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| 機器人任務規劃引擎(Task Engine) |
| Version 0.18.06.08 |
| 2018.06.08 |

Table of Contents

[機器人任務規劃引擎(Task Engine) 1](#_Toc520908566)

[*Version 0.18.06.08* 1](#_Toc520908567)

[1. Introduction 3](#_Toc520908568)

[1.1. Overview 3](#_Toc520908569)

[1.2. Glossary 4](#_Toc520908570)

[2. 通訊架構與協定 5](#_Toc520908571)

[2.1. TCP Socket 5](#_Toc520908572)

[2.2. Short Message Peer-to-Peer (SMPP) 6](#_Toc520908573)

[2.2.1. PDU (Protocol Data Unit) Type and Format Definitions 6](#_Toc520908574)

[2.2.2. PDU Format 6](#_Toc520908575)

[2.2.3. PDU Layout 6](#_Toc520908576)

[2.2.4. Session Description 7](#_Toc520908577)

[2.2.5. PDU Definition 8](#_Toc520908578)

[2.3. Parameter Definition 15](#_Toc520908579)

[2.3.1. Command Header Parameters 15](#_Toc520908580)

[2.3.2. Mandatory Parameters 16](#_Toc520908581)

[2.3.3. JSON Format Example 18](#_Toc520908582)

[2.3.4. Advanced JSON Format Example 18](#_Toc520908583)

# Introduction

## Overview

機器人任務規劃引擎(Task Engine，以下簡稱TE)，主要用於接收雲端(Task Composer，以下簡稱TC)之任務進行解譯與排程，並透過ROS(Robot Operating System)中XML/RPC框架下的訂閱(Subscribe)與發佈(Publish)傳送機制，將TC規劃的任務項目依排程之順序與內容，依序的傳送至所屬節點之中，並藉由等候節點回報機制，隨時掌握機器人程序間的活動狀態。同時，TE中包含機器人狀態通報模組，故根據TC希望監控之特定節點，定時的回報該節點之狀態，例如：電池節點定時透過TE回傳：電量、電壓、額定容量等資訊。除此之外，TE具備AGV各節點參數(Config)設定與配置之權限，故TC可透過TE調整AGV各項參數，包括門檻值等。

TC與TE主要之通訊方式為TCP Socket，並遵守Short Message Peer-to-Peer(以下簡稱SMPP)之通訊協定進行行程間的資料傳輸。在此架構中TC為Server，TE則為Client，由TE主動發起各項請求(Request)，包括：連線、任務、裝置狀態、確認連線等請求，而TC則根據不同之請求進行回覆(Response)，並透過一來一回之通訊模式下，確認連線是否正常，排除網路突然瞬斷、封包遺漏、封包不完整等狀況發生，以避免佔用過多網路頻寬及Server記憶體使用異常等現象。除此之外，為解決TC須保持監控機器人之運作狀況與方便TC資料庫蒐集資料，故將任務規劃與機器人狀態通報模組以兩個不同的Port分開傳輸資訊。

## Glossary

|  |  |
| --- | --- |
| **TE** | Task Engine |
| **TC** | Task Composer |
| **ROS** | Robot Operating System |
| **XML** | Extensible Markup Language |
| **RPC** | Remote Procedure Call |
| **TCP** | Transmission Control Protocol |
| **API** | Application Programming Interface |
| **SMPP** | Short Message Peer-to-Peer |
| **PDU** | Protocol Data Unit |
| **HEADER** | Leading portion of the PDU message, common to all PDUs |

# 通訊架構與協定

## TCP Socket

為維持穩定且可靠之傳輸，本系統選擇使用TCP Socket進行資料交換。本系統基於TCP/IP網絡之通訊架構，使用BSD標準規格設計之Socket Library API，處理Server與Client間之連線溝通方式，TCP Socket架構如下圖所示。為解決TC(Server)須隨時監控機器人之運作情形，與方便TC資料庫蒐集機器人回報之狀態資料，故透過分開的兩條連線(Port)進行任務規劃及機器人狀態通報。



## Short Message Peer-to-Peer (SMPP)

本系統遵循SMPP之通訊協定，完成行程間之訊息溝通。本系統主要仿造SMPP之協定資料格式(Protocol Data Unit，以下簡稱PDU)，打造符合實際場域合適之通訊模式，並透過封包一來一回之結構下，確認網路連線狀態是否異常，排出許多突發狀況之發生。以下將介紹本系統基於SMPP通訊協定，所制定之協定資料格式(PDU)。

### PDU (Protocol Data Unit) Type and Format Definitions

|  |  |
| --- | --- |
| **Integer** | An unsigned value with the defined number of octets.  The octets will always be transmitted MSB first **(Big Endian)**. |
| **Octet String** | A series of octets, not necessarily NULL terminated. |
| **Octet String**  **(Decimal)** | A series of ASCII characters, each character representing a decimal digit  (0 - 9) and not necessarily NULL terminated. |
| **Octet String**  **(Hex)** | A series of ASCII characters, each character representing a Hexadecimal digit (0 - F) and terminated with the NULL character. |

### PDU Format

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDU Header | | | | PDU Body |
| Command  Length | Command  Id | Command  Status | Sequence  Number | Mandatory Parameters |
| 4 octets | Length = (Command Length value - 4) Octets | | | |

### PDU Layout

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | PDU Field | Size Octets | Type | Description |
| H  E  A  D  E  R | command length | 4 | Integer | The command length field defines the total octet length of the PDU packet including the length field. |
| command id | 4 | Integer | The command id field identifies the particular PDU.  A unique command identifier is allocated to each request PDU in the range:  **0x00000000 to 0x000000FF**  A unique command identifier is also allocated to each response PDU in the range:  **0x80000000 to 0x800000FF** |
| command status | 4 | Integer | The command status field indicates the success or failure of a request.  It is relevant only in the response PDU and it must contain a NULL value in a request PDU. |
| sequence number | 4 | Integer | This field contains a sequence number which allows requests and responses to be associated for correlation purposes. The use of sequence numbers for message correlation allows PDUs to be exchanged asynchronously.  The sequence number should be increased monotonically for each request PDU and must be preserved in the associated response PDU.  The sequence number may range from:  **0x00000001 to 0x7FFFFFFF** |
| B  O  D  Y | Mandatory Parameters | Var. | mixed | A list of mandatory parameters corresponding to that PDU defined in the command id field. |

### Session Description

A session between a server and a client is initiated by the client first establishing a network connection with the server and then issuing a CMP Bind request to open a session.



CMP Client and CMP Server entire communication process, mainly divided into Bind, Commands, Unbind three parts

### PDU Definition

PDU格式為Header與Body之組合，其中Body之資料格式皆為JSON，字元格式為utf-8，且須於結尾加上‘ \0 ’之結束字元。[(JSON + \0).utf-8]

* **Bind request syntax**：連線請求，用於向Server要求建立通訊通道。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to bind request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated bind response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y | Device’s Mac address | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string | 2.3.2 |

* **Bind response syntax**：回覆連線請求，Server向Client通知通訊通道已建立。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to bind response. | 2.3.1(2) |
| command status | 4 | Integer | Indicates the status of the original request. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to the sequence number of original bind request. | 2.3.1(4) |
| B  O  D  Y |  |  |  |  |  |

* **Unbind request syntax**：連線取消請求，用於向Server要求關閉通訊通道。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to unbind request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated unbind response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y | Device’s Mac address | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string | 2.3.2 |

* **Unbind response syntax**：回覆連線取消請求，Server向Client通知通訊通道已關閉。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to unbind response. | 2.3.1(2) |
| command status | 4 | Integer | Indicates the status of the original request. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to the sequence number of original unbind request. | 2.3.1(4) |
| B  O  D  Y |  |  |  |  |  |

* **Enquire link request syntax**：確認連線請求，當系統經過特定時間未接收到任何的請求與回覆時，自動發送Enquire link確認連線狀態。若無回應時，自動將連線切斷後重新連線。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to enquire link request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated enquire link response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y |  |  |  |  |  |

* **Enquire link response syntax：**確認連線正常，收到確認連線請求封包後，應須盡速回覆此封包，確保通訊通道可繼續維持。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to enquire link response. | 2.3.1(2) |
| command status | 4 | Integer | Indicates the status of the original request. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to the sequence number of original enquire link request. | 2.3.1(4) |
| B  O  D  Y |  |  |  |  |  |

* **Mission request syntax**：任務請求，由裝置(Client)端定時向Server確認是否有任務須執行。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to mission request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated mission response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y | Device’s Mac address | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string | 2.3.2 |

* **Mission response syntax：**回覆任務請求，若有任務時，回覆任務內容，而當無任務時，則回覆空的Body。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to mission response. | 2.3.1(2) |
| command status | 4 | Integer | Indicates the status of the original request. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to the sequence number of original mission request. | 2.3.1(4) |
| B  O  D  Y | mission content | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string  mission / JSON array | 2.3.2 |

Mission (JSON array)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| M  I  S  S  I  O  N | mission id | 4 | String | Each submission’s id | 2.3.2 |
| mission type | 4 | String | Mission’s type | 2.3.2 |
| mission parameter | 4 | String | Mission’s Communicated parameter | 2.3.2 |

* **Mission status request syntax**：任務狀態回報請求，由裝置(Client)端向Server回報任務狀態，若成功，success : true, fail : false, error\_msg：none，若失敗，則success : false, fail : mission type, error\_msg：error message。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to mission status request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated mission status response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y | mission status | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string  success / string  fail / string  error\_msg / string | 2.3.2 |

* **Mission status response syntax：**回覆任務狀態回報。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to mission status response. | 2.3.1(2) |
| command status | 4 | Integer | Indicates the status of the original request. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to the sequence number of original mission status request. | 2.3.1(4) |
| B  O  D  Y |  |  |  |  |  |

* **Robot status request syntax：**機器人診斷資訊回報請求，由裝置(Client)端向Server回報機器人目前的健康狀態，包括：電池健康度(溫度+電壓)、載重、WIFI品質(確定有收到WIFI訊號，並數值確認未異常)、馬達健康度(確認有收到motor\_rotate’s topic)、IMU健康度(確認有收到IMU’s topic)、Laser健康度(確認有收到 Laser’s topic)。["battery", "weight", "wifi\_quality", "motor", "imu", "laser"]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to robot status request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated robot status response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y | robot status | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string  all collect data format: data\* / string | 2.3.2 |

* **Robot status request syntax**：機器人狀態回報請求，由裝置(Client)端向Server回報機器人目前的狀態，包括：電池百分比、電池溫度、馬達轉速、馬達耗電流、偏移量、是否有障礙物、是否碰撞、停留過久、里程數、導航狀態。

["battery\_percent", "battery\_temperature", "motor\_rotate", "motor\_current", "offset", "obstacle", "collision", "long\_time", "odometry", "nav\_status"]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to robot status request. | 2.3.1(2) |
| command status | 4 | Integer | Set to STATUS\_ROK. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to a unique sequence number. The associated robot status response PDU should echo the same sequence number. | 2.3.1(4) |
| B  O  D  Y | robot status | Var. | Octet  String | JSON Data Format.  (data type：key/value)  device\_id / string  all collect data format: data\* / string | 2.3.2 |

* **Robot status response syntax：**回覆機器人狀態回報。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Field Name | Size  octets | Type | Description | Ref. |
| H  E  A  D  E  R | command length | 4 | Integer | Set to overall length of PDU. | 2.3.1(1) |
| command id | 4 | Integer | Value corresponding to robot status response. | 2.3.1(2) |
| command status | 4 | Integer | Indicates the status of the original request. | 2.3.1(3) |
| sequence number | 4 | Integer | Set to the sequence number of original robot status request. | 2.3.1(4) |
| B  O  D  Y |  |  |  |  |  |

## Parameter Definition

### Command Header Parameters

1. Command length

The command length parameter indicates the length in octets of the message. The message header (including the command length field itself), the mandatory parameters and the optional parameters are all considered.

1. Command id

The command id field identifies the type of message the PDU represents. The complete set of Packet Command IDs and their associated values are defined in the following table.

|  |  |
| --- | --- |
| Command ID | Value |
| bind request | 0x00000001 |
| bind response | 0x80000001 |
| unbind request | 0x00000006 |
| unbind response | 0x80000006 |
| Enquire link request | 0x00000015 |
| Enquire link response | 0x80000015 |
| Mission request | 0x00000030 |
| Mission response | 0x80000030 |
| Mission status request | 0x00000031 |
| Mission status response | 0x80000031 |
| Robot diagnosis request | 0x00000040 |
| Robot diagnosis response | 0x80000040 |
| Robot status request | 0x00000041 |
| Robot status response | 0x80000041 |

1. Command status

The command status field of a message response indicates the success or failure of a request. It is relevant only in the response message and should be set to NULL in request messages. The complete set of Error Codes and their associated values are defined in the following table.

|  |  |  |
| --- | --- | --- |
| Error Code | Value | Description |
| STATUS\_ROK | 0x00000000 | No Error |
| STATUS\_RINVMSGLEN | 0x00000001 | Message Length is invalid |
| STATUS\_RINVCMDLEN | 0x00000002 | Command Length is invalid |
| STATUS\_RINVCMDID | 0x00000003 | Invalid Command ID |
| STATUS\_RSYSERR | 0x00000008 | System Error |
| STATUS\_RBINDFAIL | 0x00000010 | Bind Failed |
| STATUS\_RINVBODY | 0x00000040 | Invalid Packet Body Data |
| STATUS\_RINVJSON | 0x00000042 | Invalid JSON Data |

1. Sequence number

A sequence number allows a response PDU to be correlated with a request PDU. The associated response PDU must preserve this field. The allowed sequence number range is from 0x00000001 to 0x7FFFFFFF.

### Mandatory Parameters

1. Device id：裝置的編號，例如：15870。
2. Mission：任務的內容，其中包含：

* mission id：各個子任務的編號，其編號的數字大小代表執行的優先順序(由小至大)。
* mission type：各個子任務的任務類型，詳細之任務種類如下表所示。
* mission parameter：各個子任務類型所需具備的溝通參數，各任務種類對應之溝通參數如下表所示。

|  |  |  |  |
| --- | --- | --- | --- |
| Type | Meaning | Run | Parameter |
| SET | 裝置設定 | ROS node  ‘Setting\*’ | {  ‘speed’:’1’,  ‘retard\_dis’:’3’,  ‘brake\_dis’:’1’,  ‘Waiting\_time’:’10’  } |
| MAP | 建圖 | ROS node  ‘SLAM\*’  ‘Teleop\*’ |  |
| NAV | 導航 | ROS node  ‘Navigation\*’ | [  [x0,y1]  [x1,y1]  [x2,y2]…  [xn,yn]  ] |
| LOC | 近端定位 | ROS node  ‘Location\*’ |  |
| TELP | 手動遙控操作 | ROS node  ‘Teleop\*’ |  |
| MDR | 頂桿 | GPIO API  ‘GPIO\_CL\*’ | [’up’,  ‘down’] |
| CHAG | 自動充電 | ROS node  ‘Charging\*’ | {  ‘time’:’sec’, or  ‘percentage’:’%’,  } |

1. Success：根據任務成功與否，填入true或false之字串。
2. Fail：根據任務成功與否，填入false或失敗的mission type。
3. Error\_msg：根據任務成功與否，填入false或error message。例如：System error。
4. Data\*：填入裝置目前的狀態，包括：電池電量、電壓、電流、溫度、馬達轉速、座標、碰撞狀態、訊號強度等，例如：quantity：80、coordinate：[20,-6.5]、collision：True等。

### JSON Format Example

Mission Example:

{

"device\_id": "150825",

"mission": [

{

"id": "1",

"type": "NAV",

"parameter": '[[-2.65,0.2],[-2.6,0.2],[-2.55,0.2],[-2.5,0.2],'

'[-2.45,0.2],[-2.4,0.2],[-2.35,0.2],[-2.3,0.2],'

'[-2.25,0.2],[-2.2,0.2],[-2.15,0.2],[-2.1,0.2],'

'[-2.05,0.2],[-2,0.2],[-1.95,0.2],[-1.9,0.2]'

},

{

"id": "2",

"type": "MDR",

"parameter": "up "

}

]

}

Mission Example:

{

"device\_id": "150825",

"mission":

{

"quantity": "80",

"voltage": "110",

"current": "11",

"temperature": "20",

"rpm": "80",

"coordinate": "[20, 6.5]",

"collision": "True",

"dBm": "10"

}

}

### Advanced JSON Format Example

基於某些特殊的情境、場域與要求下，使用上述一般的JSON格式無法清楚描述任務的內容與動作，因此本系統支持額外的表達型態，也就是可透過添加邏輯判斷之項目以增強任務內容描述之多樣性。以下將以一個實際例子說明：

{

"device\_id": "150825",

"rule": {

"0": {

"avoidance": "stop",

"battery power": "50"

},

"1":{

"avoidance": "bypass",

"LED": "blue"

},

"2":{

"barcode reader": "true",

"LED": "yellow"

},

"3":{

"LED": "blue",

"exception": "1"

}

},

"mission": [

{

"id": "1",

"rule": "0",

"type": "NAV",

"parameter": "[[-2.65,0.2],[-2.6,0.2],[-2.55,0.2],[-2.5,0.2]..(A->B)",

"next id": "2"

},

{

"id": "2",

"rule": "1",

"type": "LOC",

"parameter": "None",

"next id": "3"

},

{

"id": "3",

"rule": "2",

"type": "MDR",

"parameter": "up",

"next id": "4"

},

{

"id": "4",

"rule": "0",

"type": "NAV",

"parameter": "[-2.45,0.2],[-2.4,0.2],[-2.35,0.2],[-2.3,0.2],..(B->C)",

"next id": "5"

},

{

"id": "5",

"rule": "3",

"type": "MDR",

"parameter": "down",

"next id": "-1"

},

{

"id": "6",

"rule": "0",

"type": "NAV",

"parameter": "[-2.0,0.2],[-2.05,0.2],[-2.1,0.2],[-2.15,0.2],..(C->A)",

"next id": "1"

}

],

"exception": [

{

"from": "1",

"to": "5",

"timer": "3",

"except\_id": "6"

}

]

}

關於此任務包之任務內容(子任務)依序如下：

子任務(1)：由A點移動至B點。

子任務(2)：開啟近端定位功能。

子任務(3)：頂桿舉起。

子任務(4)：由B點移動至C點。

子任務(5)：頂桿放下。

\*註：next id為下一個任務的編號，其中-1為結束任務。

而每項子任務遵循且具備之任務規則如下：

子任務(1)遵守規則0：當碰到障礙物時停下、當電池小於50%時回報Server。

子任務(2)遵守規則1：當碰到障礙物時繞過去、LED亮藍光、當電池小於50%時回報Server。

子任務(3)遵守規則2：需要掃條碼、LED亮黃光、當碰到障礙物時停下、當電池小於50%時回報Server。

子任務(4)遵守規則0：當碰到障礙物時停下、當電池小於50%時回報Server。

子任務(5)遵守規則3：LED亮黃光、例外狀況(1)、當碰到障礙物時停下、當電池小於50%時回報Server。

\*註：規則0為基本規則，所有子任務皆遵守且具備此規則，但若有其他規則與此內容衝突時，則覆蓋基本規則並依循其他描述之規則。

而當任務規則中，具備例外狀況，如：規則3中之"exception": "1"，此時將執行例外編號1之內容，其描述如下：

例外(1)：執行額外子任務(6)，並從子任務(1)至子任務(5)重複做三次。

\*註：例外狀況主要為陳述程式語言中之for迴圈。