The Study and Application of Smart Art Community Service with "ESPSAS" Internet of Things Platform

Jheng-Chun Yang and Su-Chu Hsu(✉)

Department of New Media Art, Taipei National University of the Arts, Taipei, Taiwan
jerrysvy@gmail.com, suchu.hsu@gmail.com

Abstract. In this research, we developed "ESPSAS" platform of IoT. It is based on ESP-12F, and the platform consists of three systems, thing system, website system and communication system. The platform solves the issues in art creation: the need for light, cheap chips in volume. In addition, another feature of the ESPSAS platform is its connection design. We propose a double-registered synchronization that confirms the complex communication within the thing system. We have already installed "ESPSAS" IoT Platform at Taipei Nan-men Elementary School in Taiwan and has run "Windflower ESPSAS" project, allowing students in elementary school to be makers and to create their own windflower things and to decorate the campus with social network art creation as their community cultural development on campus. Owing to the structure design of the windflower IoT thing and ESPSAS platform we developed, the windflower is a spinning pinwheel by day, a colorful lantern by night. People can appreciate the spinning of their own windflower on campus remotely via cellphone, and alter its light color remotely with cellphone. This study utilizes IoT technology to equip things and interfaces with transparency in a space, so that individual's emotional memory may become transparent and extend from the campus into the cloud. We look forward to the applications of this outcome to more artistic design and creative fields in the days to come.

Keywords: Community cultural development · Internet of Things · ESP-12F · Maker · Social network art · MQTT

1 Introduction

On the World Semiconductor Council (WSC) in May 2014, it was said the next trend shall be the Internet of Things (IoT), which proclaims, "The next big thing is the Internet of Things" [1]. The IoT has been commonly associated with smart life in recent years, but less with art creation, though, especially with community service. Our "Windflower ESPSAS" project is a research but also a social network art that uses IoT on community cultural development. It is also a rare case in the world that combines traditional artisanship, IoT and art social service to achieve the community cultural development on campus. We encourage elementary school students to be makers and create windflowers with traditional Taiwanese bamboo-pinwheels and digital chips. Hence, we decorated the campus with everyone's windflower through social network art. Due to the design

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of bamboo structure and the embedded IoT chip, the windflower is a spinning pinwheel by day, a colorful lantern by night. One thing worthy of mentioning is that "Windflower ESPSAS" project was executed through the "ESPSAS" IoT platform we developed. Therefore, people can appreciate the spinning of their own windflowers on campus remotely via cellphone, and alter its light color remotely with cellphone. Thus, individual's emotional memory may become transparent and extend from the campus into the cloud.

The IoT nodes used in the social network art creation and design oftentimes requires chips that are light, cheap and in volume, and the platform also need to fit the freedom and flexibility in art creation. We had inquired and experimented many chips in vain. As such, we developed the "ESPSAS" IoT platform (abbreviated as ESPSAS) of our own. The name is derived from the IoT board "ESP-12F" plus "Smart Art-Design Service". That is, this IoT platform is developed for art-design service. Our ESPSAS is built with ESP-12F as its core thing hardware, featuring cheap in price, small in size, light in weight, and easy to assemble with Wi-Fi connectivity. We use it as a board to connect other electronic components and keep it in a minimum size, so that it can be inserted into the small things used in art creation. On ESPSAS, we developed various communication modes: "peer-to-peer", as well as "one-to-many" and "many-to-many". As long as a thing is connected to our platform, people can link, operate and interact with the thing via the webpage on the cellphone. The research and application of "Windflower ESPSAS" can be extended to diverse art designs and creative application in the future.

2 Related Work

2.1 The Board and System of IoT

The "Internet of Things" was proposed in 1999 by Kevin Ashton from the U.K. [2]. It is an internet working among things, which allows the things to transmit and receive data and automatically response to the data. Human can also give orders to the things or retrieve data collected by them. Back then, Ashton built the IoT with RFID, a near-field-communication IoT system. The IoT nowadays covers a wider range and scope, such as smart family life and smart monitoring system, and things can connect to one another from afar. The wireless communication technology commonly adopted are Wi-Fi, Bluetooth, IEEE 802.15.4 and RFID, in which Wi-Fi is most popular and able to connect to the Internet directly without a gateway to convert signals. Our ESPSAS uses Wi-Fi for the communication among things as well.

Introduction of ESP-12F. The ESP modules commonly seen on the market are ESP-01 to ESP-14. These modules have many merits, a board suitable for DIY next to Arduino and Raspberry Pi. Particularly for ESP-12F, it is a module equpped with the IoT chip ESP8266, featuring Wi-Fi connectivity and microcontroller [3]. ESP8266 is cheap, light and stable with low energy consumption. After its launch in August 2014, it has become a trend throughout the world with strong community support [4] and various open-source development and projects.

There are numerous electronic boards available for the IoT, some of which require additional communication modules while others do not. Our ESPSAS uses ESP-12F as the electronic board because its module is small enough (16 mm × 24 mm) with more pins (22 in total), larger memory (4 MB) and an on-board antenna [5].

ESP module can serve as a board, but transistors and resistance have to be installed due to its physical limitation, nevertheless. There are many boards on the market equipped with ESP module since it is easier for pin insertion and a port for power input. Yet, the size of it will be two to three times of its original size, unable to fit into our smaller art things. On our ESPSAS platform, ESP-12F, electronic resistance and power supply module are assembled directly to serve as a board. Then, we stack vertically to expand the module chips while keeping the size of the area close to that of the electronic board. Thanks to this vertical stacking technique, we are able to keep the area of the board small enough to fit into small things.

Communication Protocol of IoT. The common protocols used for data transmission of IoT are HTTP REST, CoAP and MQTT [6]. Most of the IoT platforms today are based on these three protocols to provide cloud service and data analysis. Developers use the API provided to allow things to transmit data over the cloud. Some services like Arduino Cloud[1] even integrate with hardware. Nonetheless, such service has its limitation, like the limit on fee collection or the limit on connection. ESPSAS platform we developed uses MQTT protocol [7]. In addition to the merits of low energy consumption, stable connection and strong expansion capability, it carries many-to-many connectivity, too. It can also mount a cloud server to maximize the development flexibility for the service on the platform.

2.2 Application on Community Cultural Development

Community cultural development refers to the improvement of the neighborhood with local cultural at its core conducted by the residents and art workers to increase the well-being of the community as a whole. There are new creative communities emerging worldwide that combine with digital media to help foster community consensus and improve the neighborhood, in order to usher in new energy and innovative idea for the community [8]. PRIXARS ARS Electronica Festival opened the "Digital Community" in 2004 [9] to encourage the world to construct virtual or authentic communities with digital approach, so as to influence the society and better the life of the people. Many of the awarded works are online collective art creation. That shows that is has become an important trend and power to develop communities with digital approaches across the world.

There are already renowned cases of Digital Community across borders. The project "canal*ACCESSIBLE", launched by a Spanish artist Antoni Abad in 2006, invited some 40 physically-challenged individuals. They photographed, tagged, and put on description on a digital map through their cellphones as they roamed in the city of Barcelona and found any unfriendly facility or environment, so that the general public as well as

[1] Details in https://cloud.arduino.cc.

the government could see the problems and improve as such [9]. A similar case is "FixMyStreet" website, created by a British NPO "mySociety" in 2007. They focused on the streets and public infrastructure instead, however. The users found problems and published those onto it, which were relayed to the government to urge the government to act on it or encourage people to solve them voluntarily [9]. "El Campo de Cebada" in Madrid, Spain in 2010 is a movement that the local citizens developed the idle lands owned by the government. After negotiations, the development was led by the citizens with support from the government. People and the government cooperated instead of fought against each other, and all the information and resources were open to the public [9]. The work "Hello Lamp Post"[2] by Pan Studio in the U.K., in 2013 was based on SMS service platform, inviting people to interact and converse with the facilities on the street like lamp posts and mailboxes via text messages as if these objects had been intelligent and human. Our "Windflower ESPSAS" project is more close to "Hello Lamp Post", which is embedded with the concept of IoT. We combine traditional bamboo handicraft to design windflower things in maker's way, to realize the community cultural development on campus at Taipei Nan-men Elementary School in Taiwan.

3 Structure of ESPSAS IoT Platform

Our ESPSAS Platform consists of three systems: thing system, website system and communication system (see Fig. 1). The thing system is the process to insert chips into thing to equip it with Wi-Fi connectivity. The website system serves as the platform for the communication between users and things with webpage as the user interface. The communication system is the bridge to connect the thing system and the website system.

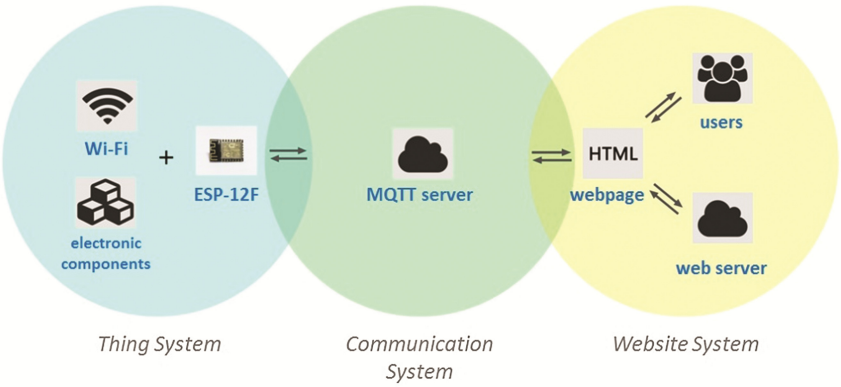

Fig. 1. The integration and operation of ESPSAS platform

- **Thing system:** A thing has to be equipped with wireless connectivity, sensors or functions to execute orders to be called as an IoT thing. This system is intended to

[2] Details in http://www.hellolamppost.co.uk/.

transform an ordinary thing without IoT connectivity to an IoT thing after being embedded with some IoT electronic devices. Our windflower thing system includes the assembling of ESP-12F board, the design of electronic architecture, the writing of firmware, power supply and Wi-Fi setup. Since ESP-12F uses Wi-Fi to communicate, it is vital to set up a space with Wi-Fi access. ESP-12F needs to be activated within a space accessible to Wi-Fi to be able to access the Internet. For example, for a windflower to be able to detect rotation speed and lighting, the electronic installation process is as followed: (a) electronic architecture design (ESP-12F board, full color LED light, small motor and power supply); (b) electronic welding; (c) firmware writing; (d) connection testing. During the connection testing, ESP-12F will automatically connect to a Wi-Fi AP. Should the connection fail, it will require manual set-up to connect. It then will automatically connect to the designated AP next time when it is on.

- **Website system:** It includes web server, database, website structure, interaction interface, monitoring and management, so that the data of the thing system's operation can be retrieved in real time, which can be visualized and transcribed in text. A user can connect to things via webpages. Each URI of webpage corresponds to a single thing, and each URI is therefore deemed as the single access portal to the interactive interface of that specific thing.
- **Communication system:** Message Queue Telemetry Transport (MQTT) protocol is used to handle the connection between the thing system and the website system like a bridge for communication. MQTT plays the role of connection relay. It is a publish-subscribe-based "lightweight" machine-to-machine (M2M) communication protocol for use on top of the TCP/IP protocol [7]. The data published by the publisher will be relay to the subscriber via a MQTT server; then the publisher and the subscriber on the same topic can be seen as connected (see Fig. 2).

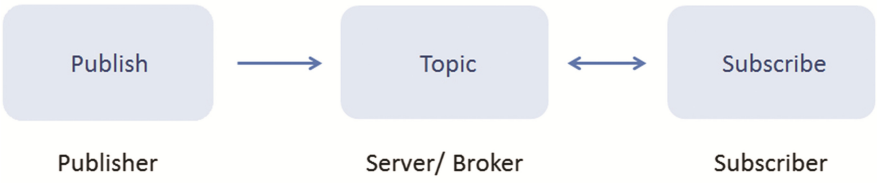

Fig. 2. Communication of MQTT

4 Method of "Windflower ESPSAS"

"Windflower ESPSAS" Project is the first collective online action art using IoT technology in community cultural development in Taiwan. The IoT thing windflower is

composed of traditional Taiwanese bamboo-pinwheel[3], which is inserted with ESP-12F module as the key thing for the project execution. The windflower is a spinning pinwheel by day, a colorful lantern by night. Through a website, people can see how the windflower spins remotely anytime anywhere. Also, they can set the colors of windflower's led light remotely from the webpage. Our community cultural development on campus at Nan-men Elementary School has two installations of windflower - "Windflowers on Pillars" and "Windflowers on Tree Rings" (see Fig. 3).

Fig. 3. Two windflower installations - "Windflowers on Pillars" and "Windflowers on Tree Rings"

4.1 Making of Windflower

Our "Windflower Maker Workshop" at the school allowed children to be makers and create their own windflowers (see Fig. 4), including bamboo handcraft, windflower painting and installation. Hence, each windflower is one of kinds as they carry the memories of the children's design. We designed 38 windflowers in total, 30 of which is installed on "Windflowers on Pillars" while 8 of which are installed on "Windflowers on Tree Rings". It is more than a maker movement, but a community cultural development on campus; furthermore, it is a digital interactive public art.

The materials used on windflower are bamboo strips, thin bamboo sticks, fix balls, cardboard, electric wires, small motors, full-color LED and ESP-12F board. The main features of windflower are light and spinning. Therefore, on the structural design, we use full-color LED for the lighting and small motor for spinning. Figure 5 is the illustration for the assembling of the electronic components with the bamboo pinwheel. Before the assembling, the electronic components are attached to a thin bamboo stick. The electronic components are extended by wires with plug and socket connected together. You can see the light of LED. After assembling, the fix ball holds the bamboo pinwheel and the small motor together. There are four reasons why a small motor is used: (a) small enough to be placed in the bamboo pinwheel; (b) cheap with a price range

[3] Bamboo-pinwheel is a traditional Taiwanese handcraft. It is composed of four thin bamboo strips woven into a ball. The bamboo ball has eight bamboo protrusions, which can be attached with eight flower pedals. Such structural design allows the bamboo-pinwheel to spin when the wind blows. For more details, check: https://www.youtube.com/watch?v=cCZkczvLG4A.

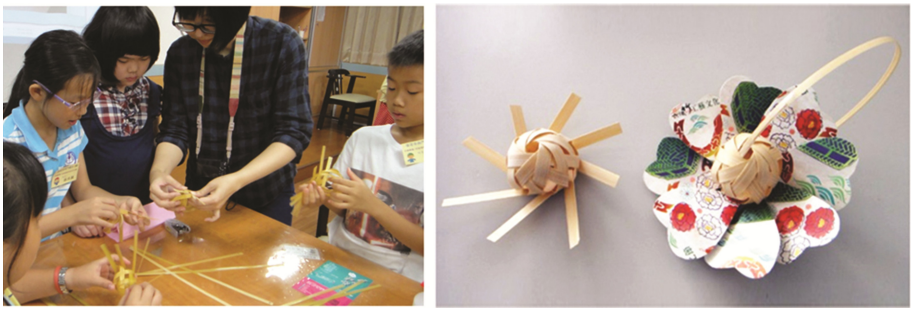

Fig. 4. Windflower maker workshop

US$0.3–1; (c) to avoid wire twist; (d) accurate rotation speed. One thing worthy of mentioning about (c) is that we take the advantage of voltage change when the small motor revolves and turns it into the rotating speed of the pinwheel, cleverly solving the issue of wire twist of the sensor due to the rotation. As for (d), the voltage variation the board detects is analogue signal range 0–1023 and the magnitude of voltage range 0–1 V [3]. Due to the rotation of the bamboo pinwheel, the value is somewhere from 0 to 60, so there is no overloaded issue. Besides, since it is a direct numerical conversion without mathematical translation, it is an effective and accurate value that can be used directly.

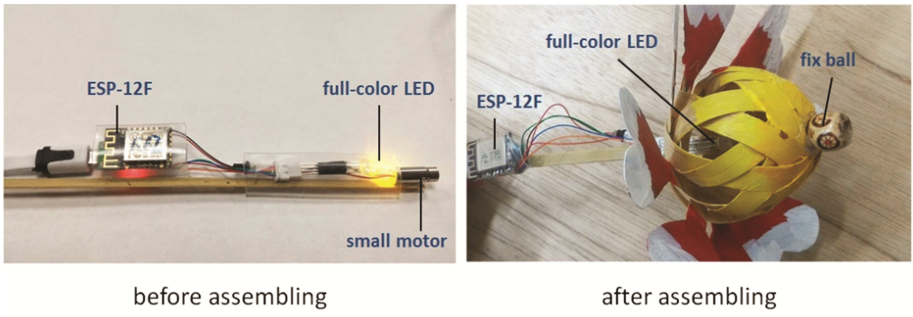

Fig. 5. Assembling of electronic components with a bamboo pinwheel

4.2 Scenario for Interaction

The installed windflower thing will automatically connect to a Wi-Fi AP, and communicate constantly with MQTT on the cloud 24/7. A user needs only to scan the QR code or type the link to access the online website[4] of our project. Each windflower on either "Windflowers in Pillars" or "Windflowers in Tree Rings" has a unique ID. On the webpage, one may access to a specific windflower by accessing the webpage of certain ID. As soon as the link is established successfully, one may see the visualization of the

[4] Details in http://fbilab.org/windflower.

windflower, check its real action, and even give it orders. Should there is an issue with the link, the system would prompt the user as well. Children or adults alike can see how the windflower spins via the webpage through the online platform during the day (see Fig. 6). If the users browse the webpage on a cellphone, they can even see the animation of windflower's spinning. By night, they can see how the windflower glow and set as well as alter the colors of the light on the windflower. If we stand in front of the public art "Windflowers on Pillars" or "Windflowers on Tree Rings", we can see the animated windflowers on webpage and check the synchronization of the real windflowers on campus. If we are away, we can still tap into the memories of the windflowers and enter the campus through the cloud via the platform.

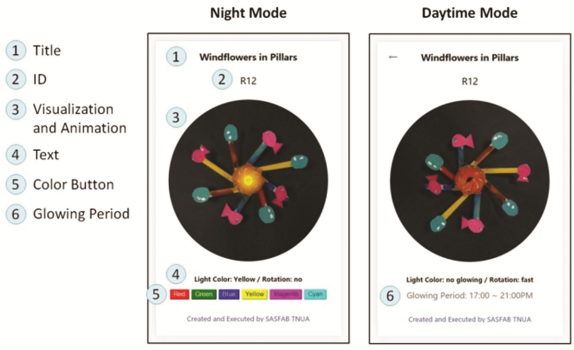

Fig. 6. The webpage of windflower

4.3 The Link Between Thing and Webpage

The link between the thing and the webpage is based on the system of ESPSAS platform. There are four presumptions in our design of our platform.

- Each windflower has one ID of its own.
- Each windflower has one corresponding webpage (URI: http://…/id).
- Each windflower and webpage use ID as their reference for MQTT topic; for instance, it may be "myWindflower/id" to subscribe and publish onto the MQTT server.
- Each windflower and webpage will subscribe to the MQTT server first at the initial setting, which is required only once.

Since the MQTT server needs to receive the subscription of windflower only at the beginning and the link stays connection without further subscription. As for publishing, it is an action has to be taken repeatedly. Therefore, when the thing and the webpage are at the initial setting, they will subscribe and only need to subscribe once.

The windflower has the detection abilities of rotation speed and lighting. Based on the four presumptions, we shall further elaborate on the communication processes of rotation speed mode and lighting mode respectively.

Rotation Speed Mode. The main purpose of rotation speed mode is to allow people to check the spinning of the windflower on campus online simply by clicking on the

windflower webpage on the cellphone. That is, the webpage will send a request via the link to retrieve the rotation status of the windflower. In the mode of rotation speed, the "thing-webpage" communication is unidirectional. The communication process from the webpage to the windflower is presented as Fig. 7.

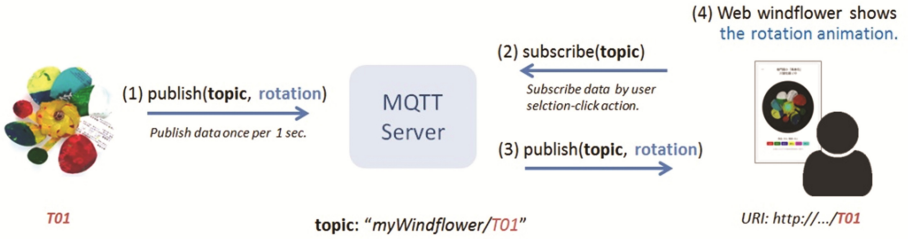

Fig. 7. Rotation speed mode – the communication flow from the windflower to the webpage

(1) The thing, when connected, will publish the data of rotation speed constantly per second to the MQTT server.
(2) When the user clicks on the windflower on the webpage, the webpage will send the subscription request of certain windflower topic to the MQTT server.
(3) As the MQTT server is constantly receiving the rotation speed data, it would also match according to the topic request sent by the webpage and publish the corresponding rotation data of the windflower to the matched webpage.
(4) As the webpage at the user end receives the rotation data, it would convert the data and present the rotation data with the animation of a windflower spinning. The larger the value is, the faster the animated windflower spinning will be, along with a text to indicate the speed of the rotation.

As long as the thing-webpage link sustains, such flow would execute repeatedly and feed the data of the thing to the webpage as they are synchronized.

Lighting Mode. There are two main functions in lighting mode: to allow the user to check the lighting of the windflower on campus when they click on the windflower over the webpage on the cellphone; to allow the user to alter the light color of the windflower on campus over the webpage. In lighting mode, the "thing-webpage" communication is bidirectional. We shall discuss it in two directions respectively: from webpage to windflower and from windflower to webpage.

From Webpage to Windflower. The link from webpage to windflower means people can view the lighting of the windflower on campus at the time as they click on the windflower on the cellphone's webpage. That is, the webpage will send a request to retrieve the lighting of the windflower in real-time. The flow from webpage to windflower is presented in Fig. 8. In the flow chart, (1)–(3) are the same as that of Rotation Speed Mode; the only difference is the data transmitted, which is light color here. On (4), the webpage will treat the light color as a parameter to execute the light visualization and text prompt of the windflower.

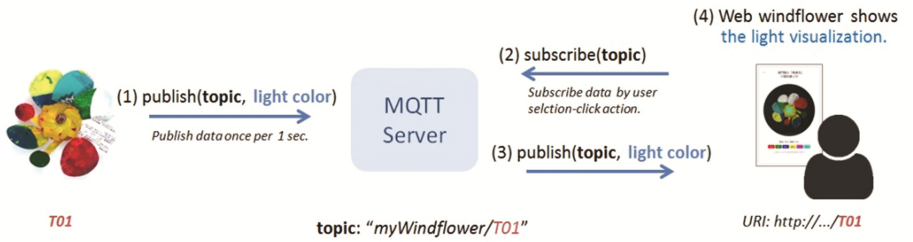

Fig. 8. Lighting mode – the communication flow from webpage to windflower

From Windflower to Webpage. The communication from windflower to webpage means people can alter the light color of the windflower on campus on the webpage, and the windflower sends out requests to learn about the alternation and react accordingly. The communication flow from the windflower to webpage is presented in Fig. 9.

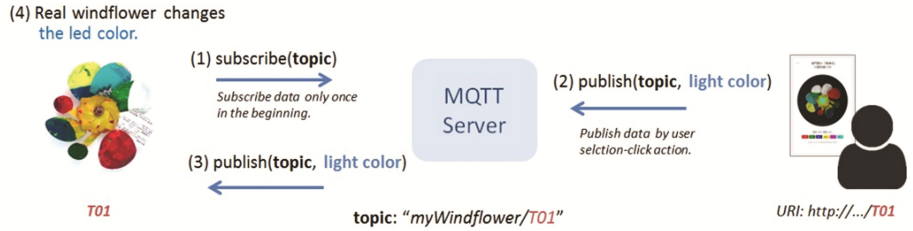

Fig. 9. Lighting mode – the communication flow from windflower to webpage

(1) The windflower subscribes once to the MQTT server initially for the light color.
(2) The user clicks on the light color of the windflower over the webpage, and the webpage will publish the data of the selected color of the windflower to the MQTT server.
(3) The MQTT server receives the data of the selected color, matches the topic, and publishes the updated light color to the matched windflower accordingly.
(4) The windflower in reality changes the light color according to the data received.

This direction of the communication flow differs with the other direction of the flow in the data publishing of the webpage. When the webpage publishes, it requires a user to operate and publish, while the thing publishes automatically. In the Figs. 8 and 9 above, the flows may appear logical if we view them in two different directions. However, if we observe from the angle of "topic", we will see when the two topics are identical, it will not be able to tell which direction the data came from, and therefore results in the confusion of program logic. To avoid such situation, we tag a codename of the subscribed target after the original topic like "myWindflower/id". For example, the topic for the subscription for windflower is "myWindflower/id/thing"; the topic for the subscription for webpage is "myWindflower/id/webpage". The same applies to the publishing.

As such, if we combined the scenarios discussed above, the overall flow of the communication can be illustrated as Fig. 10. As we separate topic into two different ones, we can thus distinguish the direction of the transmission accordingly. In the flows, (1)–(7) is the flow of user giving light color order. (1.1) is that the windflower publishes its light color to the MQTT server per second. (1.2) is that it only needs to do the subscription to the MQTT server once at the beginning. (4) is that when the webpage is connected, it will receive the light color of the windflower and present the light visualization and text prompt accordingly. (7) is that when the windflower in reality receives the color alternation selected by the user, it will change the light color accordingly.

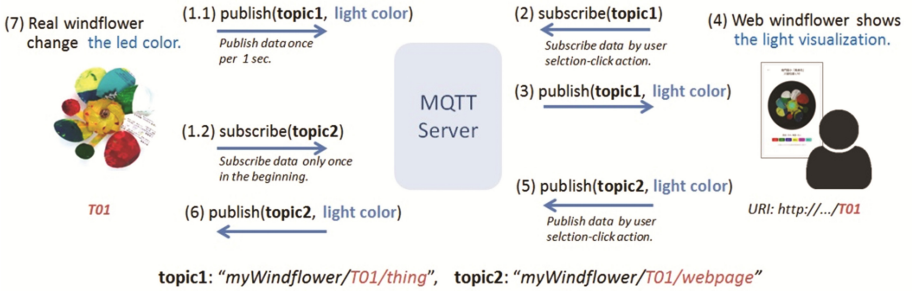

Fig. 10. The overall communication flow of lighting mode

In addition, our Platform has another feature: to ensure the thing receives data and to ensure the synchronization of both ends, we adopt "double-registered synchronization" in the communication. Hence, only after the other end confirms the transmission can this end be notified as order transmitted.

5 Conclusions and Future Work

"Windflower ESPSAS" Project is the first social network art using IoT technology in community cultural development in Taiwan. It is not only a public art installation, but a long-term project.[5] The elementary school partner will throw activities related to windflower from time to time, inviting children, parents and residents in the neighborhood to partake (see Fig. 11). This work is not merely a result of Maker Workshop and an art installation, but something transforms the campus into a more friendly space with aesthetic. It helps to promote the education of the Internet of Things as well as community interaction. On top of that, it creates a memory shared by the community on the cloud as well. This study, with the technology of IoT, aims to achieve the goal digital art workers try to accomplish for a long time – media transparency, i.e. connecting things via IoT on the cloud so as to make it transparent, as emotional memories are connected at the same time.

[5] Details in http://sasfab.org/?p=4502.


Fig. 11. "Windflower ESPSAS" project at Nan-men Elementary School

The ESPSAS platform we developed builds a framework with three systems: thing, website and communication. Such framework is easy to extend and use as it saves a huge amount of time for base development. In addition, the ESPSAS platform is the solution to the issue in art creation: the need for light, cheap chips in volume. Besides the basic webpage and thing communication function, we also developed the administrator page, auto-control page for us to monitor, operate and execute at certain time, as well as synchronize and auto-control among the things. We shall continue optimizing ESPSAS platform in the future, and apply the result to more artistic design and creative fields.

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