Robotic recycling cell high level flow chart

Main entry point

```
┌─────────────────────┐
│   Main entry point   │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│   Initialization of  │
│     systems and      │
│   communications     │
└─────────────────────┘
           │
           ▼
    ╱───────────────╲
   ╱ Select operational╲
   ╲      mode        ╱
    ╲───────────────╱
           │
           ▼
┌─────────────────────┐
│                      │
│   Battery recycling  │
│                      │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│        Done          │
└─────────────────────┘
```
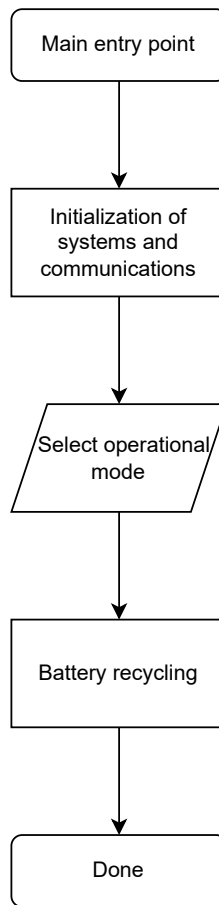
Robotic recycling cell flow chart

Function: Battery recycling

```
┌─────────────────┐
│   Entry point   │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│ Battery pack lid│
│     removal     │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│Battery pack analysis│
└─────────────────┘
         │
         ▼
┌─────────────────┐
│ Swap bad modules│
└─────────────────┘
         │
         ▼
┌─────────────────┐
│  Place missing  │
│     modules     │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│Reinstall battery pack│
│       lid       │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│     Return      │
└─────────────────┘
```
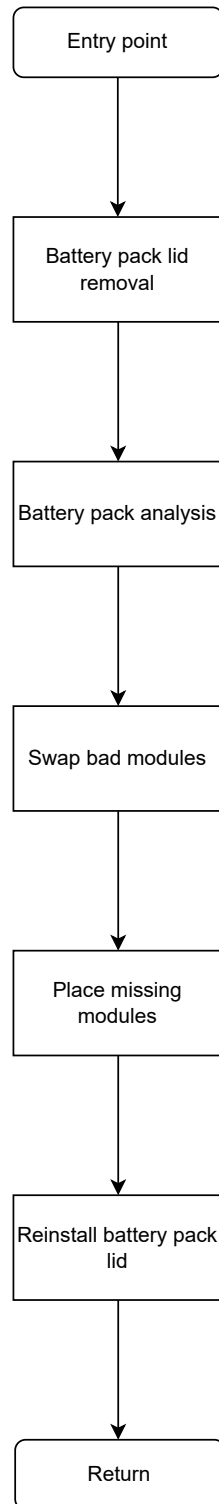
Robotic recycling cell flow chart

Function: Battery pack lid removal

move-J represents a joint move of the TCP

move-L represents a linear move of the TCP

app. is short for approach and reffers to the approach position for a specific target

```
Entry point
     │
     ▼
Robot action
Open gripper
     │
     ▼
Robot move-J
Home
     │
     ▼
Robot move-J
Lid pickup app.
     │
     ▼
Robot move-L
Lid pickup
     │
     ▼
Robot action
Close gripper
     │
     ▼
Robot move-L
Lid pickup app.
```

```
Robot move-J
Lid storage app.
     │
     ▼
Robot move-L
Lid storage
     │
     ▼
Robot action
Open gripper
     │
     ▼
Robot move-L
Lid storage app.
     │
     ▼
Robot move-J
Home
     │
     ▼
Return
```
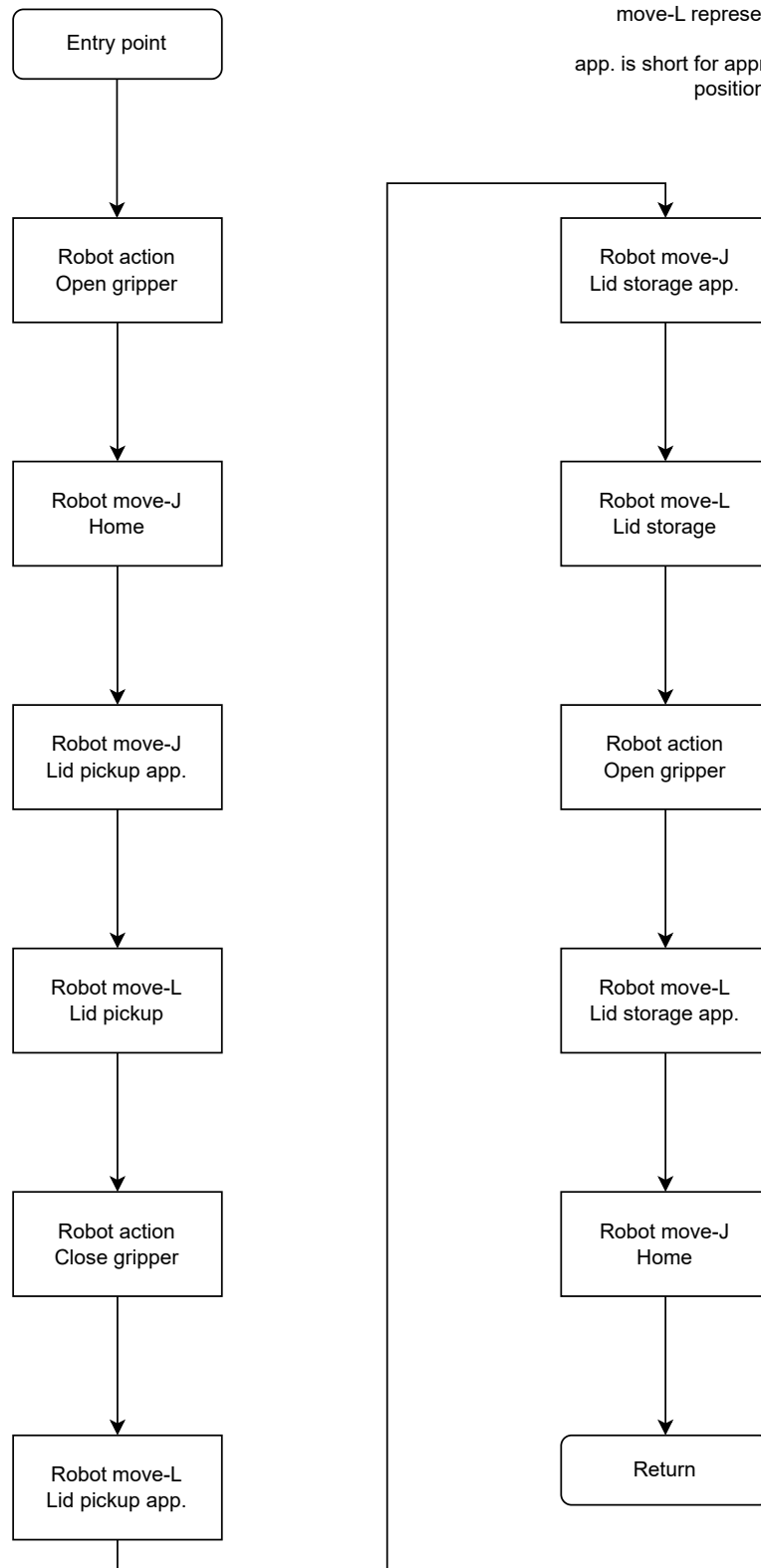
Robotic recycling cell flow chart

Function: Battery pack lid retrieval

move-J represents a joint move of the TCP

move-L represents a linear move of the TCP

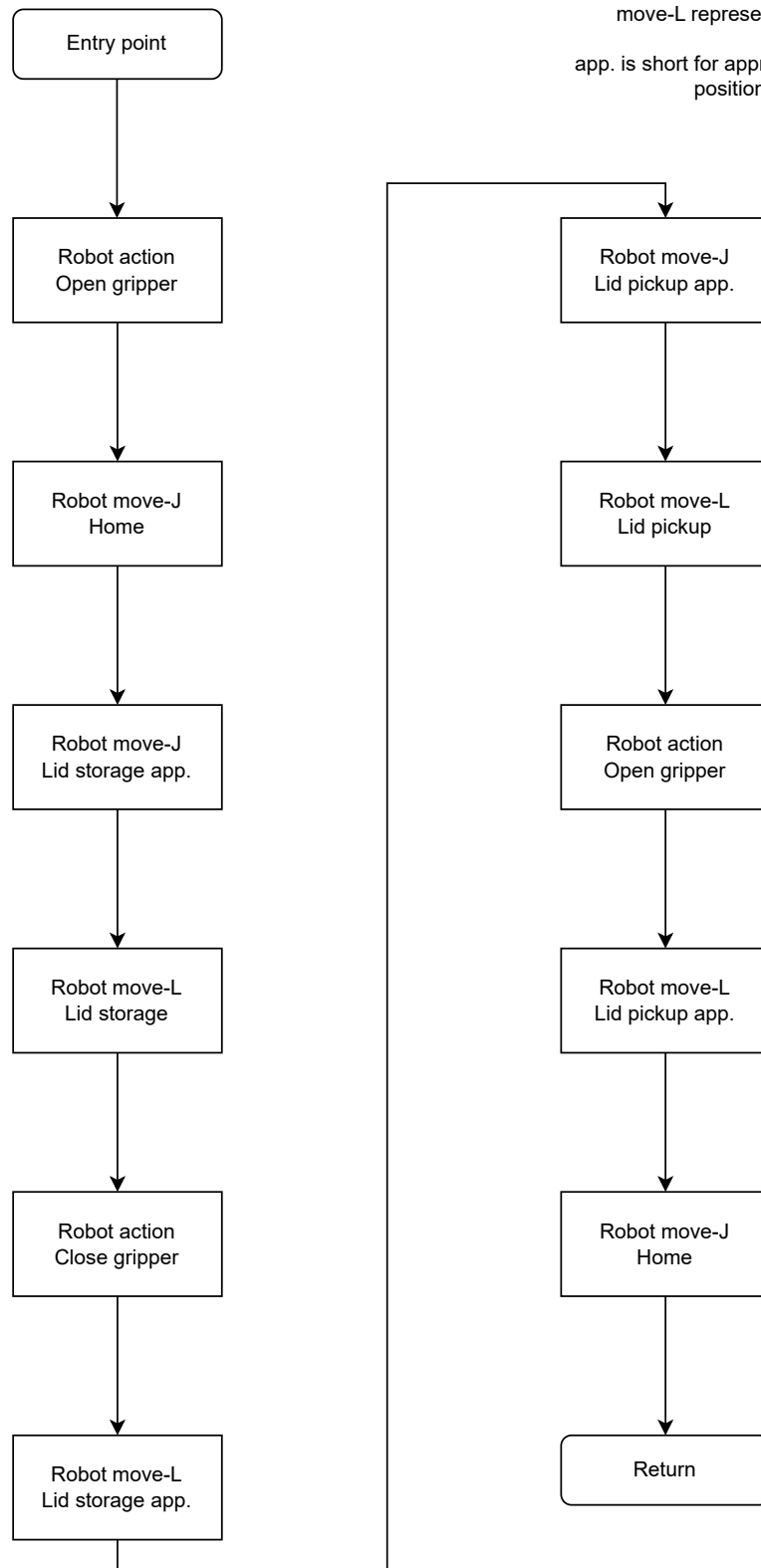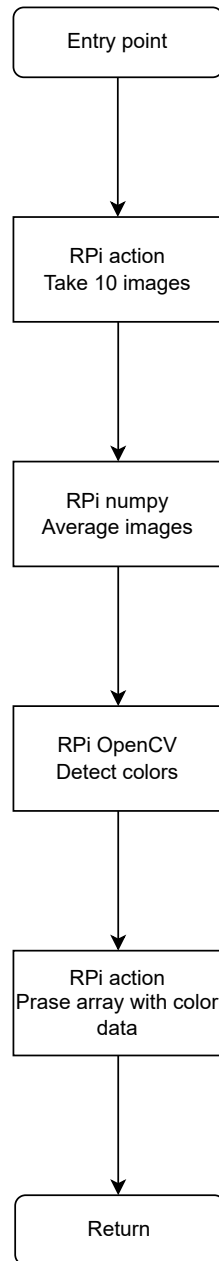app. is short for approach and reffers to the approach position for a specific target

```
                ┌──────────────────┐
                │   Entry point    │
                └──────────────────┘
                         │
                         ▼
                ┌──────────────────┐              ┌──────────────────┐
                │   Robot action   │              │  Robot move-J    │
                │   Open gripper   │              │  Lid pickup app. │
                └──────────────────┘              └──────────────────┘
                         │                                 ▲
                         ▼                                 │
                ┌──────────────────┐              ┌──────────────────┐
                │  Robot move-J    │              │  Robot move-L    │
                │     Home         │              │   Lid pickup     │
                └──────────────────┘              └──────────────────┘
                         │                                 │
                         ▼                                 ▼
                ┌──────────────────┐              ┌──────────────────┐
                │  Robot move-J    │              │  Robot action    │
                │  Lid storage app.│              │  Open gripper    │
                └──────────────────┘              └──────────────────┘
                         │                                 │
                         ▼                                 ▼
                ┌──────────────────┐              ┌──────────────────┐
                │  Robot move-L    │              │  Robot move-L    │
                │   Lid storage    │              │  Lid pickup app. │
                └──────────────────┘              └──────────────────┘
                         │                                 │
                         ▼                                 ▼
                ┌──────────────────┐              ┌──────────────────┐
                │  Robot action    │              │  Robot move-J    │
                │  Close gripper   │              │     Home         │
                └──────────────────┘              └──────────────────┘
                         │                                 │
                         ▼                                 ▼
                ┌──────────────────┐              ┌──────────────────┐
                │  Robot move-L    │              │     Return       │
                │  Lid storage app.│              └──────────────────┘
                └──────────────────┘
```

Robotic recycling cell flow chart

Function: Battery pack analysis

```
┌─────────────────────┐
│     Entry point     │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│     RPi action      │
│   Take 10 images    │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│     RPi numpy       │
│   Average images    │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│    RPi OpenCV       │
│   Detect colors     │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│     RPi action      │
│ Prase array with color│
│        data         │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│       Return        │
└─────────────────────┘
```
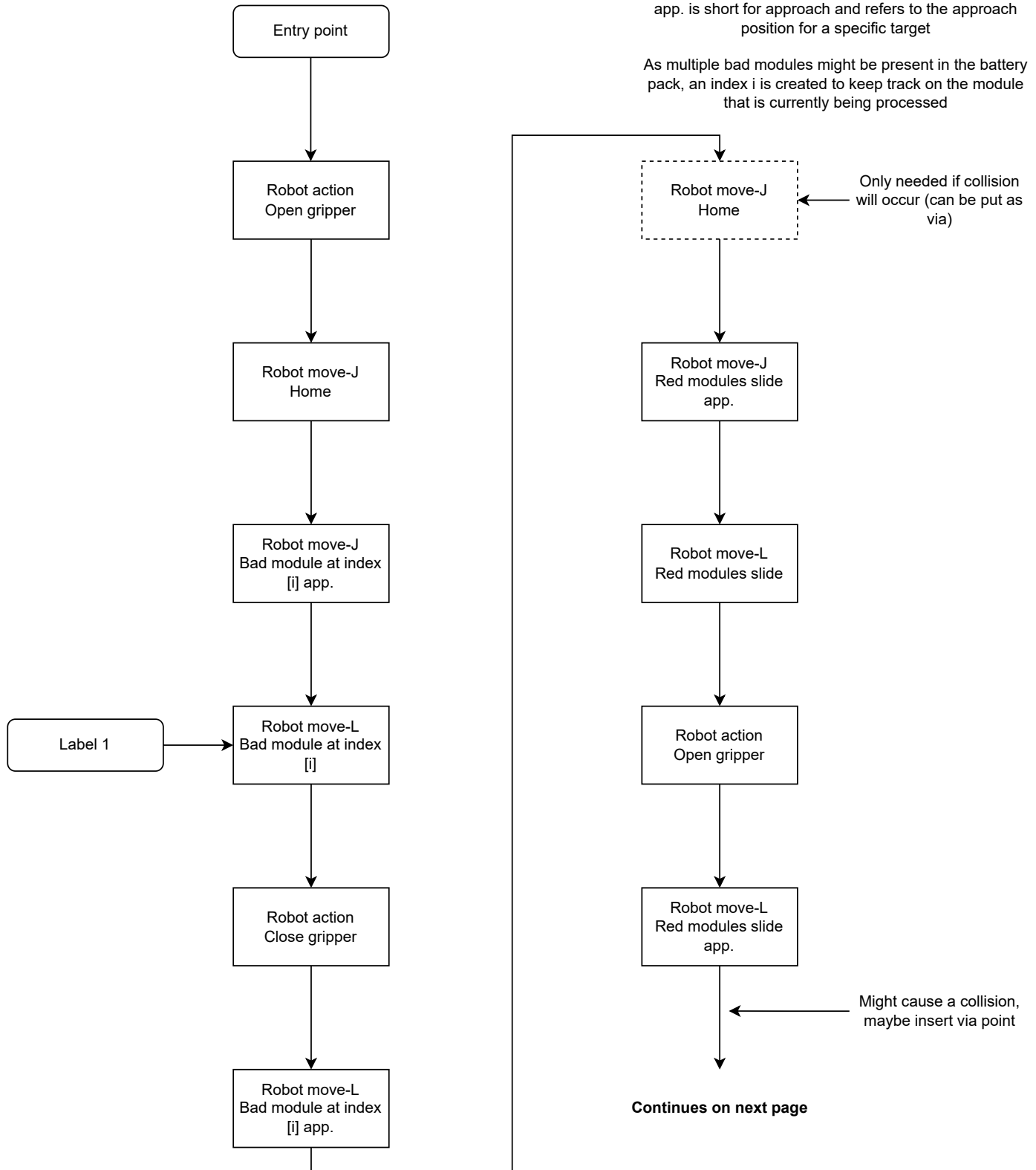
Robotic recycling cell flow chart

Function: Swap bad modules

move-J represents a joint move of the TCP

move-L represents a linear move of the TCP

app. is short for approach and refers to the approach position for a specific target

As multiple bad modules might be present in the battery pack, an index i is created to keep track on the module that is currently being processed

Entry point

Robot action
Open gripper

Robot move-J
Home

Robot move-J
Bad module at index [i] app.

Label 1 → Robot move-L
Bad module at index [i]

Robot action
Close gripper

Robot move-L
Bad module at index [i] app.

Robot move-J
Home

Only needed if collision will occur (can be put as via)

Robot move-J
Red modules slide app.

Robot move-L
Red modules slide

Robot action
Open gripper

Robot move-L
Red modules slide app.

Might cause a collision, maybe insert via point

Continues on next page

Extension from previous page

```
┌─────────────────┐                          ┌─────────────────┐
│   Robot move-J   │                          │   Robot move-L   │
│ Blue modules slide│                         │ Bad module at index│
│      app.        │                          │       [i]        │
└─────────────────┘                          └─────────────────┘
         │                                            │
         ▼                                            ▼
┌─────────────────┐                          ┌─────────────────┐
│   Robot move-L   │                          │   Robot action   │
│ Blue modules slide│                         │   Open gripper   │
│                  │                          │                  │
└─────────────────┘                          └─────────────────┘
         │                                            │
         ▼                                            ▼
┌─────────────────┐                          ┌─────────────────┐
│   Robot action   │                          │   Robot move-L   │
│  Close gripper   │                          │ Bad module at index│
│                  │                          │     [i] app.     │
└─────────────────┘                          └─────────────────┘
         │                                            │
         ▼                                            ▼
┌─────────────────┐                          ◇─────────────────◇                    ▱─────────────────▱
│   Robot move-L   │                          │                  │         No         │                  │
│ Blue modules slide│                        ◇  All bad cells handled? ◇───────────────▶│  index = index +1 │
│      app.        │                          │                  │                    │                  │
└─────────────────┘                          ◇─────────────────◇                    ▱─────────────────▱
         │                                            │                                        │
         ▼                                          Yes                                        ▼
┌─────────────────┐                                  │                          ┌─────────────────┐
│   Robot move-J   │                                  ▼                          │   Robot move-L   │
│      Home        │                          ┌─────────────────┐                │ Bad module at index│
│                  │                          │   Robot move-J   │                │     [i] app.     │
└─────────────────┘                          │      Home        │                └─────────────────┘
         │                                    │                  │                        │
         ▼                                    └─────────────────┘                        ▼
┌─────────────────┐                                  │                          ╭─────────────────╮
│   Robot move-J   │                                  ▼                          │     Jump to      │
│ Bad module at index│                        ╭─────────────────╮                │     Label 1      │
│     [i] app.     │                          │     Return       │                ╰─────────────────╯
└─────────────────┘                          ╰─────────────────╯
```

Robotic recycling cell flow chart

Function: Place missing modules

move-J represents a joint move of the TCP
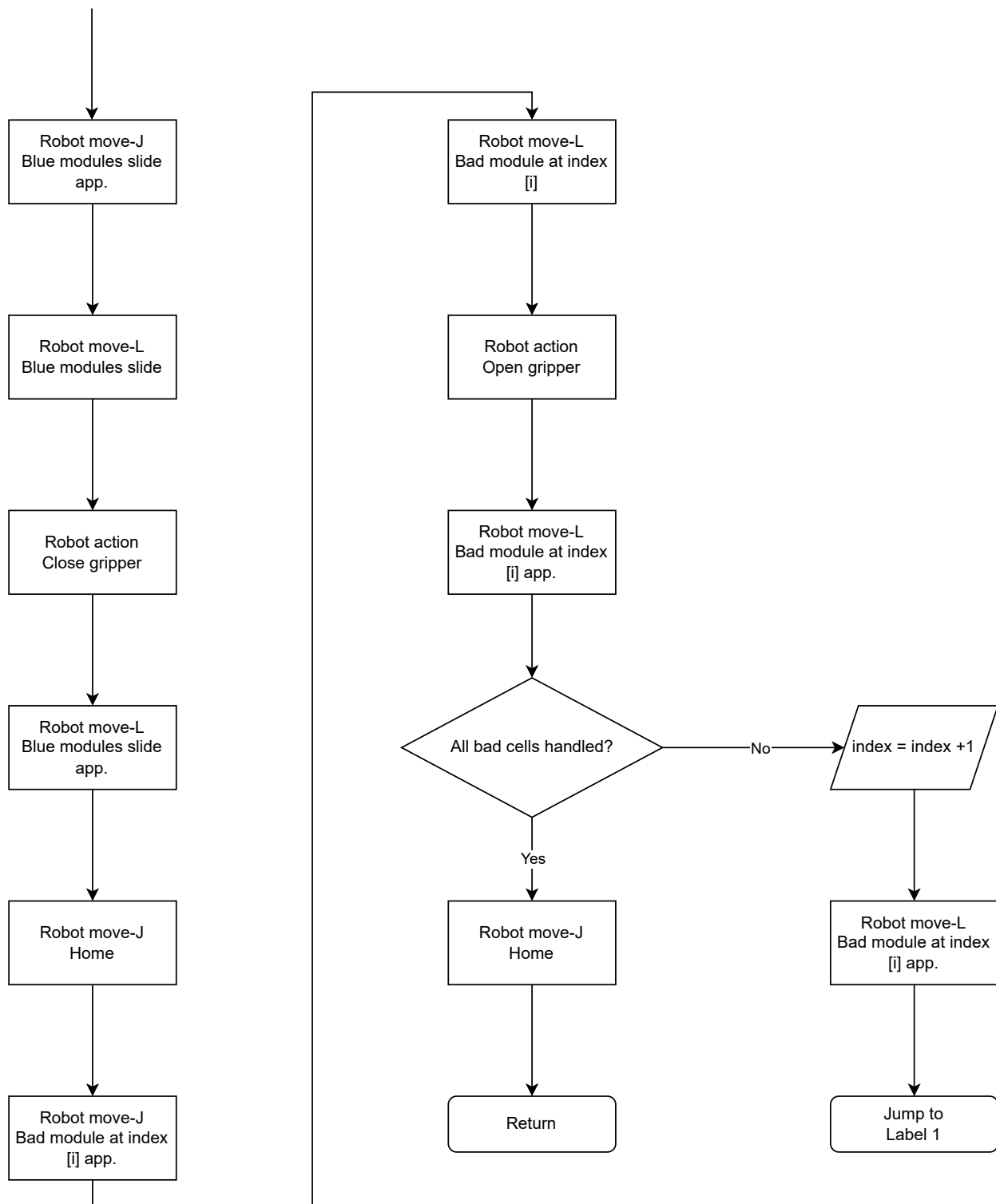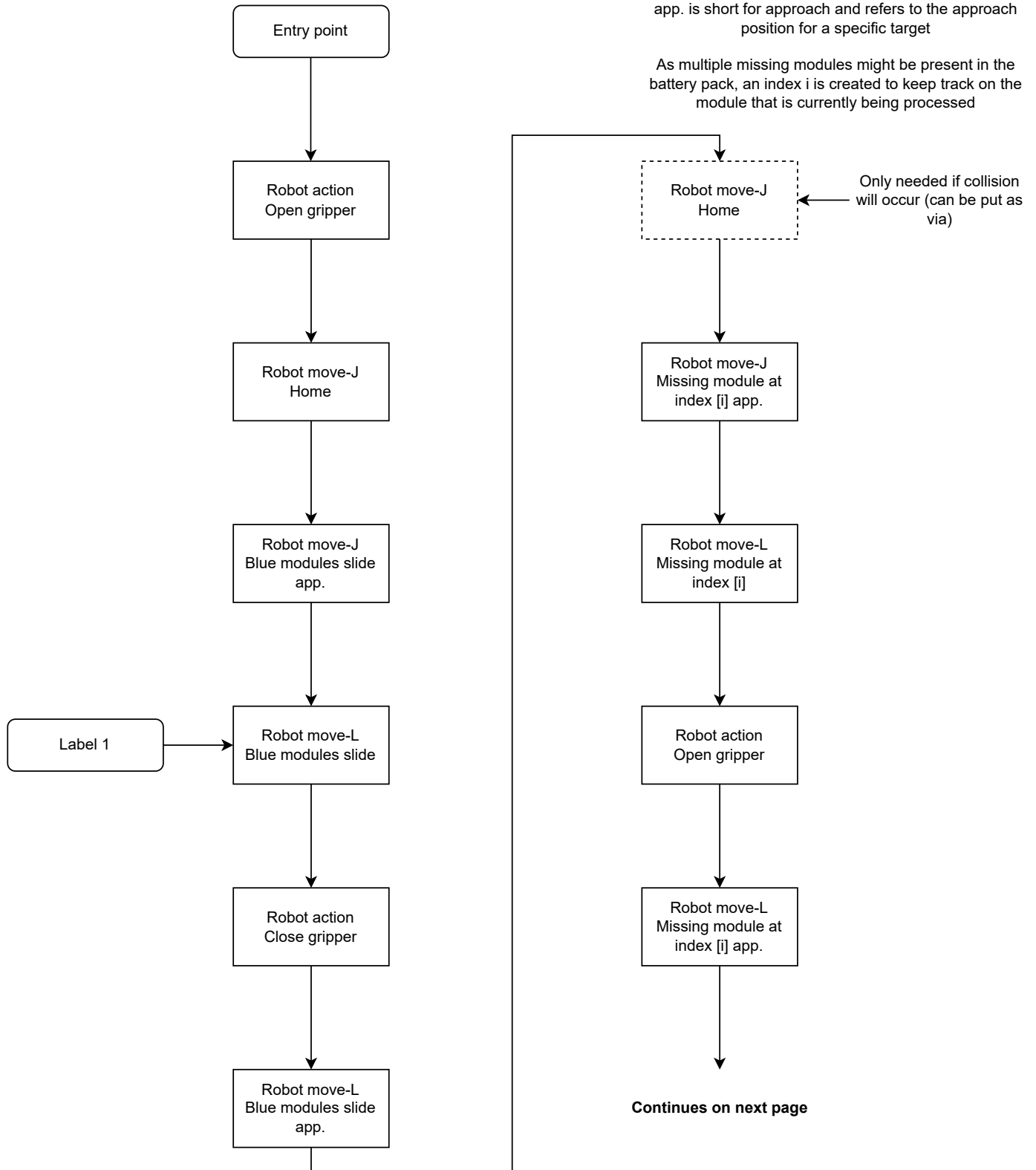
move-L represents a linear move of the TCP

app. is short for approach and refers to the approach position for a specific target

As multiple missing modules might be present in the battery pack, an index i is created to keep track on the module that is currently being processed

```
Entry point
    │
    ▼
Robot action
Open gripper
    │
    ▼
Robot move-J
Home
    │
    ▼
Robot move-J
Blue modules slide
app.
    │
    ▼
Label 1 ──────▶ Robot move-L
Blue modules slide
    │
    ▼
Robot action
Close gripper
    │
    ▼
Robot move-L
Blue modules slide
app.
```

```
Robot move-J      ◀──  Only needed if collision
Home                    will occur (can be put as
    │                   via)
    ▼
Robot move-J
Missing module at
index [i] app.
    │
    ▼
Robot move-L
Missing module at
index [i]
    │
    ▼
Robot action
Open gripper
    │
    ▼
Robot move-L
Missing module at
index [i] app.
    │
    ▼
```

Continues on next page

Extension from previous page

All missing cells handled? ──No──→ index = index +1

Yes

Robot move-J
Home

Robot move-J
Blue modules slide
app. ←── Might cause a collision,
maybe insert via point

Return

Jump to
Label 1