Remotely monitor a single compartment Little Free Library (LFL) for emptiness – meaning without books.

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Version history

Version	Description	Date	Notes
1.01	First edition	09/23/19	

Environment

A typical Little Free Library consists of a small wooden box with one hinged door with a transparent front (photo attributed to Jwh at Wikipedia Luxembourg, CC BY-SA 3.0 lu, https://commons.wikimedia.org/w/index.php?curid=63884624). It will have power available (5V) and light via an LED string which will be switched on only when the door is opened. Typical dimensions are: 18 inches tall, 21 inches wide, and 17 inches deep (source Amazon).

For this development phase the box doesn't have any shelves meaning there is one and only one space for the books (a shelf will divide the space into two open spaces). There is only one space for books.

Requirements

The challenges are :

(a) Establish a smart way of knowing if there are any books or not
(b) Hourly - transmit that knowledge back along with Door open/close count
(c) Daily – send an image

High level technical proposal:

1. Use a small micro-controller that consumes at the most 5v DC power, equipped with a small camera so that the overall footprint is very small.
2. Attach this contraption to the inside of the box.
3. Monitor brightness, take pictures periodically.
4. Use a smart algorithm to analyze the pictures to determine if there are books.
5. Assess/average this knowledge over an hour and come up with a 0 or 1 answer (0 meaning empty)
6. Transmit the conclusion using a customer provided modem to the responsible party once every hour.

Additional considerations

1. Each Little Free Library must have its own Id so that once it is found to be empty. This Id can be the Id of the modem or a derivation of it.
2. It should not interfere with the opening and closing of the door panel.
3. It should not interfere with the act of taking or depositing books.
4. Based on the lighting conditions, the aperture of the camera needs to be adjusted for a decent image which can be the basis for the assessment.
5. Based on the camera signals, opening and closing of the door can be easily detected but this knowledge may not be necessary.

Camera placement for practical considerations

1. The camera placement needs to be such that the books are in focus.

2. The camera should be away from most used parts e.g. the door if possible as it may be in the way, or books can damage it or move it.

3. The camera should also be away from the elements to minimize the effect of rain and humidity.

4. The camera also needs to be out of sight as most of these little libraries are in public places and there will always be someone who will be interested in it and will want to steal it.

5. As this placement decision will be best formed with some trial and error in conjunction with the customer, this can be tried as the project moves along.

Camera placement options	Advantages	Disadvantages
Orange	- Hidden and less subject to curiosity and vandalism - Weather-proof location - Can take images all day and report often	Sub-optimal for taking images with full view of the shelf.
Blue	- Best positioned for taking best image with full view of shelf - Best image availability (examples shown later in the document)	- Exposed to curiosity, vandalism and weather - Door needs to open between 45-120 degrees. A detection/trigger mechanism is required.
Overhead		

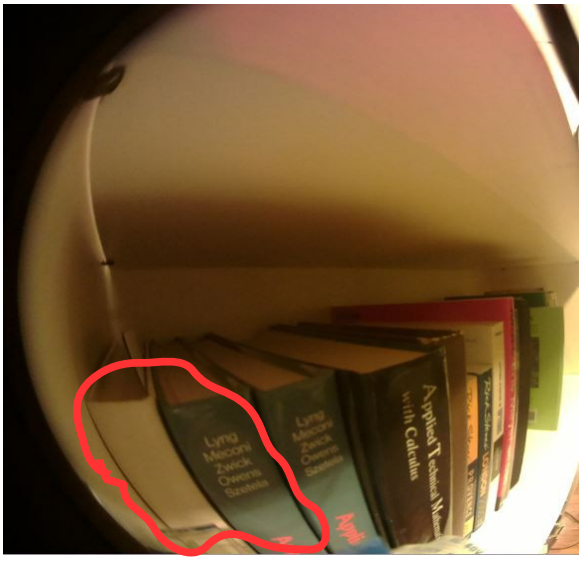
Technical Considerations

Physical camera placement for optimal image capture

Provisionally in one of the corners right above the door, as hidden as it can be from public sight and away from the elements.

The camera placement is very important as it is imperative to get a detailed view of the books. With a high resolution camera placed in the top left inside corner in the same plane as the door, here are some images.

Taken with a 5MP camera



Taken with a 5MP camera with a Fisheye lens

It is clear that the regular camera placed in a position close to Orange in the previous page missed 2 books shown in red. The camera with a fish-eye lens picks up the 2 books without a problem.

Taking the image from the front with the door open at 90 degrees produces the best picture as shown below:

Include overhead shots as they will be different.

For image analysis, this image is preferred over the two above.

Power needs:

5V, 2A either via USB or 110V normal electric outlet.

Detailed Design

Physical design considerations

The placement inside the library's wooden enclosure and in an upper inside corner will automatically provide protection to the camera/micro-controller assembly. Additionally they will be placed inside a housing/case to provide them additional protection from dust/insects/accidental touches.

Picture coming soon.

Algorithmic architecture

As the door of the LFL is opened, an led strip is turned on and the customer provided sound file is played – both are on for a duration of 30 seconds. This is configurable.

Next, towards assessing if the LFL is empty or if there are books, a series of images are taken

The need is to absolutely know if there is a book or not inside the box. This means that the book(s) could be standing vertically or horizontally or at any angle.

We will use already known mature image processing algorithms and fine tune them to identify books in different positions in a single shelf for this project. Upon completion of the Design Milestone, additional details of algorithm architecture will be provided to the customer on request.

Customer wants the images to be taken when the door is open as the led strip is powered. In addition to that this algorithm also takes pictures every 10 minutes turning on the led at the same time to take an image.

Opens door of LFL

Lab environment

A lab environment comes in extremely handy for
(a) future development
(b) test bug fixes
(c) test current capabilities

A lab environment in this case will be extremely simple and consist of a camera/micro-controller combo that can be housed either inside a 'Free little library' or a similar type of box with some books and a door with a transparent panel allowing ambient light.

Hardware install/replacement strategy

The entire assembly of the camera/micro-controller combo is mounted on a bracket with two holes for screw mounting the bracket in the upper left/right corner of the 'Little Free Library' just above the door. That will make installation super simple and will consist of 2 steps:

a. Attach the power cord into the usb/power plug

b. Screw the bracket carrying the camera/micro-controller assembly using 2 screws.

That's it.

Replacement will be equally easy:

a. Detach the power cord

b. Unscrew the 2 screws holding the bracket carrying the camera/micro-controller assembly.

Message collector and platform for assessing LFL status

To receive messages from all the LFLs and for customer to monitor the status of the various LFLs fitted with this solution, a centralized message receiver is necessary where all the LFLs can send their status messages to. On receipt of such messages, this system should then be able to provide an easy UI (User Interface) to the customer to monitor the status of any LFL for suitable action.

Alternately, this system could be designed such that it can trigger action by forwarding the status/message to a suitable actor via SMS or other means for some action.

Patching/Fixing software and application of patches

To ensure that all installations of the solution hardware/software are patch current, it is possible to architect the software such that the micro-controller is equipped with software that checks nightly for patches and pulls them from a common repository.

Patches that have been tested and approved for release can be placed in a pre-configured site for being pulled by devices nightly. This automated patching arrangement is a much better arrangement that deploying patches manually or pushing them.

For this to be available, a customer provided website is expected where patch(es) after passing customer lab testing will be placed. These will then be deployed for remote application by pulling.

Questions

1. Prefit existing LFLs or are all of these going to be new ?
2. Where will the location of the power be ?
3. Where will they be placed ? Totally public places ? Todays LFLs are privately sponsored and sit next to private homes.
4. A 2G SIM with unlimited SMS will be a good start to send messages and capture them in a website to get status of LFLs