**Specifications of Online Database and Raspberry Pi (RPi) Controller Programing**

**Online Database System Overview**

User

RPi Controller

**Internet**

**Internet**

**Online Database Serve**

User

RPi Controller

User

Administrator

RPi Controller

**Internet**

RPi Controllers:

Raspberry Pi 3 is a single-board computer (<https://www.raspberrypi.org/>) and the operation system used for this project is Raspbian Jessie[[1]](#footnote-1) with PIXEL[[2]](#footnote-2). In this project, Raspberry Pi 3 is integrated with sensors and actuators to form a RPi controller, which is used to monitor and control mechanical systems installed in buildings. There will be up to 1000 RPi controllers connected to the online database.

RPi controllers monitor mechanical system operation by measuring various **system operational status**, including temperature, flow, current, pressure, and relay state. Time interval of measurement is usually 10 seconds. However, it may be changed to different values based on application requirements. Measured system operational status is saved to a local file and sent to the online database. RPi controllers may be equipped with a webcam to take pictures of the mechanical system. A real-time picture is token and sent to the online database when it is requested by users or the administrator.

RPi controllers perform an optimization calculation to determine operation schedule of the mechanical system. The optimization is based on system operational status measured by the RPi controller and **optimization input parameters** obtained from the online database. Users and the administrator set values of optimization input parameters. RPi controllers request for optimization input parameters from the online database after sending the system operational status to the online database.

Users:

Users can log into the online database to view/download certain system operational status and change values of certain optimization input parameters. The administrator determines the list of building mechanical systems and specific system operational status and optimization input parameters that are accessible by each user.

Administrator:

Administrator is a superuser with access to all RPi controllers. Administrator can view, download, and change values of all system operational status and optimization input parameters. Administrator can create new user account, edit password, and assign permissions to system operational status and optimization input parameters.

**Data Structure**

The online database needs to store four groups of data (listed below). Each data field has two attributes, user permission and display name. User permission has three options: no permission, view only, and full permission (view and edit). Display name allows the administrator to use names better reflect specific configurations of the mechanical system.

User Management Data (only accessible to the administrator)

|  |  |  |
| --- | --- | --- |
| **Data field** | **Data Type** | **Note** |
| User ID | Integer | “No permission” for users |
| User name | Character | “No permission” for users |
| Password | Character | “No permission” for users |
| List of Building ID accessible to the user | Array of 5 integer data | “No permission” for users Limit user permission to five systems |
| Active or not | Boolean | “No permission” for users |

Mechanical System Configurations

|  |  |  |
| --- | --- | --- |
| **Data field** | **Data Type** | **Note** |
| Building ID | Integer | “No permission” for users |
| Active or not | Boolean | “No permission” for users |
| Building Name | Character | System configuration data, “view only” for users |
| Address | Character | System configuration data, “view only” for users |
| City | Character | System configuration data, “view only” for users |
| Zip code | Integer | System configuration data, “view only” for users |
| Starting Date of Service | Date | System configuration data, “view only” for users |
| Water Heater Brand | Character | System configuration data, “view only” for users |
| Water Heater Capacity | 32-bit floating point | System configuration data, “view only” for users |
| Water Heater Rated Efficiency | 32-bit floating point | System configuration data, “view only” for users |
| Storage Capacity | 32-bit floating point | System configuration data, “view only” for users |

Optimization Input Parameters

|  |  |
| --- | --- |
| **Data field** | **Data Type** |
| 24-hour system demand | Array of 24 data, 32-bit floating point |
| 24-hour electricity price | Array of 24 data, 32-bit floating point |
| 24-hour ambient temperature | Array of 24 data, 32-bit floating point |
| 24-hour solar energy output | Array of 24 data, 32-bit floating point |
| 24-hour demand response scaler | Array of 24 data, 32-bit floating point |
| Request for webcam picture | Boolean |
| Input Variable #1 | 32-bit floating point |
| Input Variable #2 | 32-bit floating point |
| Input Variable #3 | 32-bit floating point |

System Operational Status

**Permission**: Assigned by administrator. True of False. If true, allow users to view and download data. If false, the data field is not visible to users. Default values are provided in the following table.

**Display name**: Assigned by administrator. character. Default values are provided in the following table.

**Unit**: Assigned by administrator. character. Default values are provided in the following table.

**Data Aggregation Method**: Assigned by administrator. The field specifies the method to reduce the number of data point to be displayed.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Data field** | **Data Type** | **Display Name** | **Unit** | **Data Aggregation Method** | **Permission** | **Example Data** |
| Building ID | Integer |  |  |  | False | 12345 |
| Time Stamp | Date and time |  |  | Middle Value | True |  |
| Temperature 1 | Floating point | How Water Supply | DegF | Average | True | 71 |
| Temperature 2 | Floating point | Cold Water Supply | DegF | Average | True | 72 |
| Temperature 3 | Floating point | Ambient | DegF | Average | True | 73 |
| Temperature 4 | Floating point | Water Heater Input | DegF | Average | False | 74 |
| Temperature 5 | Floating point | Water Heater Output | DegF | Average | False | 75 |
| Temperature 6 | Floating point | Tank Input | DegF | Average | False | 76 |
| Temperature 7 | Floating point | Tank Output | DegF | Average | False | 77 |
| Temperature 8 | Floating point | Outdoor | DegF | Average | False | 78 |
| Temperature 9 | Floating point | Evaporator Output | DegF | Average | False | 79 |
| Temperature 10 | Floating point | Pipe Surface 1 | DegF | Average | False | 80 |
| Temperature 11 | Floating point | Pipe Surface 2 | DegF | Average | False | 81 |
| Flow 1 | Floating point | Hot Water Supply | GPM | Average | True | 2.1 |
| Flow 2 | Floating point | Circulation Flow | GPM | Average | False | 2.2 |
| Flow 3 | Floating point | Water Heater Input | GPM | Average | False | 2.3 |
| Flow 4 | Floating point | Tank Input | GPM | Average | False | 2.4 |
| Pressure 1 | Floating point | How Water Supply | PSI | Average | False | 10.1 |
| Pressure 2 | Floating point | Cold Water Supply | PSI | Average | False | 10.2 |
| Pressure 3 | Floating point | Tank Input | PSI | Average | False | 10.3 |
| Current 1 | Floating point | Building Consumption | Amp | Average | True | 5.1 |
| Current 2 | Floating point | Solar Generation | Amp | Average | True | 5.2 |
| Current 3 | Floating point | Water Heater | Amp | Average | True | 5.3 |
| Current 4 | Floating point | Air Conditioner | Amp | Average | True | 5.4 |
| Current 5 |  | Dryer | Amp | Average | False |  |
| Current 6 |  | Pool pump | Amp | Average | False |  |
| Current 7 |  | Plugin Load 1 | Amp | Average | False |  |
| Current 8 |  | Plugin Load 2 | Amp | Average | False |  |
| Current 9 |  | Plugin Load 3 | Amp | Average | False |  |
| Current 10 |  | Plugin Load 4 | Amp | Average | False |  |
| Switch 1 | Boolean | Circulation Pump | No unit | Max | False |  |
| Switch 2 | Boolean | Water Heater Valve | No unit | Max | False |  |
| Switch 3 | Boolean | Tank Valve | No unit | Max | False |  |
| Switch 4 | Boolean | Circulation Valve | No unit | Max | False |  |
| Switch 5 | Boolean | Pool Pump Control 1 | No unit | Max | False |  |
| Switch 6 | Boolean | Pool Pump Control 2 | No unit | Max | False |  |
| Switch 7 | Boolean | Pool Pump Control 3 | No unit | Max | False |  |
| Switch 8 | Boolean | Pool Pump Control 4 | No unit | Max | False |  |
| Switch 9 | Boolean | Recirculation | No unit | Max | False |  |
| Output 1 | Floating point | Water Heater Power Consumption | kWh | Sum | True | 4.1 |
| Output 2 | Floating point | Hot Water Supply Volume | Gallon | Sum | True | 4.2 |
| Output 3 | Floating point | Energy Factor | No unit | Average | True | 4.3 |
| Output 4 | Floating point | Storage Volume | Gallon | Average | False | 4.4 |
| Output 5 | Floating point | Energy Savings | kWh | Sum | True | 4.5 |
| Output 6 | Floating point | Supply From Storage | Gallon | Average | False | 4.6 |
| Output 7 | Floating point | Building energy Consumption | kWh | Sum | True | 4.7 |
| Output 8 | Floating point | Pool Pump energy Consumption | kWh | Sum | True | 4.8 |
| Webcam Image | Image. To preserve memory, up to 20 images are saved and old images are deleted. |  |  |  | True |  |

**Functions of Online Database Server**

The online database server needs to provide the following functions:

* Allow users and the administrator to sign in and sign out
* After successful login, provide a list building names for selection. For user, only show buildings accessible to the user. For the administrator, show the complete list of building ID and name.
* After a building name is selected, provide a list data tables for selection. For users, show three data tables (excluding User Management Table). For administrator, show the list of all four data tables.
* After a data table is selected, retrieve and display data from the database. For user management, system configuration, and optimization input parameter data, present the data in a table.   
  For system operational status data, present data in trend plots. Similar types of data should be presented in the same plot, e.g. all temperature data are presented in the same trend plot. Allow users to select time range and update the trend plots.  
  Allow users to download and saved the data as a CSV file.
* Allow users/administrator to select data field, modify the value, and save the new value into the database.

**RPi Controller Programing**

RPi controllers include programs to achieve the following three functions:

1. Collect measurement data of system operational status
2. Communicate with the online database to send and retrieve data
3. Determine optimal operation schedule

The attached Python program files are for the first function. This project needs to develop Python program to address the second function. Program for the third function will be developed in the second phase of the project.

The second function includes two components: send measured values of system operational status to and retrieve optimization input parameters from the online database. Measured operational status and optimization input parameters should be saved in memory to be used by the optimization program. They should also be saved in a local file. When there is no internet connection, optimization input parameters in the local file will be used to perform optimization calculation.

1. https://www.raspberrypi.org/blog/raspbian-jessie-is-here/ [↑](#footnote-ref-1)
2. (https://www.raspberrypi.org/blog/introducing-pixel/ [↑](#footnote-ref-2)