanced navigation systems to further explore and derive these route and itinerary information segments into continuous images that more accurately simulate a real driving experience. It has been a continuous challenge to offer citizens in smart cities a vision-based urban navigation solution, despite invasive drone navigation to support emergency response, which may lead to privacy concerns [19].

2.2. Content-Based Image Retrieval

In a fully connected smart city, open data aims to achieve vital and valuable results from the contextual analysis of information retrieved from public and private sectors. Extensive research efforts on Content-Based Image Retrieval (CBIR) methods have been initiated to efficiently explore relevant visual documents on a large-scale crowd-sourced multimedia database. It is mainly based on the content information or query standard of a given query picture. In the image database, the query is in accordance with the given condition.

The extraction of image features in preferably adopted CBIR is the basis of content-based image retrieval techniques. Common extractable features include colors, textures, and shapes [20]. Google's image search engine also adopts CBIR technology. It provides users an efficient engine to upload pictures to search for other similar pictures. Similarly, another crowd-sourced service provider, Flickr, also utilizes CBIR technique to explore images by color. In this prototype implementation, we utilize Flickr to retrieve scenery pictures for analysis. Through a syntactical search of location information, photo time, and photo label, highly related and valuable pictures shared on the social network database were retrieved for intelligent feature extractions, such as a rich set of climate and weather conditions for the associated city.

2.3. Image Processing

To update corresponding street views in accordance with swiftly changing situations, the original image was revised in consideration of the city's weather and climate features. Numerous techniques have been developed for solving conventional image process problems. One of the fundamental issues is edge detection. In an image, a significant change between bright and dark areas usually represents a boundary change. These changes come from differences in depth, surface direction, material property, or illumination between different regions. Commonly used image processing approaches include Sobel, Laplacian, Canny methods, and so on [21].

Another fundamental problem is noise removal. A number of methods have been developed for solving this problem. For example, the bilateral filter is a well-used, non-linear, and edge-preserving approach. The intensity value of each pixel is replaced by a weighted average of intensity values from nearby pixels. The weights not only depend on Euclidean distance of pixels but also on the radiometric differences. Bilateral filters are also used to solve other image processing problems, such as Texture Editing/Relighting [22] and Feature-Aware Filtering [20]. Sky detection is also a research topic in image processing. Several methods have been developed to detect the region of sky based on colors [23]. However, it is still difficult to implement a general-purpose solution.

In this study, the principle images used were primarily collected from Google Street View. We first used the Sobel method for rough segmentation between the background sky region and foreground objects. Then we developed a hybrid approach to detect the region of sky by utilizing gradient and color data. In addition, we used the flood-fill algorithm to connect separated sky regions. For edge enhancement, we used the Canny edge-detection method. A bilateral filter was used for noise-reduction smoothing.

2.4. Non-Photorealistic Rendering

Augmented Reality technology has engaged citizens with innovative smart city activities by integrating visual and real components of the city. To satisfy people's affection and imagination toward precise buildings or places, a semi-realistic, visual, and tactile demonstration of the visiting city is presented. NPR (Non-Photorealistic Rendering) [24] is a comparatively new research issue in the field of computer graphics. NPR is mainly used to simulate different artistic drawing styles. For example, L.H. Chen et al synthesized watercolor-styled images by using the Lattice Boltzmann method for fluid simulation [25]. In addition, L.H. Chen et al also proposed a 3D mesh approach, which generates the thickness of strokes to represent the volumetric effects on canvas [26]. In this paper, to provide users with a street view experience from different perspectives, we adopted several styles of NPR effects, including pencil sketch, watercolor, and cartoonized effects. A smart city is expected to offer citizens sustainable memories and exciting adventures.

3. *CANavi*: Synthesizing Cartoon-Like Animation for Street Navigation

The *CANavi* System Flowchart utilizes multiple modules, including route recommendation, a crowd-sourcing database, sky color analysis, retouching, image interpolation, animation, etc., as shown in Figure 4. In the first step, we utilize Google Maps API (Application Programming Interface) to implement our system interface (Figure 5) and generate the GPS sequence of recommended routes. It is worthy to note here that any route recommendation service that can map its result onto Google Maps can use our system to easily synthesize street navigation animation.

The GPS sequence is then used for collecting scenery images from Google Street View. These scenery images are then input into our image retouching modules. Additionally, location information such as the city's name is used for web mining pictures from Flickr. The mining results are then used to construct a location-based sky color database, which provides the basis for color adjustments in the image retouching modules. Finally, after the scenery images are retouched, they are interpolated and concatenated to synthesize the street navigation animation.

To implement our system, in addition to the Google Maps API, free software, including *Ajax, Wget, and ffmpeg* modules, were also adopted accordingly, as shown in Figure 6.

3.1. System Interface and GPS Sequence Extraction

The system interface is developed using JavaScript and the Google Maps API. Its 2D map layout provides users a conventional and intuitive interface to directly move icons, zoom in/out, or swap the map. The recommended route calculated by Google Maps is also displayed on the map.

In addition, as shown in the sub-window at the bottom left of Figure 5, the scenery image of the user's current position is retrieved from Google Street View. Users can adjust their viewing direction and pitch angle here. In the top left of Figure 5, another sub-window enables users to preview the navigation animation with selected NPR effects. The dialog boxes at the left side of Figure 5 are used to manually control the system and display related information such as the number of GPS positions along the recommended route. Finally, a dialog box between the two sub-windows enables users to select different NPR effects to simulate different atmospheres for the street.

3.2. Location-Based Sky Color Database

We implement a crawler program using Python. This crawler program collects scenery pictures with the desired location name through the Flickr API.

After approximately 100,000 pictures are collected according to their "date" tags, the pictures are categorized into four groups: spring, summer, autumn, and winter. Furthermore, according to their "time" tags, these pictures are categorized into four subgroups: sunrise, noon, sunset, and night, as shown in Figure 7.

Then we use the upper one-third of each picture to calculate its Hue-Saturation (H-S) histogram, as shown in Figure 8. This is because, in general, the upper one-third of a scenery picture mainly consists of sky. For an outdoor scenery picture, the sky plays an important role in illumination. Therefore, we calculate and record these H-S histograms in our sky color database for later usage. Moreover, by performing a comparison on the average H-S histogram, some false images can be filtered out automatically at this stage. Finally, for further improving the accuracy of the experiment, we manually filtered out the remaining incorrect or unsuitable images. Approximately 10,000 scenery pictures are found to be suitable out of the original 100,000 pictures from Flickr.

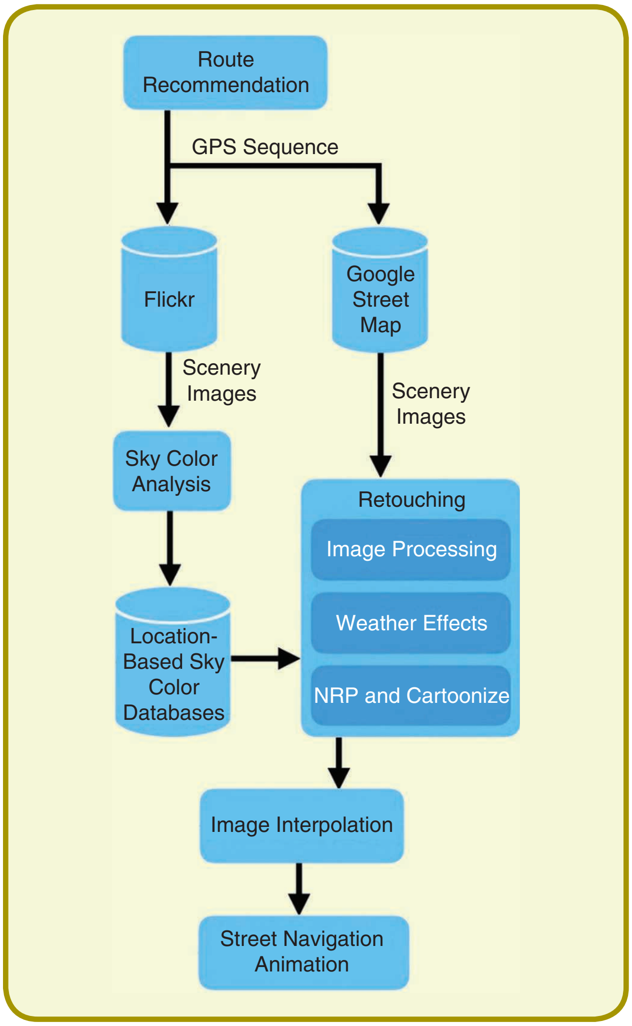

FIG 4 *CANavi* system flowchart.

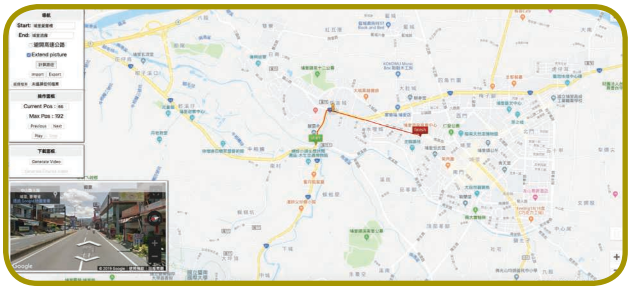

FIG 5 *CANavi* system interface.

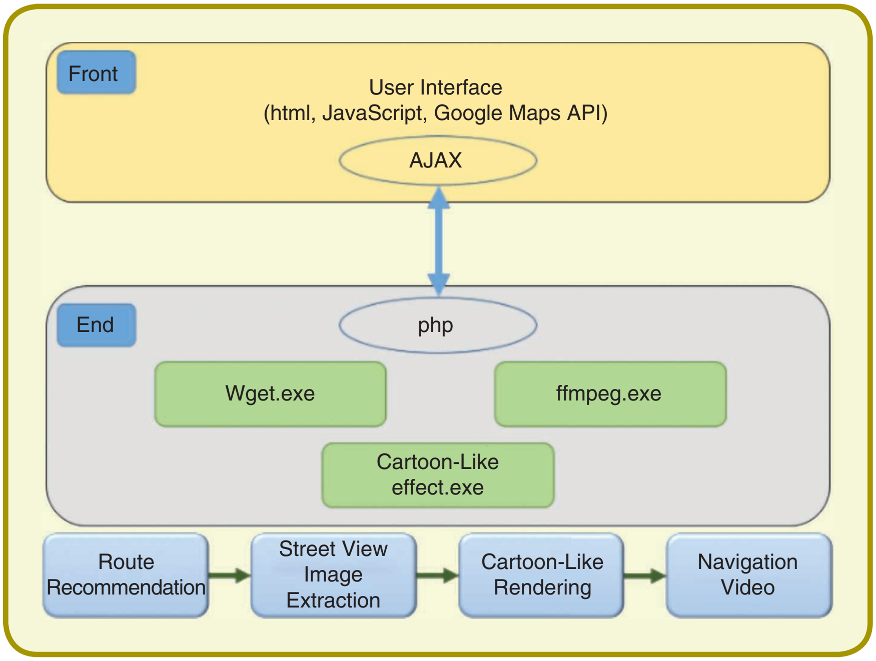

FIG 6 Free software and tools used for system implementation.

The result of Sun-Moon Lake's picture analysis is then used to retouch street images of Puli, a town adjacent to the lake area. In addition, very simple effects, such as a rising sun and starry night sky, are added to create interesting visual effects, as shown in Figure 9. However, for further cartoonizing the street pictures, it is necessary to perform sky region segmentation.

3.3. Sky Region Segmentation

We use the Flood Fill Algorithm to mark the pixels that belong to the sky. The Flood Fill Algorithm determines the area connected to a given node. Flood Fill can fill a particular bounded area with defined colors on an image. The method begins to spread from the selected seed point until the condition is satisfied.

Because most pictures on Google Street View are taken during ideal daytime conditions, we can reasonably assume that the sky will be blue or nearly blue. This assumption greatly simplified the seed color selection. The previous HS statistical results in 3.2 are used as the basis for selection. The top five color values close to blue in the HS statistics are used as the seed points' colors. For example, the green points in Figure 10 are the seed points selected from the original image of a Puli suburb.

Then we use a 5-by-5 window to scan each pixel and calculate the RGB standard deviation (σ) value and the mean value in the region. The standard deviation can represent the degree of data discretization. Therefore, only pixels with small σ, i.e., small intensity variation, will be checked. The formula is as follows, where μ is the mean value:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \tag{1}$$

$$\mu = \frac{1}{N}(x_1 + x_2 + x_3 + \cdots + x_N) \tag{2}$$

Moreover, many obtrusive objects exist in the street pictures. Some of these objects, such as the cables across the picture in Figure 10, can affect the accuracy of segmentation. Therefore, we use the expansion and erosion method to bypass the cables when an eight directions strategy of flood fill algorithm is applied. In this way, the mask of the sky region is constructed pixel by pixel. The result of the experiment is shown in Figure 11, where the gray area is the detected sky, and the black is the non-sky area.

3.4. Cartoon-Style Simulations

The range of colors used in cartoon images is usually more limited than real photos. In addition, cartoon images generally have a clearer boundary. In our system, the bilateral filter is used to reduce the number of colors while also keeping the edges clear [27]. The Canny edge detection method is used to further enhance the edge effects.

Finally, we use the previous sky mask in 3.3 to replace the sky in the street view with the cartoon sky. Figure 12 shows the sky scene of Makoto Shinkai's animated movie "Your Name". Figure 13 shows the result after the sky replacement is performed.

As mentioned above, the sky region plays an important role in illumination, especially in an image with outdoor

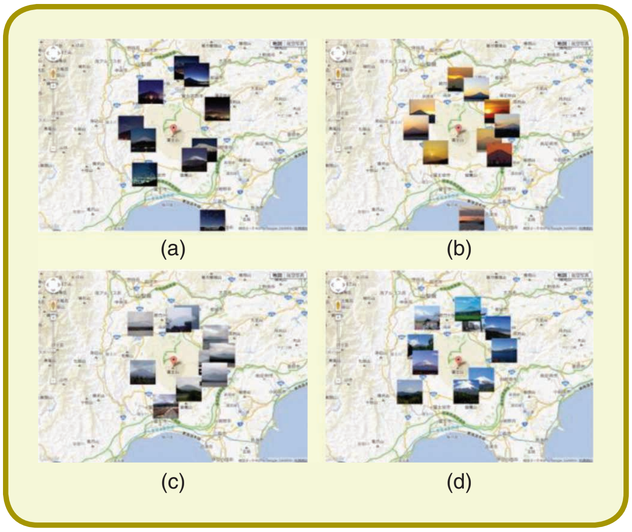

FIG 7 Pictures taken at different times have different color tones.

scenery. Therefore, the brightness and color tones of the non-sky region should change with the replaced sky. The Histogram Specification method is used here to adjust the color histogram distribution of the original picture toward that of the target cartoon image. At first, both the picture and the cartoon image are converted to the Lab color space, where L is lightness, and a and b are the color opponents of green–red and blue–yellow, respectively. Then, on these three channels, the HS method is used for brightness and color adjustment. The experiment's results for a starry night scene and a snowy daytime scene are shown in Figure 14 and Figure 15, respectively.

Finally, the cartoonized street view images along the planning route are rendered picture by picture. All of these images are sent to the *ffmpeg* module to synthesize a navigation animation, which provides users a continuous and vivid navigation experience.

4. Experiment Results

The layout of our user interface, which integrates necessary information from Google Street View and Google Maps, is shown in Figure 16. Function menus for various purposes are grouped into three customizable dialog boxes.

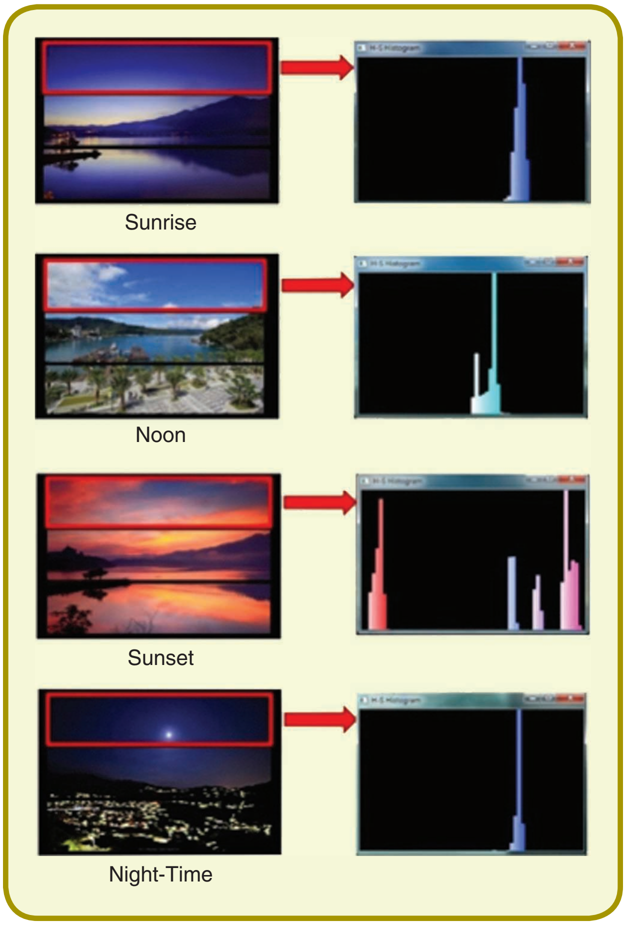

FIG 8 Example pictures and the H-S histograms of Sun-Moon Lake area in Taiwan.

FIG 9 Color adjustment of street image of Puli, a town near Sun-Moon Lake.

FIG 10 A Puli suburb with possible seed points of sky.

FIG 11 The mask of sky region.

FIG 12 A sky scene from the animated movie "Your Name."

FIG 13 An image result with sky replacement.

After users select a route by either dragging and dropping the icon onto the map or by typing the addresses into the dialog box, the system will automatically download the Google Street View images, as shown in Figure 17. The cartoonizing and NPR effects are then applied to the street images as shown in Figure 18~23.

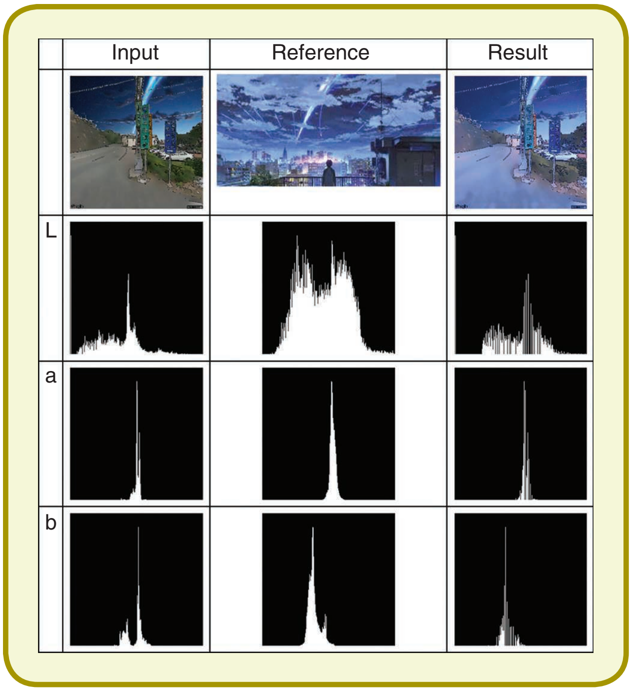

FIG 14 Cartoonized result based on a starry night scene.

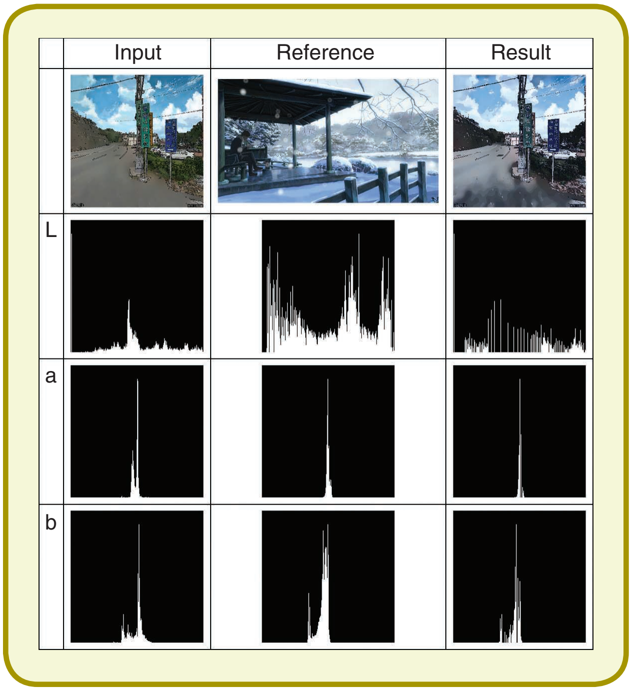

FIG 15 Cartoonized result based on a snowy daytime scene.

Three styles of navigation videos, the photorealistic, NPR and the cartoonized versions, are automatically synthesized and can be downloaded via hyperlink [28], [29].

These styles serve for different purposes in this paper. The photorealistic videos, as a preview tool, aim to enable users to focus on creating a simulated navigation experience. On the other hand, the NPR styles aim to enable users to express their affections and feelings to the streets in an artistic way. Finally, the cartoonize styles aim to provide users more flexibility to add special effects, such as a flying dragon or lightning strikes across the sky, to emphasize the style and characteristic of a street or city.

Finally, we collected user feedback by performing a questionnaire survey among 44 participants who are aged from 10 to 40, and currently living at Puli Township.

For two different routes within Puli and Tokyo, the answers to the following questions are collected after the participants used Google Map, Google Street View and our system, respectively.

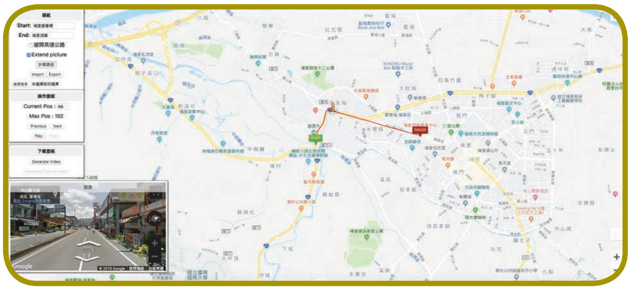

FIG 16 User interface.

The survey results are shown in the tables below. It ranged from 1 for highly disagree, 2 for disagree, 3 for neutral, 4 for agree and 5 for highly agree.

Question A: For an arbitrary route within Puli Township,

Question B: For an arbitrary route within Tokyo City,

Question C:

Most of the feedback is positive or very positive. The experimental results shown that our system can successfully provide a new and useful navigation experience. We will continue to collect user feedback by adopting this online questionnaire into our system.

5. Conclusion and Ongoing Works

In this paper, we presented a crowdsourced street navigation system, *CANavi*, that provides travelers a vivid and continuous street navigation experience in a smart city. Most of the image content is from Google Street View. The advantages of using Google Street View include: (A) It is currently free; (B) Tremendous amounts of image resources are available, covering nearly every city in the world; (C) All pictures are taken by the Google Street View Car with the same specifications.

To further enhance the user's perception of a location's ambiance and to provide a more enjoyable experience, we added cartoonized visual effects and synthesized street navigation animation. The experiment's results show that our system can successfully improve users' cognition and experiences through these street navigation animations.

Moreover, because Google Street View provides the Time Machine services, by utilizing these photos from the past, our system can also help people to preserve their memories of old streets. And this kind of memories are often too precious to

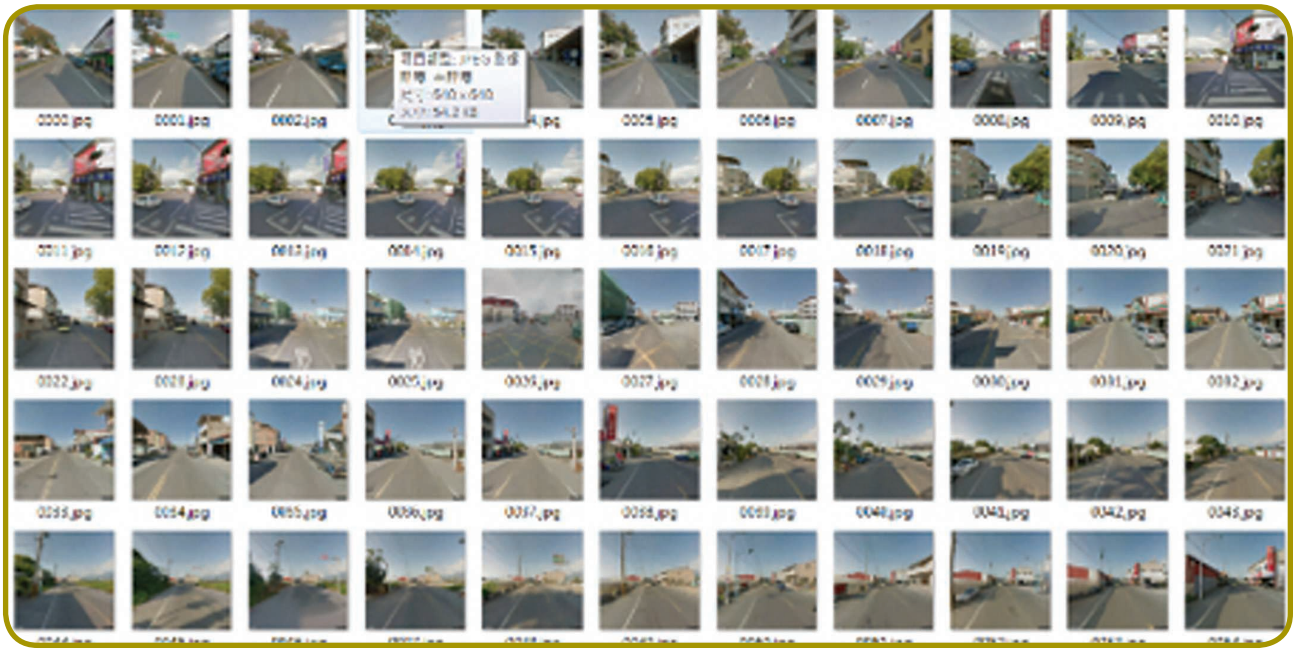

FIG 17 Images downloaded from Google Street View.

be lost for the persons concerned. For example, on February 6, 2018, a magnitude 6.4 earthquake hit Hualien, Taiwan. At least 17 deaths were reported and four buildings were severely damaged. To express our condolences, we created a navigation video between two of the most damaged buildings. And we uploaded this video, entitled as "Let the memory of home never fade away", onto YouTube two days after the earthquake:

https://www.youtube.com/watch?v=I2BxV9xwnYg.

For users to compose and edit their navigation animation in a more flexible and user-friendly way, a new GUI is currently under development. We are also developing an AR system that visualizes the information of street trees on Google Street View by using machine learning technologies and big social data. Moreover, we are planning to apply our system to the creation of navigation animations for virtual film tourism and anime pilgrimages.

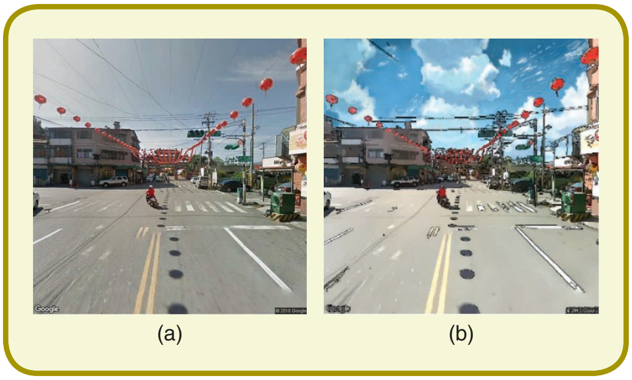

FIG 18 Left: original picture; Right: cartoonized image.

FIG 19 Left: original picture; right: cartoonized image.


FIG 20 Foggy atmosphere in winter season.


FIG 21 Rainy effects.


FIG 22 Sky replacement (cloudy).

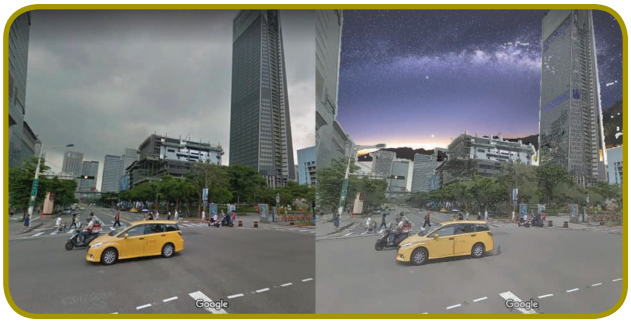
FIG 23 Sky replacement (starry).

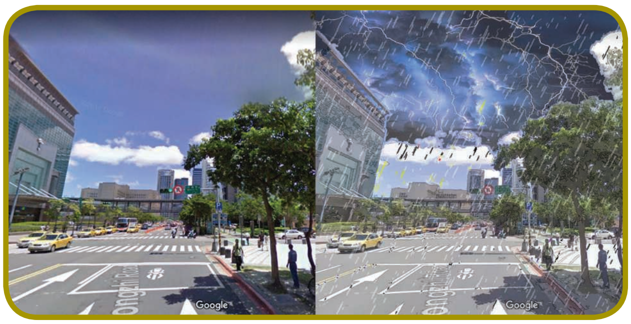
FIG 24 Thunderstorm effects.

By using the Flood fill approach, the interference of some messy objects (including electrical cable, signboard, clothes hanger, etc.) in the sky can be successfully removed. However, the same approach may not be appropriate for other parts in the picture.

In addition, the image quality of current results can be further improved. For example, as shown in Figure 20~24, because sky serves as the most important source of illumination in an outdoor environment, it is necessary to relight street images according to the hue and brightness of sky region. To relight or retouch different regions in the same image may need different approaches. Therefore, by using deep learning, we're performing segmentations to separate sky, trees, roads, buildings, cars, and people in a street image. And then different image processing methods and visual effects can be applied to different objects and regions.

Dealing with the reflection and refraction problems needs more three dimensional scene information. Therefore, a 3D shape reconstruction may be necessary for extracting more information from street images. Since it is beyond the scope of this paper, we left it as an open question.

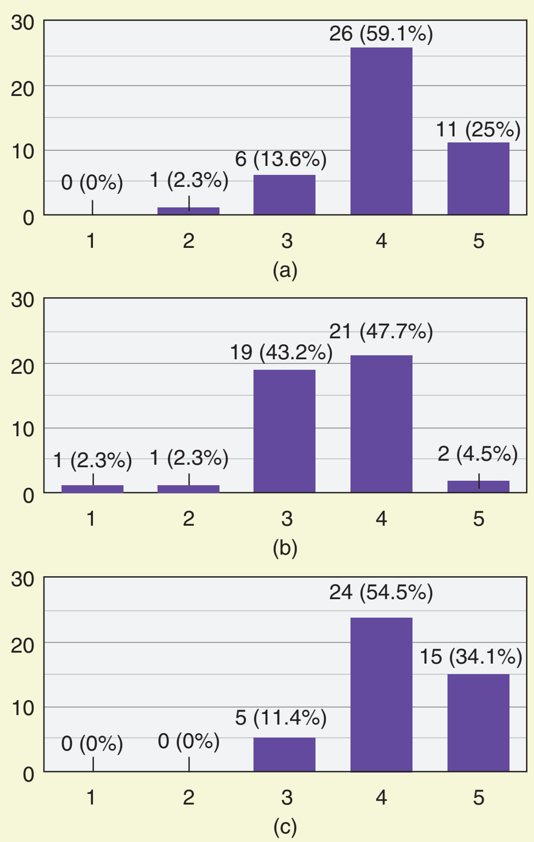

FIG 25 (a) This navigation video is useful for quickly understanding how to arrive at the destination, (b) This system is useful for understanding the local traffic conditions, (c) After watching this video, you are more familiar with the surrounding environment along the roadsides.

All of the source codes of our system proposed in this paper can be download from GitHub by the following hyperlink:

https://github.com/nanulab404/CANavi

Demonstration videos can also be viewed on YouTube:

Original video: https://youtu.be/7NTXFFrd8vA

Cartoon-like video: https://youtu.be/xXVcdieauxw

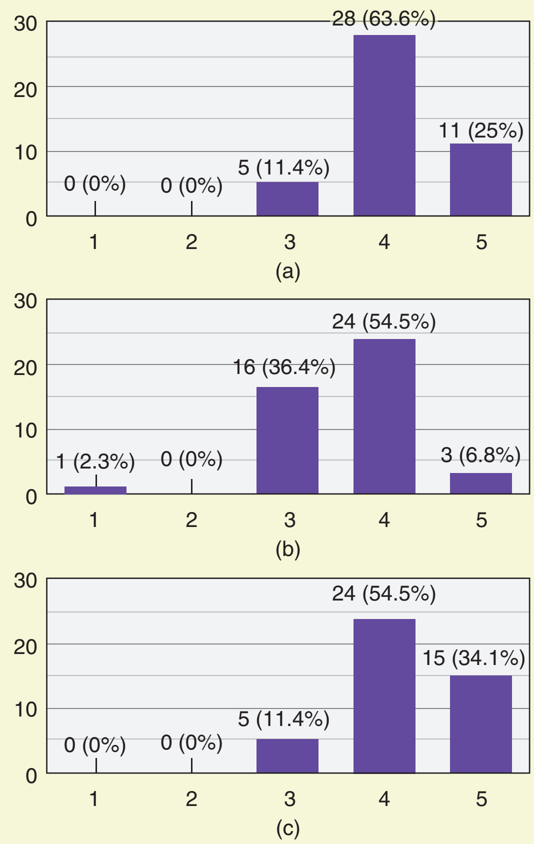

FIG 26 (a) This navigation video is useful for quickly understanding how to arrive at the destination, (b) This system is useful for understanding the local traffic conditions, (c) After watching this video, you are more familiar with the surrounding environment along the roadsides.

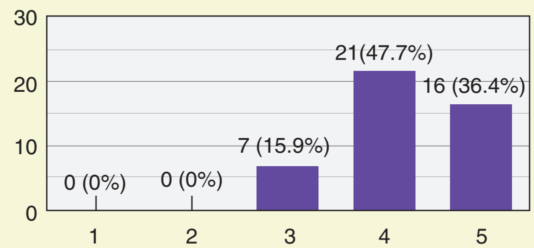

FIG 27 Do you wish there is a video navigation service in Google Map, Google Street View, or other online map tools?

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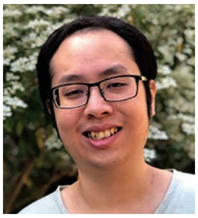

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