REPLICATOR

SYMBRION

Fault Tolerant Morphogenesis

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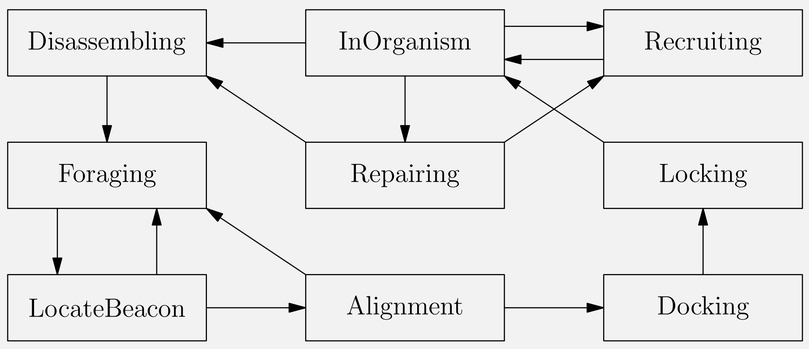
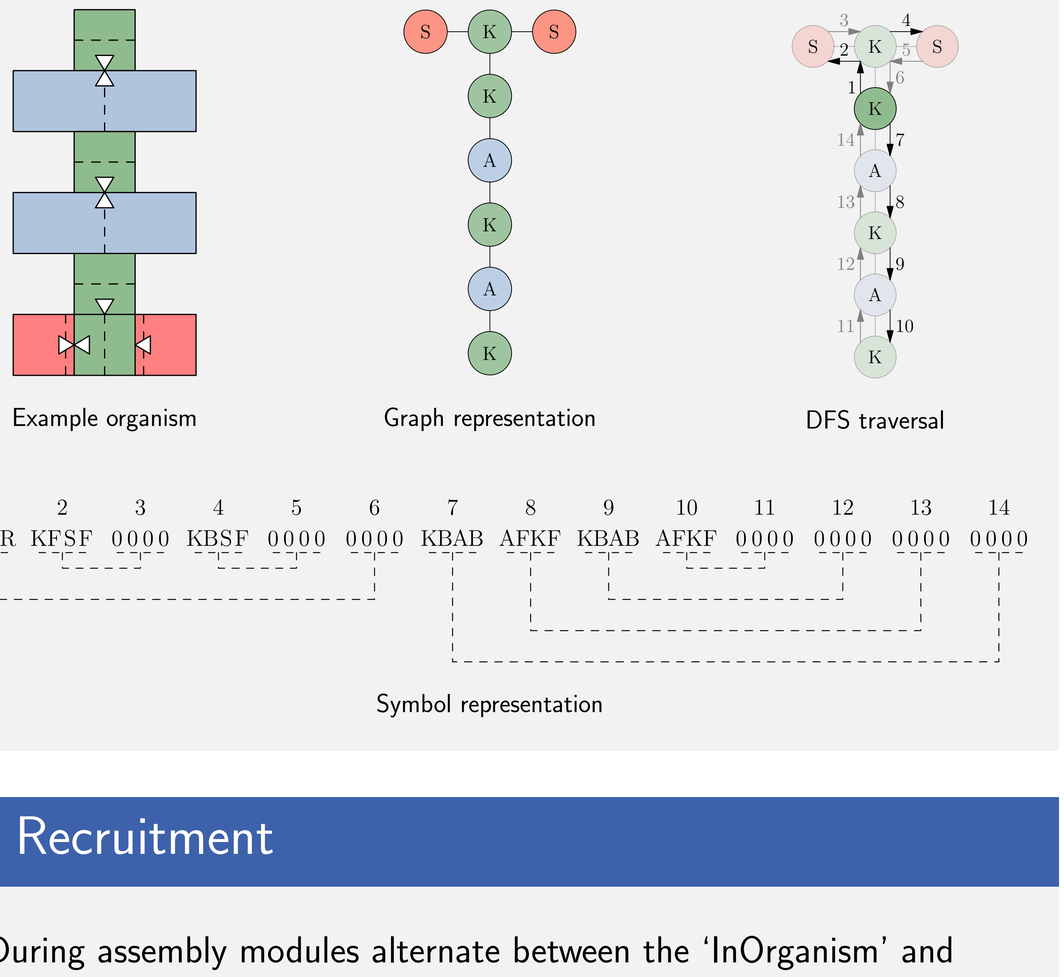
1) Introduction

We present a *morphogenesis* controller for the self-assembly of heterogeneous artificial robot organisms. Fault tolerance is provided through a 'self-repair' mechanism which allows the system to isolate and remove failed modules before continuing to assemble the remainder of the organism structure in the most efficient manner.



2) Organism Representation

Organisms may be visualised using a graph representation. Organism shapes are stored internally as symbol sequences, which are generated from a depth first search traversal of their corresponding graph.



Example organism | Graph representation | DFS traversal

Symbol representation

3) Recruitment

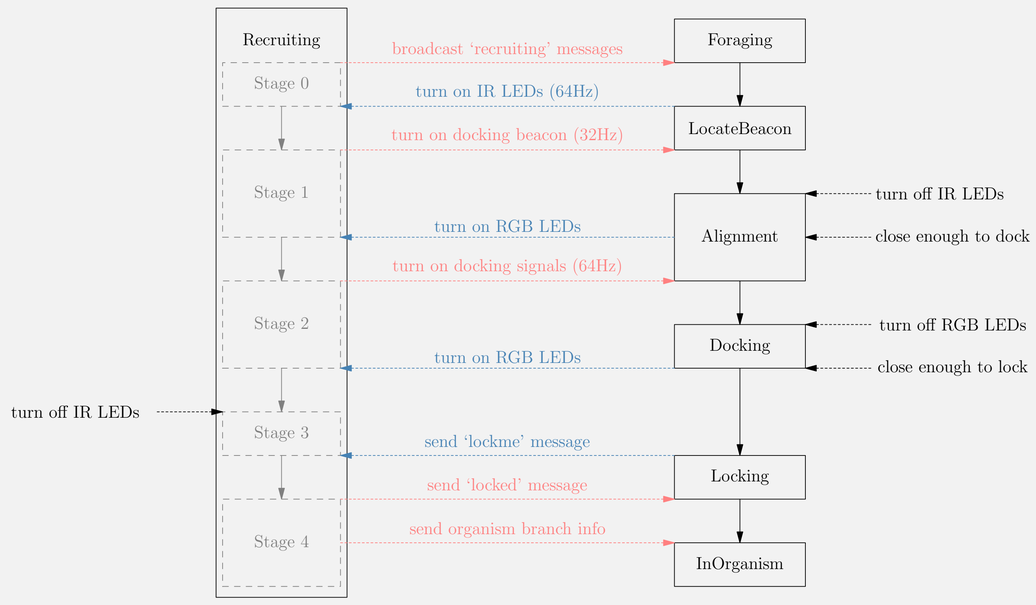
During assembly modules alternate between the 'InOrganism' and 'Recruiting' states until the formation of the organism is complete.

```
void Robot::InOrganism()
{
    if(!my_branches().empty())
    {
        enable_beacon_signal(recruiting_side);
        current_state = RECRUITING;
    }
}

void Robot::Recruiting()
{
    if( recruiting_done )
        current_state = INORGANISM;
    else if(new_robot_docked)
    {
        send_branch_info(recruiting_side);
        my_branches().remove_branch(recruiting_side);
        disable_beacon_signal(recruiting_side);
    }
    else if( current_time % RECRUITMENT_SIGNAL_INTERVAL)
        broadcast_recruitment_msg(recruitment_channel);
}
```

4) Alignment and Docking Protocol

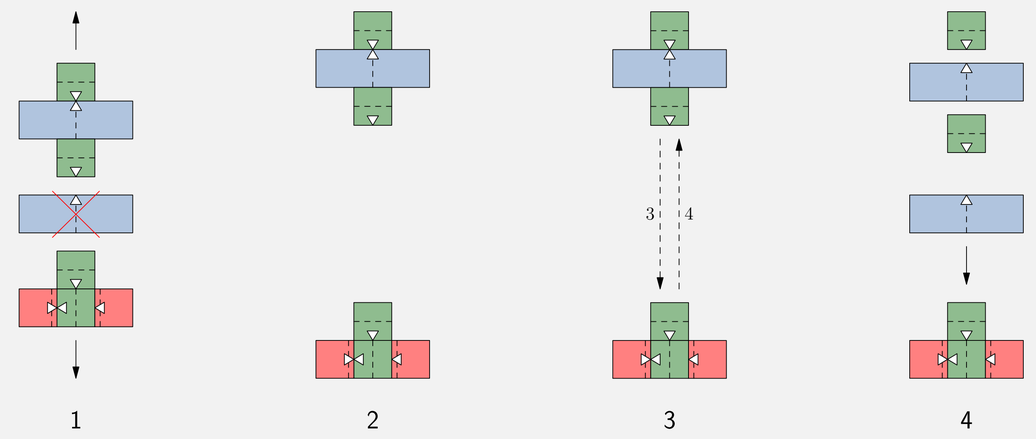
The implementation of the alignment and docking protocol on the SYMBRION robots makes use of the full range of infrared devices.



5) Self-repair

The self-repair strategy can be split into four stages:

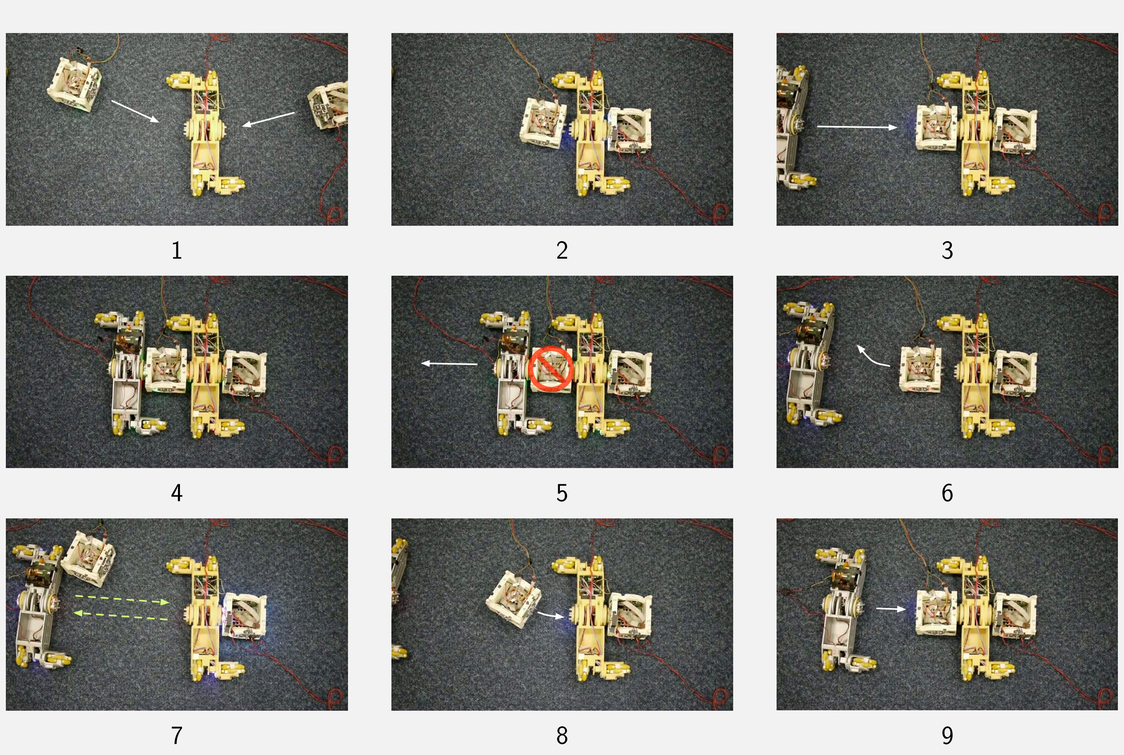
1. Upon detection of a failed module the organism is split into sub-organisms
2. Through local communication each sub-organism determines its shape and assigns itself a score based upon how similar it is to the target organism shape
3. Sub-organisms broadcast their own score and listen for the scores of other sub-organisms
4. The sub-organism with the largest score restarts assembly whilst the others enter disassembly



1 | 2 | 3 | 4

7) Implementation on SYMBRION robots

Our approach has been demonstrated using SYMBRION robots.



1 | 2 | 3
4 | 5 | 6
7 | 8 | 9