USING MULTI-SOURCE DATA TO CAPTURE THE IMPACTS OF EARTH HOUR 2021: A CASE STUDY OF HONG KONG

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ABSTRACT

Earth Hour is an annual campaign to turn off non-essential electric lights for one hour as a symbol of commitment to our planet. Small gesture as it may be, this one-hour event may lead to temporary reduction of energy usage and light pollution. In Earth Hour 2021, we conducted a large survey in Hong Kong to see its impacts using multi-source open and volunteered-crowd-sourcing data. These data were collected from 120 traffic cameras, 27 weather cameras, 2 panoramic 360 cameras, 1 wide-field camera, 7 all-sky cameras, 10 cellphones of volunteers, and 1 camera recording videos onboard of tramway. By analyzing the multi-source images and videos, we identified 122 individual buildings that participated in Earth Hour 2021. We further demonstrate in detail using image analysis techniques the extent of light pollution reduction in an urban environment. Finally, we present a demo experiment to identify light sources using artificial intelligence (AI) techniques.

Index Terms— Earth Hour, light pollution, multi-source data, change detection, Hong Kong

1. INTRODUCTION

Earth Hour is an annual campaign organized by the WWF (World Wide Fund for Nature) to raise public awareness on the challenges faced by our planet and encourage actions on environmental protection. The campaign encourages people to turn off non-essential electric lights between 8:30 and 9:30 pm local time on the last Saturday of March. Since its first launch in 2007, Earth Hour has become the most popular public event for environmental protection [1].

Small gesture as this one-hour campaign may be, studies have observed reduction usage of energy and reduced light pollution level during Earth Hour [2, 3]. Artificial light at night (ALAN) is an anthropogenic phenomenon introduced by urbanization [4]. Although light is a necessity for nighttime life, the unregulated and often abusive usage of ALAN leads to light pollution. With the continuing urbanization along with the unrestricted usage of light, unintentionally or for decorative purposes, the average radiance of ALAN on the planet Earth is increasing by 1.8% annually [5]. Outdoor decorative lighting, such as LED signboards, is one significant factor contributing to light pollution [6]. Figure 1 shows a photo taken at 7:15 pm before Earth Hour by a weather camera operated by the Hong Kong Observatory showing this massive man-made phenomenon.

During Earth Hour, part of the non-essential electric lights were turned off, showing a great contrast (Figure 1). To comprehensively assess the impacts of Earth Hour on external lighting, specifically about where and which lights were out, we conducted a large survey in 2021 using multi-source data in Hong Kong – one of the brightest and most light-polluted cities in the world [7]. Seven types of open or volunteered-crowd-sourcing image/video visual data were collected from 120 traffic cameras, 27 weather cameras, 2 panoramic 360 cameras, 1 wide-field camera, 7 all-sky cameras, 10 cellphones of volunteers, and 1 camera recording videos onboard-of-tramway. We analyzed these multi-source data to identify participating buildings and tested some automatic processing techniques.

2. DATA

The traffic camera images were obtained from the HKeMobility website[1], the public website operated by the Transport Department of the Hong Kong government. Snapshot images are taken by surveillance cameras all around the city once every 2 minutes. We pre-selected 120 of the over 700 traffic cameras which captured at least partially within the image frames man-made buildings or structures. These images were then automatically downloaded using a Python script at an interval of around 10 minutes. With similar techniques, we also

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[1]`https://www.hkemobility.gov.hk/en/traffic-information/live/cctv`

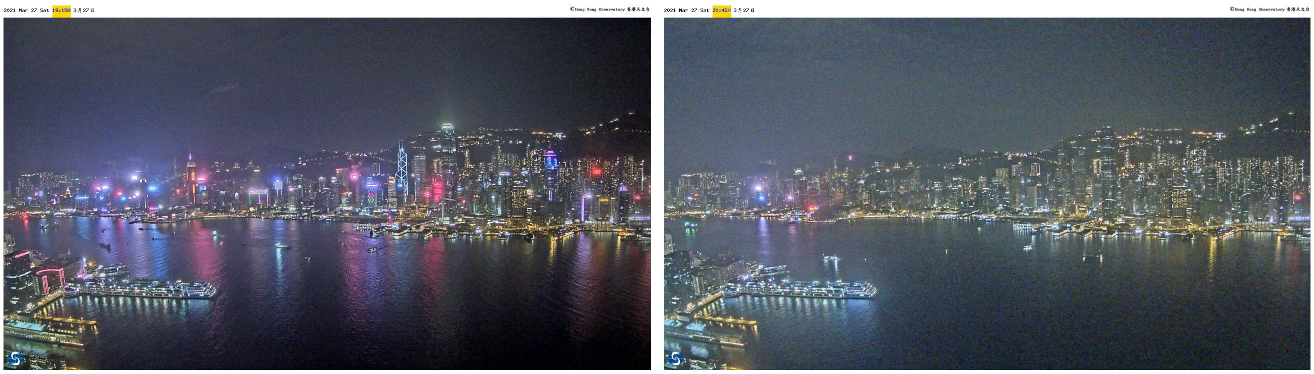


Fig. 1. Outdoor decorative lighting as a massive man-made phenomenon. *(Left)* Photo taken at 7:15 pm before Earth Hour. *(Right)* Photo taken at 8:45 pm during Earth Hour.

acquired real-time images taken by the 27 weather cameras released by the Hong Kong Observatory[2] every 15 minutes. We acquired all-sky images published by the Hong Kong Observatory.

We also gained access to images from 7 all-sky cameras located at rooftop of buildings. These bird's-eye view images provide lighting conditions of the surroundings in all directions. Furthermore, two portable panoramic cameras were placed in strategic locations on both sides of the Victoria Harbour to capture the changing lightscape on the harbour-front.

Hong Kong's unique double-deck tramways travel across commercial districts where many buildings were expected to participate in the campaign [8]. We placed a camera at the front seat of the upper deck, traveling across the commercial district 8:30-9:30 pm local time on the Friday night before Earth Hour and the Saturday night during Earth Hour. The videos were then edited to match locations and used to identify lights-out buildings. A group of 10 volunteers on the ground took photos in commercial districts during Earth Hour.

3. METHODS

Several automatic image analysis methods were used to identify the impacts of Earth Hour on external lighting. First, we applied an image subtraction method to analyze the impacts of Earth Hour on the urban lighting environment [9]. This image analysis technique was successfully applied on images from fixed cameras such as weather and traffic cameras. For images from non-fixed cameras, such as the image frames extracted from the videos from tramways, we adopted the Brute-Force Matcher algorithm from OpenCV [10].

Due to traffic conditions and red lights, although the two videos were taken from the same tramway, the alignment can be tricky. To align the two videos taken before and during Earth Hour, the videos were first coded into individual frames using OpenCV. We manually identified the closest frames between two videos and used them as the control frames to align image frames when the tram was moving. The frames taken during tram stopping were discarded.

We modified the TensorFlow Object Detection API to identify light sources in the *nighttime* videos in an experiment. We manually labeled around 200 *nighttime* images for training and used the trained model on unseen images for testing.

4. RESULTS AND ANALYSIS

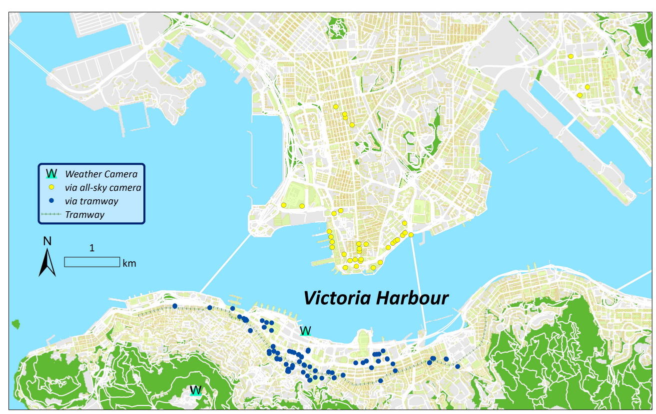
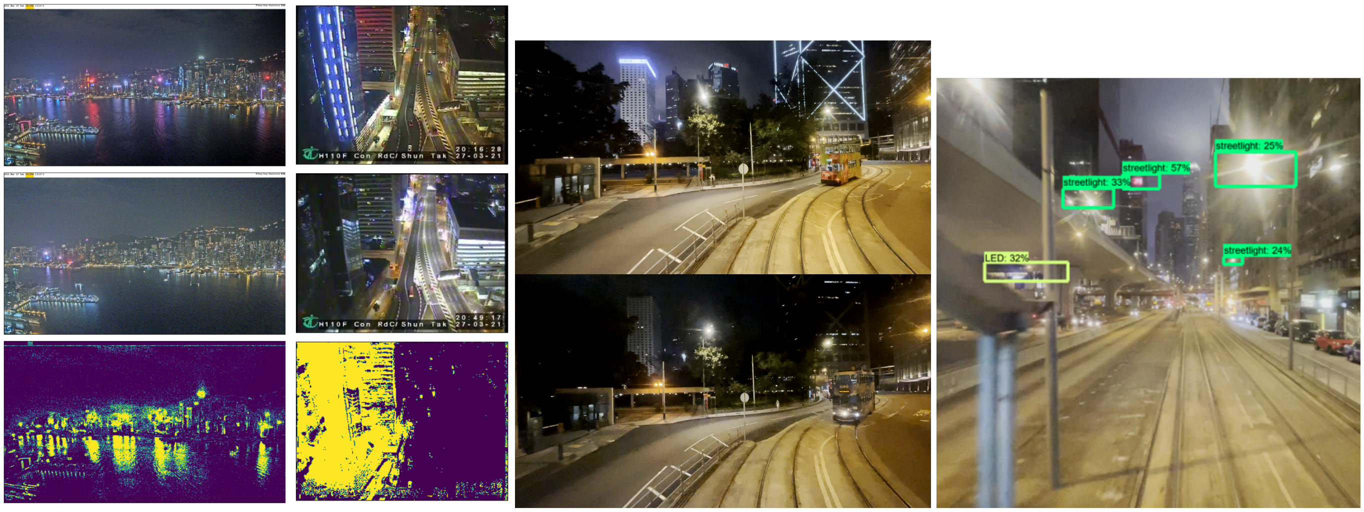


Fig. 2. Geographical distribution of the lights-out buildings during the Earth Hour 2021 campaign in Hong Kong, identified by multiple data sources.

Overall, by analyzing the data, we identified 122 individual buildings that participated in Earth Hour 2021 and mapped their locations. We show a map centering the downtown area in Figure 2. It should be noted that many of the lights-out buildings were identified by multiple methods; for example, HSBC Building, Bank of China Tower, Cheung Kong Centre, and Windsor House were identified by all of weather cam-

[2] https://www.hko.gov.hk/en/wxinfo/ts/index_webcam.htm



(a) weather camera (b) traffic camera (c) camera on board the tramway (d) AI for light detection

Fig. 3. *(a, b)* 1st-3rd row: before Earth Hour, during Earth Hour, and subtraction between two images. *(c)* the upper image was taken one night before Earth Hour, and the lower image during Earth Hour. *(d)* using AI for light source detection.

eras, wide-field cameras, tramway cameras, and cellphones. The number was the minimum estimated participated number since 1) within a building there were many restaurants and shops and 2) even with multi-source data we only covered a small fraction of the urban areas.

We further demonstrate in detail the promising capabilities of these open or crowd-sourcing data in monitoring large-scale urban events. For example, Figure 3a shows images from a fixed weather camera. We observed a large number of lights-out buildings, and even reflections of the buildings appeared to be dimmer. Figure 3b shows images from a fixed traffic camera. A simple comparison of the before-during-Earth-Hour images can identify the front building that was lights-out. This lights-out building also affected the nearby environments and buildings, which were darkened during Earth Hour. Figure 3c shows an image snapshot from two concatenated videos that were taken one day before Earth Hour at 8:30-9:30 pm (upper) and during Earth Hour (lower). The preview video can be accessed at `https://youtu.be/B6hXvqMPvyE`. A significant light brightness reduction was observed during Earth Hour, and the night sky appeared to be darker (less light-polluted). Figure 3d shows a case using AI for light source detection at night. These multi-source data demonstrated their promising capabilities in monitoring the impacts of large urban events like Earth Hour.

Fig. 4. Case of non-essential decorative lighting affecting the opposite building and the urban environment. First row before Earth Hour, second row during Earth Hour, and last row after Earth Hour and the image subtraction.

We identified some interesting cases during Earth Hour that show the importance of regulation of lighting usage. Figure 4 shows images from a traffic camera in a mixed commercial-residential area in Wan Chai. The upper row shows images before Earth Hour, the middle row shows images during Earth Hour, and the last row shows (left) the image when non-essential lighting was turned on and (right) the image subtraction between two images before and during Earth Hour. From the image subtraction, not only the source building was significantly dimmer, its impacts on the opposite building was also greatly reduced. By turning off non-essential lighting, the chance of disruption to our night-time sleep from *light trespass* can be reduced [11]. And with multi-source data demonstrated in our study, we can easily identify areas with great risk of *light trespass*.

While it is promising to use multi-source data to monitor Earth Hour and other massive urban events, we acknowledge that limitations exist, primarily focusing on the automated processing of these massive multi-source visual data. Preliminary advances on these data have been focused on event recognition and classification [12]. In our experiment in monitoring the impacts of Earth Hour – a simple civil event – we find that automated and intelligent algorithms are in urgent need in the following applications.

1. Automated recognition of light sources in *nighttime* setting. Deep learning algorithms such as semantic segmentation and object recognition have developed rapidly in the past ten years. Yet, we cannot find existing algorithms and datasets for recognizing light sources (streetlamps, LEDs, etc.). We managed to train a model ourselves for light source detection (Fig. 3d), with limited accuracy. The nighttime setting also complicates the adaption of existing algorithms.

2. Video alignment. Fixed cameras on board moving vehicles gave us a detailed tour of examining lights-out during Earth Hour. Yet, two videos from the same route cannot be simply auto-aligned due to interruptions from traffic conditions and red lights. GPS/GNSS may be a starting solution but is still limited by the precision of about 10 meters and up in high-rise urban environments like Hong Kong.

3. Image matching from two videos with slightly different observation angles. After video alignment, additional image matching is necessary if we want to do image subtraction because of the slightly different observation angles. For this application, existing image matching algorithms did give us a better matching accuracy, and yet we were expecting a better, higher-accuracy automated process in the era of AI.

5. CONCLUSIONS

We presented a large-scale survey using open and volunteered crowd-sourcing data in monitoring Earth Hour 2021 in Hong Kong. These multi-source data, including images from traffic cameras, weather cameras, and panoramic 360 cameras, and videos recorded on a tram, can help us identify lights-out buildings during Earth Hour. Of all sources, images from traffic and weather cameras were the most cost-effective, because they were open data streaming online. Their fixed nature makes processing easier. Tramway videos captured the majority of lights-out buildings along a single route, though matching videos was labor-expensive. We hope for more automated methods from artificial intelligence and Earth observation communities. Before that, handling multi-source data is still a promising yet labor-intensive work for monitoring urban events like Earth Hour.

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