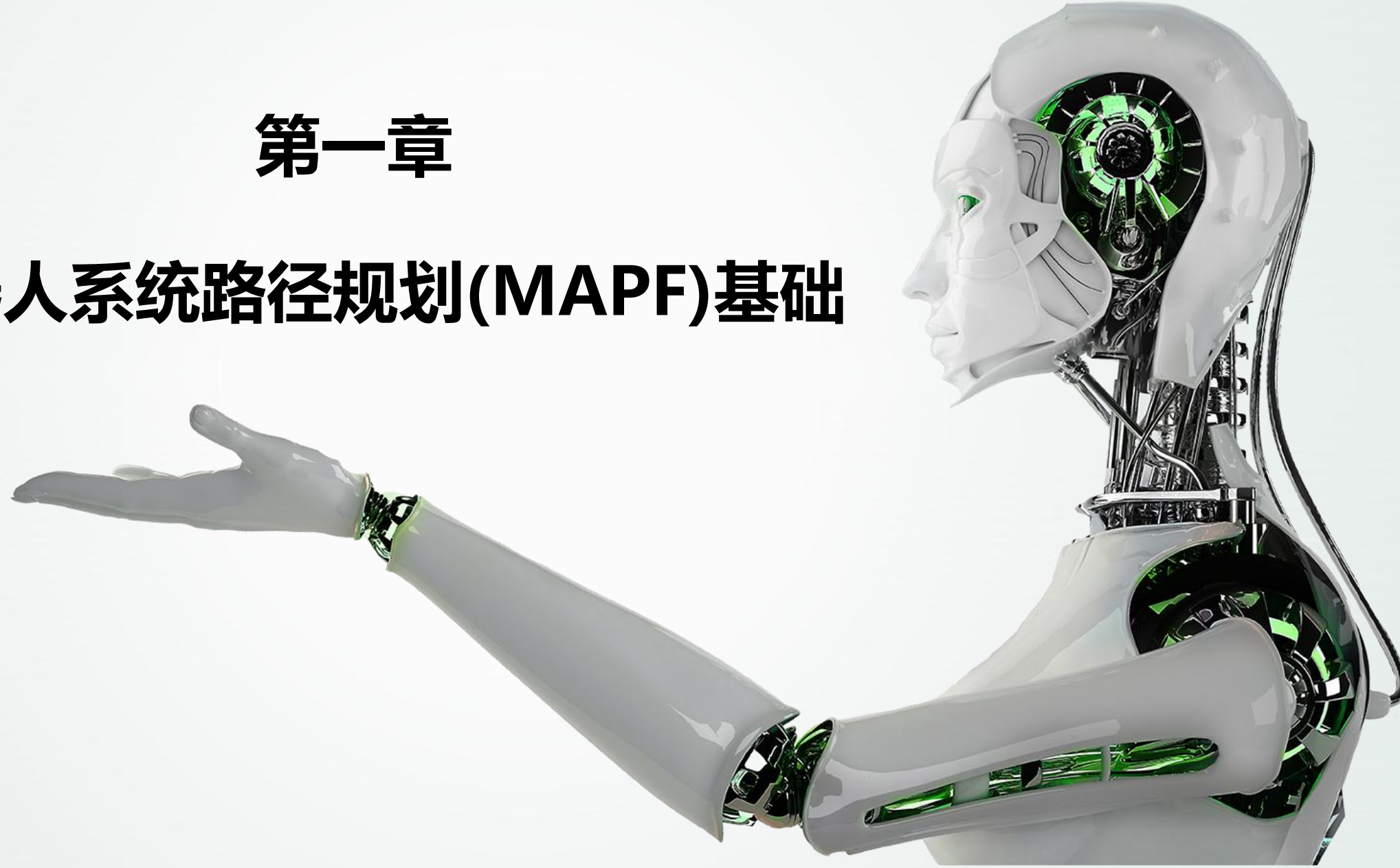
第一章

多机器人系统路径规划(MAPF)基础



课程说明

1. 课程目标
2. 课时安排（直播课之后已经调整）

章节	讲授时长	作业建议时长
一章 MAPF基础	15-20min	-
二章 VRP算法	15-20min	60min
三章 全局规划基础	90-120min	120min
四章 设计全局算法	90-120min	60min
五章 局部优化-避障	90-120min	120min
六章 主动避障	120-180min	120min
七章 CBS	120-180min	240min
八章 仓储案例	120-180min	240min
九章 足球机器人案例	120min	240min
十章 IoT仓储案例	120min-180min	-

课程说明

3.讲授风格： 尽量把学术性的东西转化成朴素的话来说

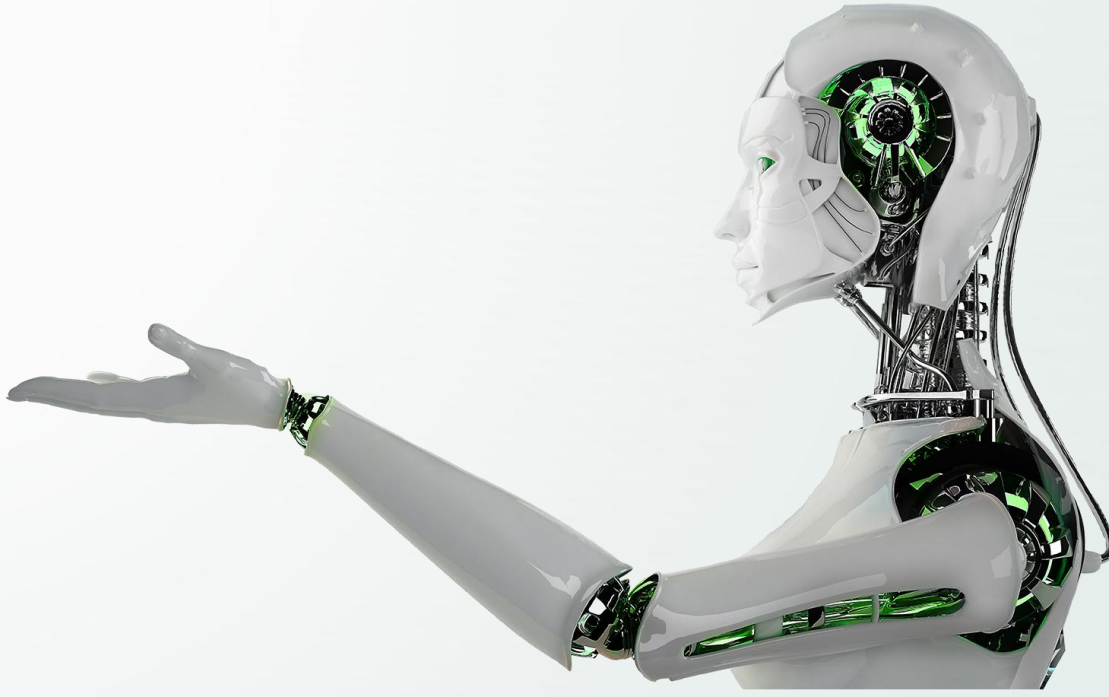
4. 工程or学术？

5. 关于作业

第一章　多机器人系统路径规划(MAPF)基础

1. MAPF是什么
2. MAPF解决什么问题
3. MAPF两个核心问题
4. MAPF 的应用场景

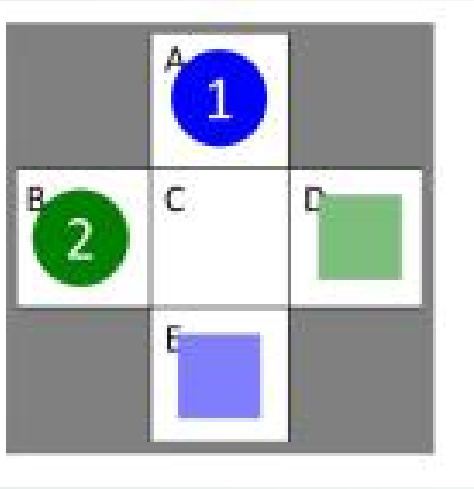
本章建议学习时长：15min



1. MAPF是什么

The MAPF problem can be described as follows: On math paper, some cells are blocked. The blocked cells and the current cells of n agents are known. A different unblocked cell is assigned to each agent as its goal cell.

The problem is to move the agents from their current cells to their respective goal cells in discrete time steps and let them wait there. The optimization objective is
to minimize the sum of the travel times of the agents until they reach their goal cells



1. MAPF是什么

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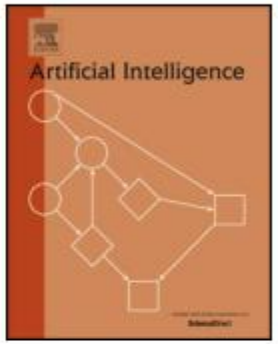


Conflict-based search for optimal multi-agent pathfinding

Guni Sharon [a,*], Roni Stern [a], Ariel Felner [a], Nathan R. Sturtevant [b]

[a] Information Systems Engineering, Ben Gurion University, Be'er Sheba, 85104, Israel
[b] Department of Computer Science, University of Denver, Denver, CO, USA

1. MAPF是什么

移动信息

位置信息

2.1. Problem input

The *input* to the *multi-agent pathfinding problem* (MAPF) is:

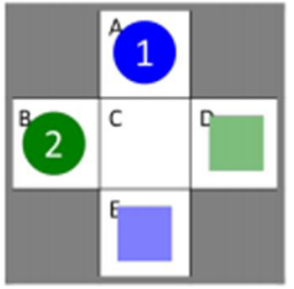
(1) A directed graph $G(V, E)$. The vertices of the graph are possible locations for the agents, and the edges are the possible transitions between locations.

(2) k agents labeled $a_1, a_2 \ldots a_k$. Every agent a_i has a start vertex $start_i \in V$ and a goal vertex, $goal_i \in V$.

Time is discretized into time points. At time point t_0 agent a_i is located in location $start_i$.

初始位置

目标位置



2.2. Actions

Between successive time points, each agent can perform a *move* action to a neighboring vertex or a *wait* action to stay idle at its current vertex. There are a number of ways to deal with the possibility of a chain of agents that are *following* each other in a given time step. This may not be allowed, may only be allowed if the first agent of the chain moves to an unoccupied location or it may be allowed even in a cyclic chain which does not include any empty location. Our algorithm is applicable across all these variations.

移动

等待

1. MAPF是什么

一个点位同一时间最多
只能被一个机器人占据

2.3. MAPF constraints

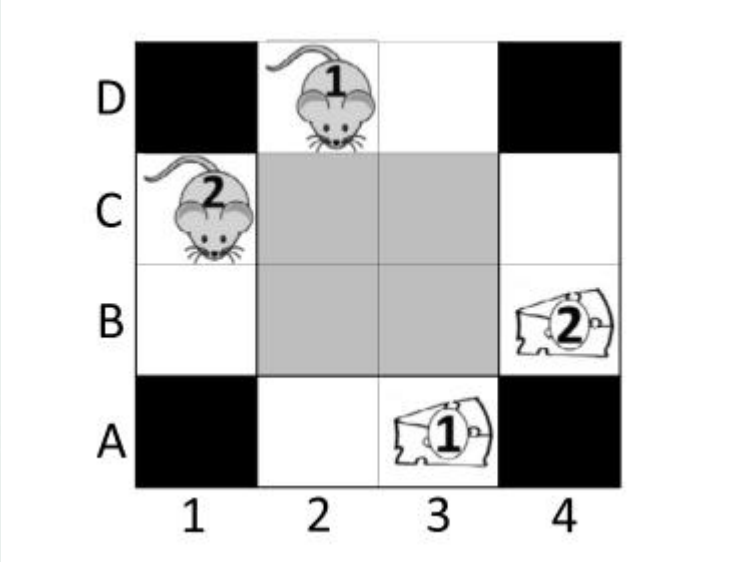
The main constraint in MAPF is that each vertex can be occupied by at most one agent at a given time. There can also be a constrain disallowing more than one agent to traverse the same edge between successive time steps. A *conflict* is a case where a constraint is violated.

2.4. MAPF task

A solution to the MAPF problem is a set of non-conflicting paths, one for each agent, where a path for agent a_i is a sequence of {*move*, *wait*} actions such that if a_i performs this sequence of actions starting from $start_i$, it will end up in $goal_i$.

无冲突路径

1. MAPF是什么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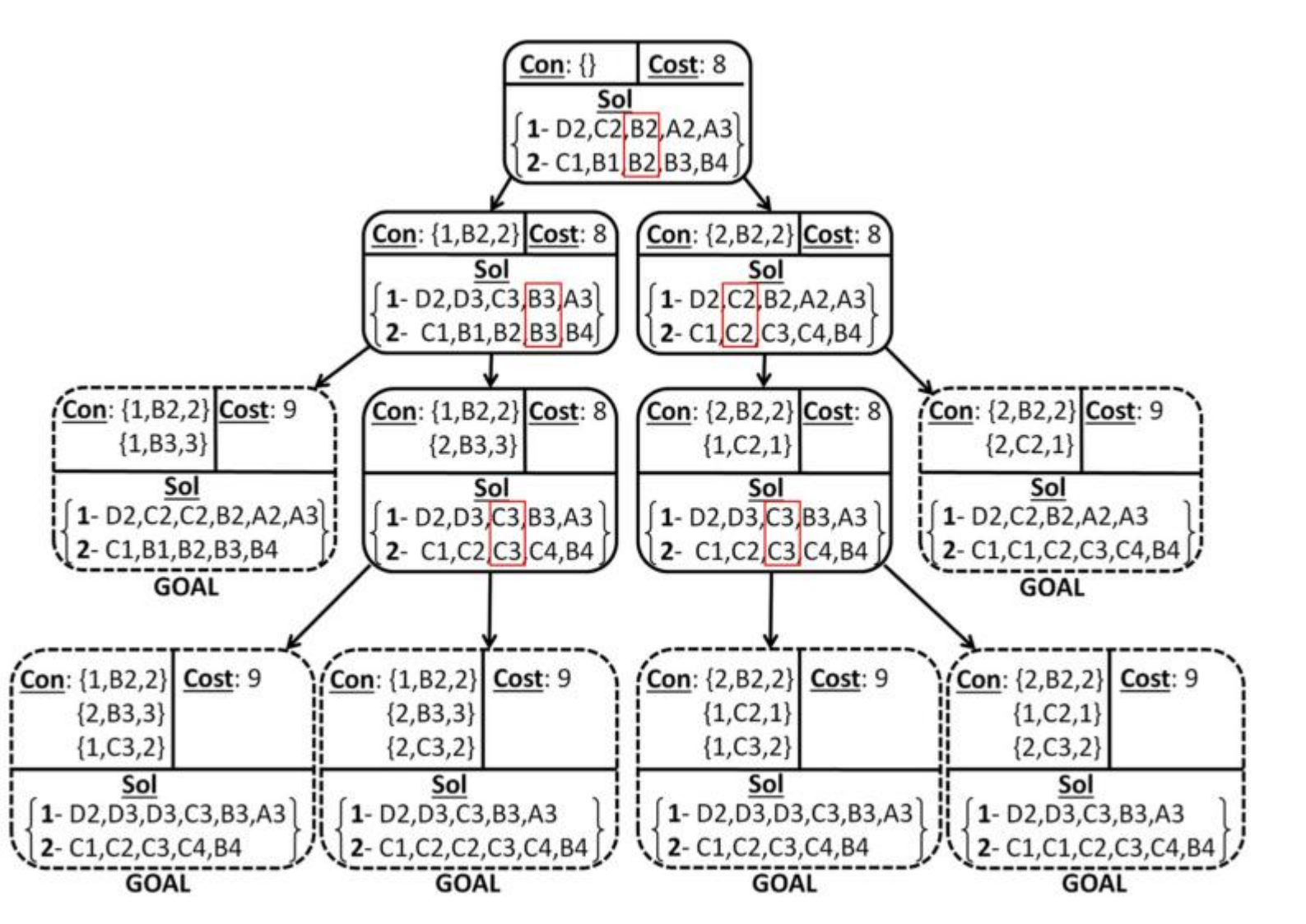
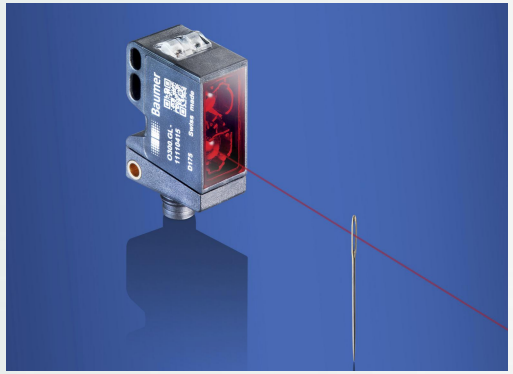

Con: {} Cost: 8
Sol
1- D2,C2,B2,A2,A3
2- C1,B1,B2,B3,B4
Con: {1,B2,2} Cost: 8
Sol
1- D2,D3,C3,B3,A3
2- C1,B1,B2,B3,B4
Con: {2,B2,2} Cost: 8
Sol
1- D2,C2,B2,A2,A3
2- C1,C2,C3,C4,B4
Con: {1,B2,2} {1,B3,3} Cost: 9
Sol
1- D2,C2,C2,B2,A2,A3
2- C1,B1,B2,B3,B4
GOAL
Con: {1,B2,2} {2,B3,3} Cost: 8
Sol
1- D2,D3,C3,B3,A3
2- C1,C2,C3,C4,B4
Con: {2,B2,2} {1,C2,1} Cost: 8
Sol
1- D2,D3,C3,B3,A3
2- C1,C2,C3,C4,B4
Con: {2,B2,2} {2,C2,1} Cost: 9
Sol
1- D2,C2,B2,A2,A3
2- C1,C1,C2,C3,C4,B4
GOAL
Con: {1,B2,2} {2,B3,3} {1,C3,2} Cost: 9
Sol
1- D2,D3,D3,C3,B3,A3
2- C1,C2,C3,C4,B4
GOAL
Con: {1,B2,2} {2,B3,3} {2,C3,2} Cost: 9
Sol
1- D2,D3,C3,B3,A3
2- C1,C2,C2,C3,C4,B4
GOAL
Con: {2,B2,2} {1,C2,1} {1,C3,2} Cost: 9
Sol
1- D2,D3,D3,C3,B3,A3
2- C1,C2,C3,C4,B4
GOAL
Con: {2,B2,2} {1,C2,1} {2,C3,2} Cost: 9
Sol
1- D2,D3,C3,B3,A3
2- C1,C1,C2,C3,C4,B4
GOAL

2. MAPF解决什么问题

主要解决的是局部路径的冲突问题。
传感器能解决的最多就是不撞，但是能提前优化路径让他避免或者减少冲突的概率不是更好吗？这就是MAPF最重要的作用



对移动机器人而言，传感器确实非常重要。但是过度重视传感器的作用会导致两个非常严重的问题：一是追求更高精度意味着更高的硬件成本，特别是激光传感器；二是重硬件轻软件导致算法跟不上。

2. MAPF解决什么问题

部分学员比较关心的MAPF和任务分配/调度的关系

一般认为是相关的两个阶段，先分配任务，再规划路径。这个是比较常用的。

其实完全可以做成JIT的，更高效。

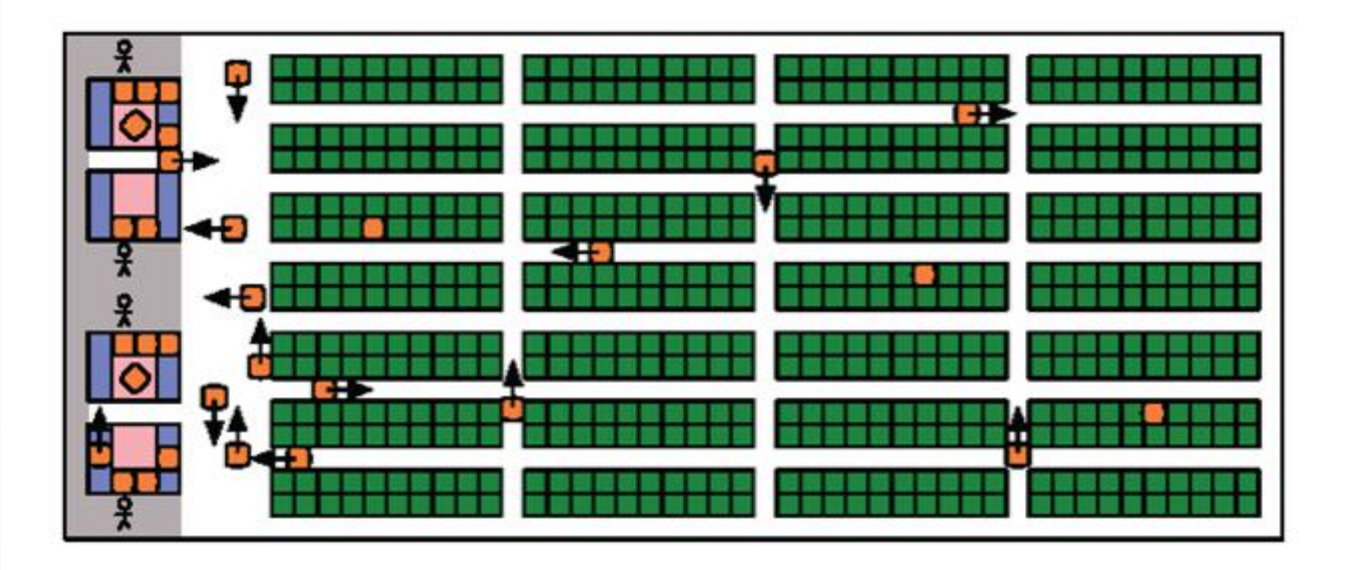
目前我在写的一篇文章就是这样的，具体思路就是订单聚类，分批任务调度，每一批调度完立刻规划路径，这样的话就实现了错位的融合调度和规划。细节就不说了，因为还没有发表。

3. MAPF两个核心问题

两大核心问题：全局路径规划

局部路径优化

最难的部分在于局部路径的优化



3. MAPF两个核心问题

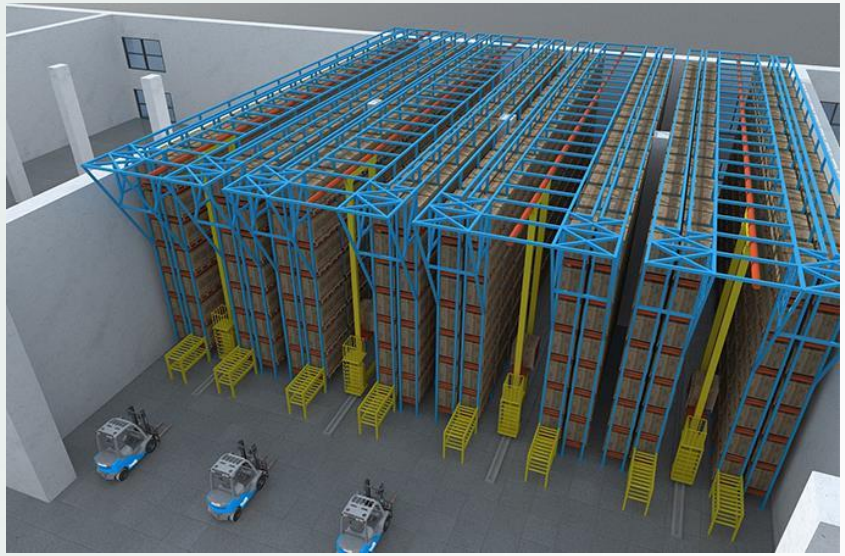
MAPF和多机器人系统路径规划的关系-理论到工程的转化

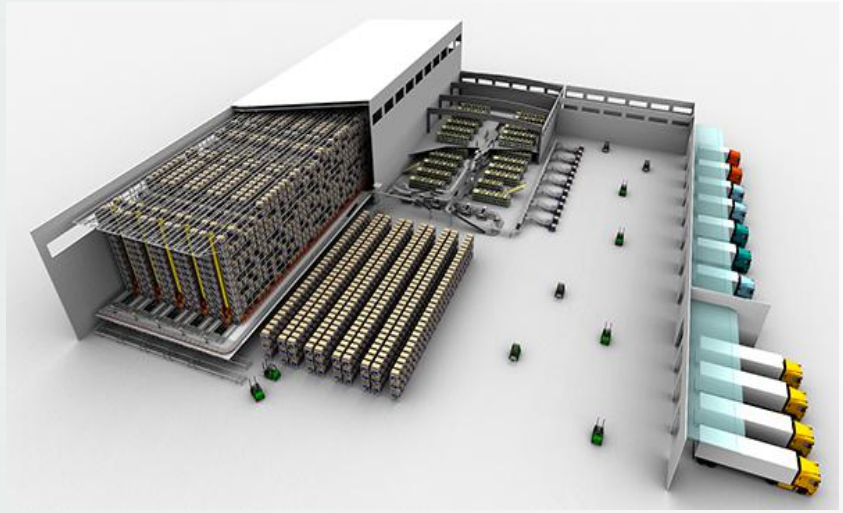
主要是删除理想化的约束

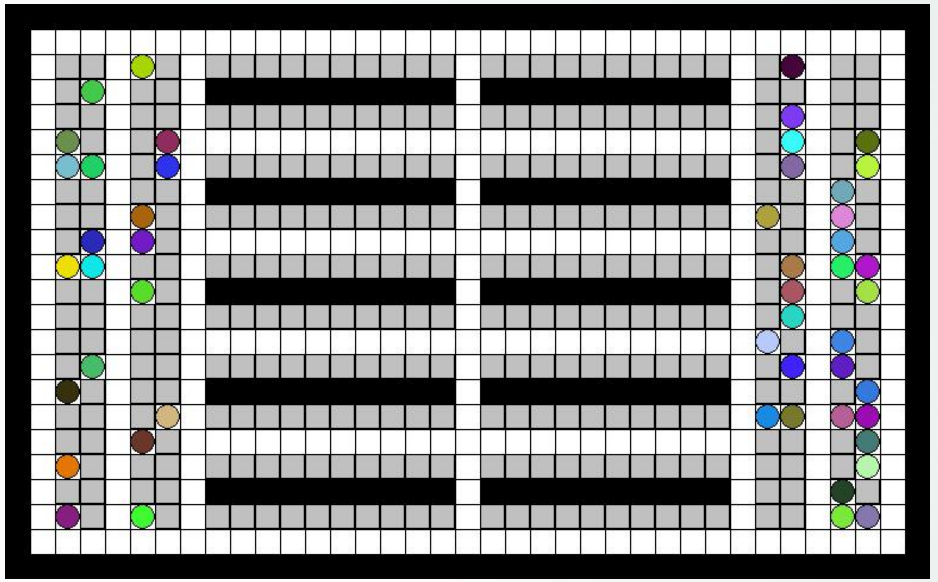
在学术研究中，很多理想化假设和约束是为了方便实验，但这在工程上是行不通的。工程中需要考虑到各种状况，例如行进中突然宕机的伙伴，在线动态调度突然变成离线无法通信，环境中突然闯入的人等等。

多机器人路径规划是MAPF的一个实用案例，MAPF是多机器人路径规划的理论基础。是一个由理论到实践的过程。

4. MAPF应用场景

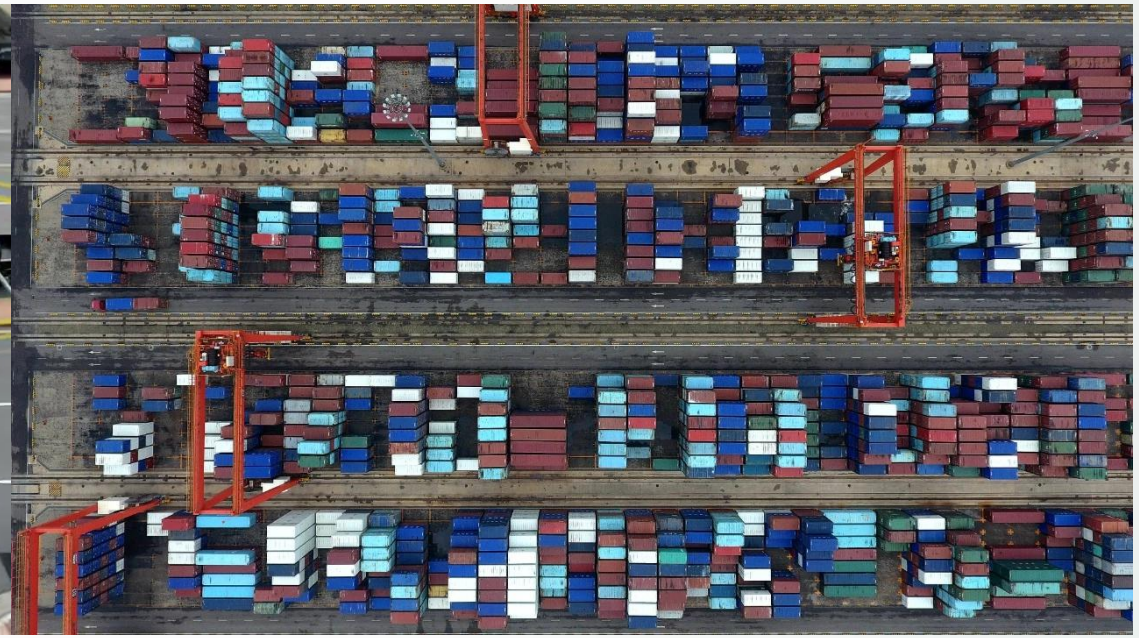






仓储系统

4. MAPF应用场景



本章作业

阅读一二章参考文献压缩包中的综述类文章

第二章

车辆路径规划（VRP）算法

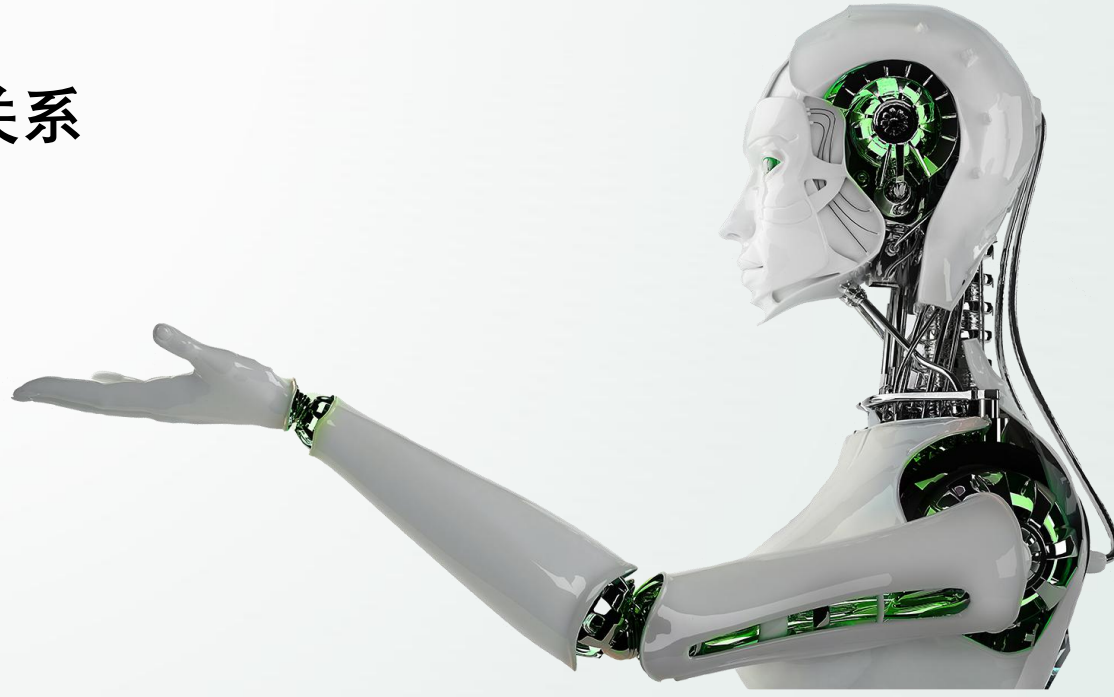
第二章　车辆路径规划（VRP）算法

1. VRP问题简述

2. 经典VRP算法-A*

3. MAPF与多车VRP的关系

本章建议学习时长：20min-30min



1. VRP问题简述

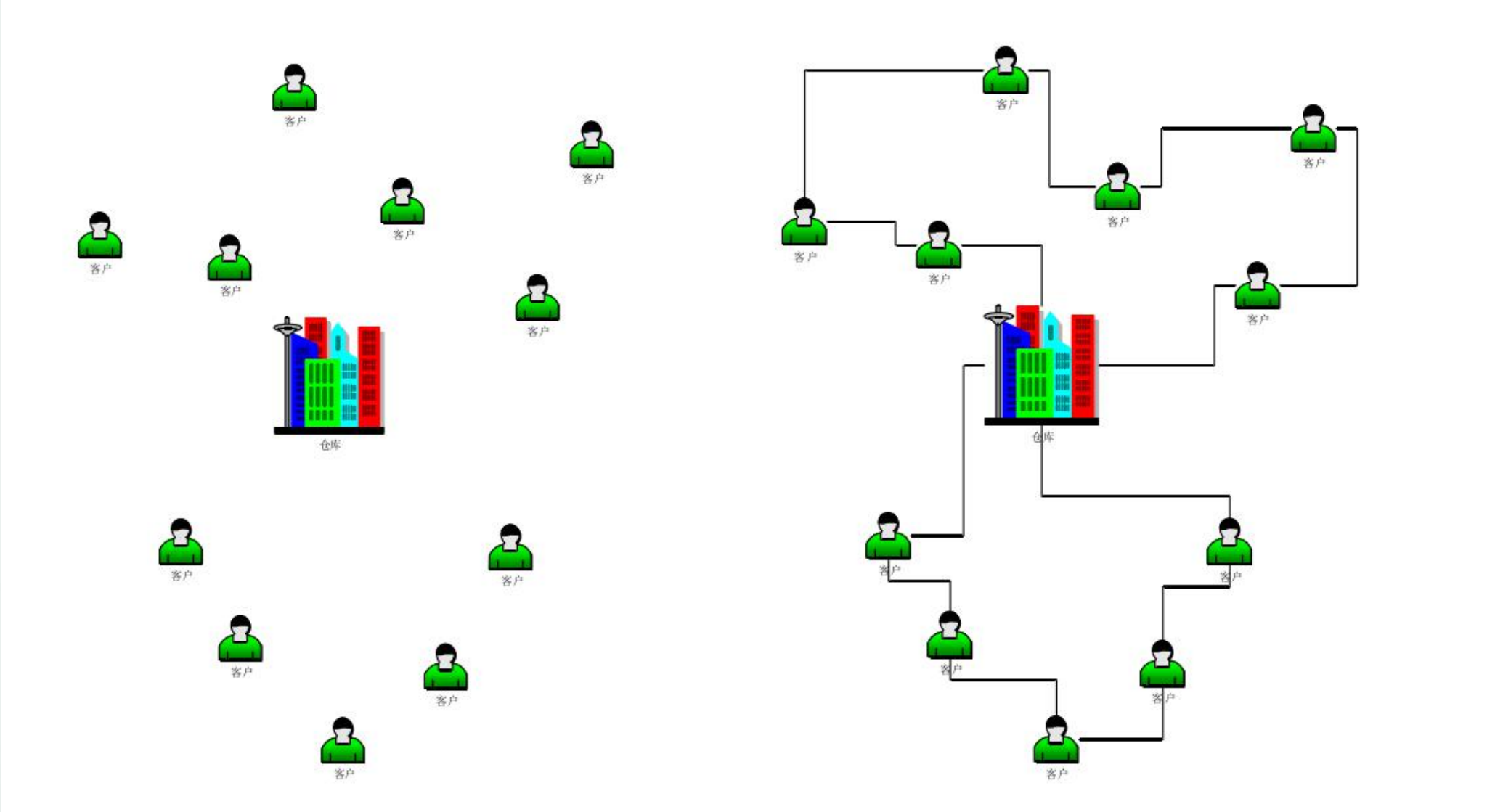
车辆路径问题（Vehicle Routing Problem，VRP）最早是在 1959 年由 Dantzig 和 Ramser首次提出。一般是指在由节点以及节点间路径连接组成的网络中，从某一节点出发，安排若干车辆遍寻各个节点并要求满足特定的需求，如运输车辆的核定载重量、车辆的运行路程或时间等。在不违背各项约束条件的基础下规划各个车辆的具体行驶情况。并要求最终得到的行驶路径能够使得总行驶路程或时间、行驶过程中产生的总成本等取得最优值，即找到最优的路径规划方案

机器人路径规划有着比VRP更严苛的要求

根据外部的环境信息实时的对自身所规划的路线作出调整，来应对多变复杂的环境，并且不会大量增加计算量。

移动过程中，行进路线一般是安全且平滑的，且可以躲避不规则的障碍物

1. VRP问题简述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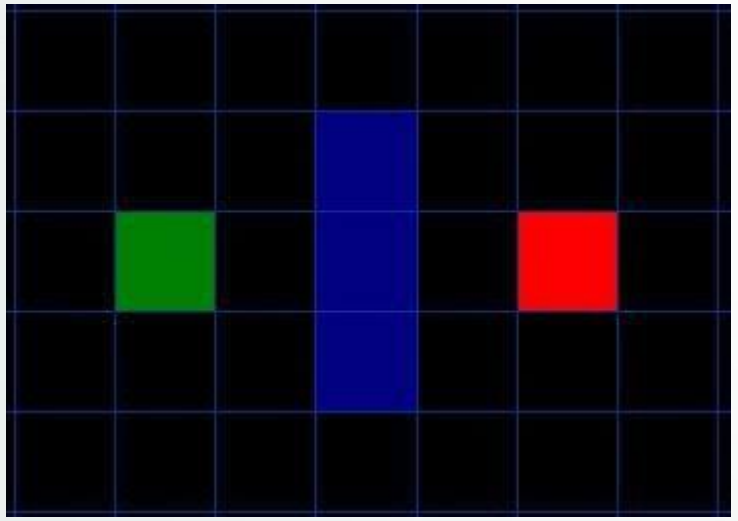
2. 经典VRP算法-A*

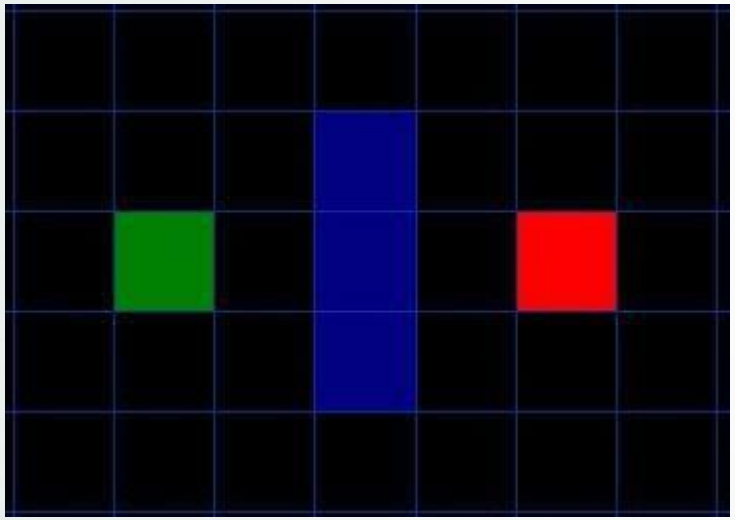
A*算法是一种静态路网中求解最短路径的高效搜索方法

https://www.gamedev.net/articles/programming/artificial-intelligence/a-pathfinding-for-beginners-r2003/

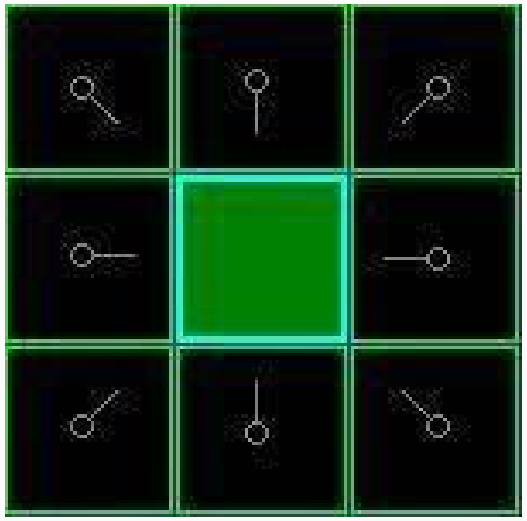


1 确定搜索范围
2 开始搜索
3 路径排序
4 重复搜索排序过程
5 得到路径序列

确定搜索范围



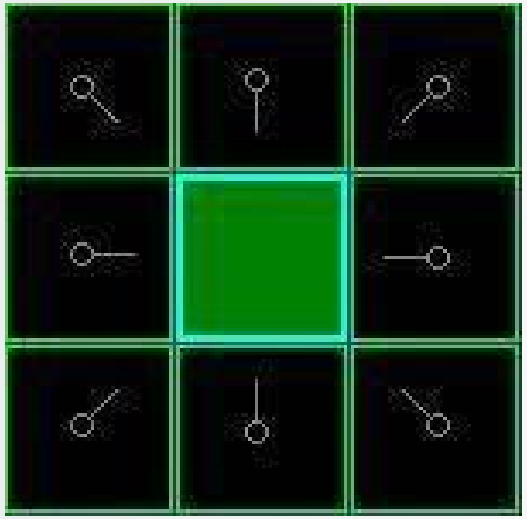
开始搜索



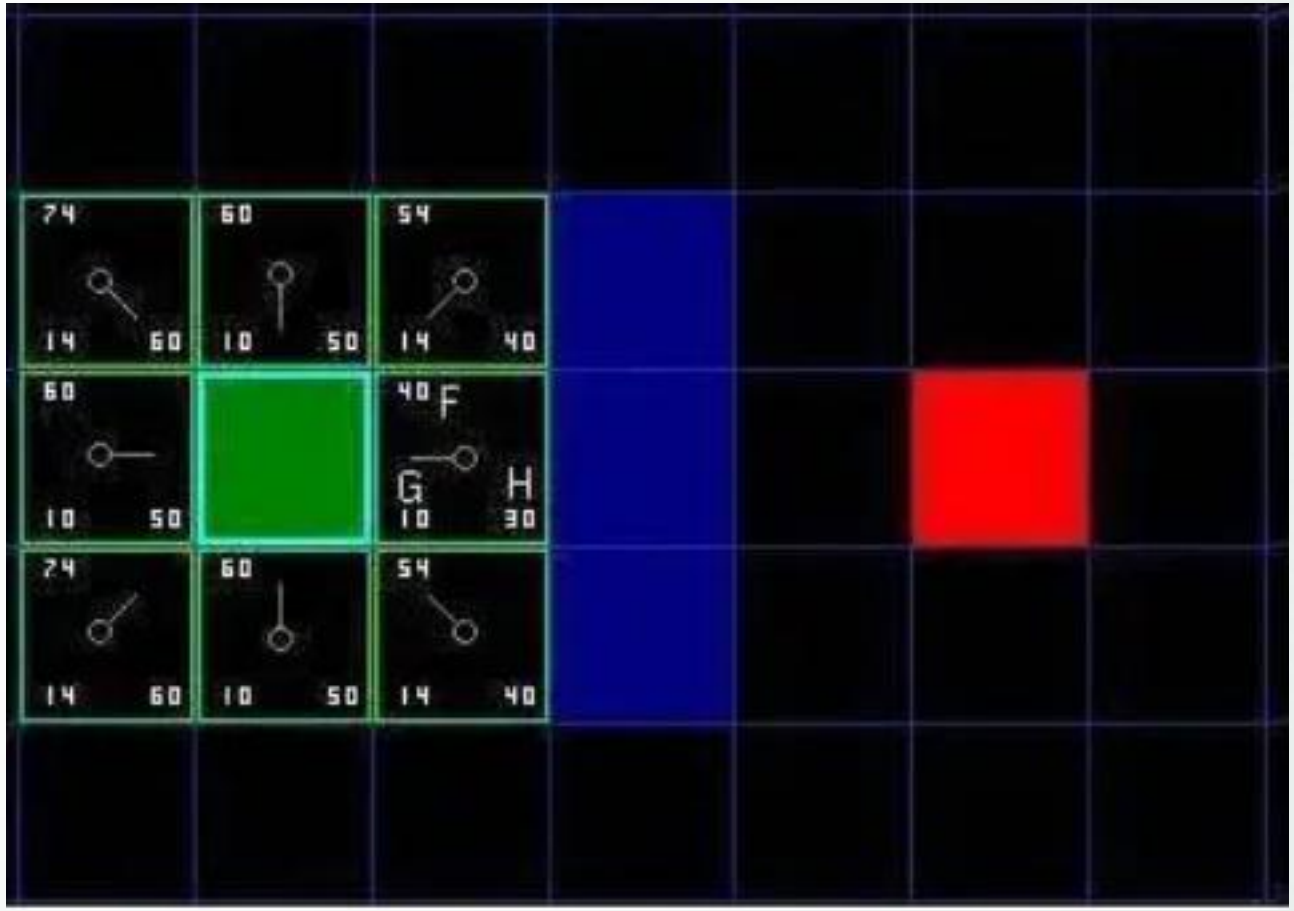
1.以绿色方格为起点，搜索与之相连的八个方格
2.Openlist和Closelist

从绿色出发，绿色是当前的位置，放入Closelist；绿色周围的八个方格是需要搜索的位置，放入Openlist备用

路径排序



如何在八个相邻方格中选择
最合适的一个？



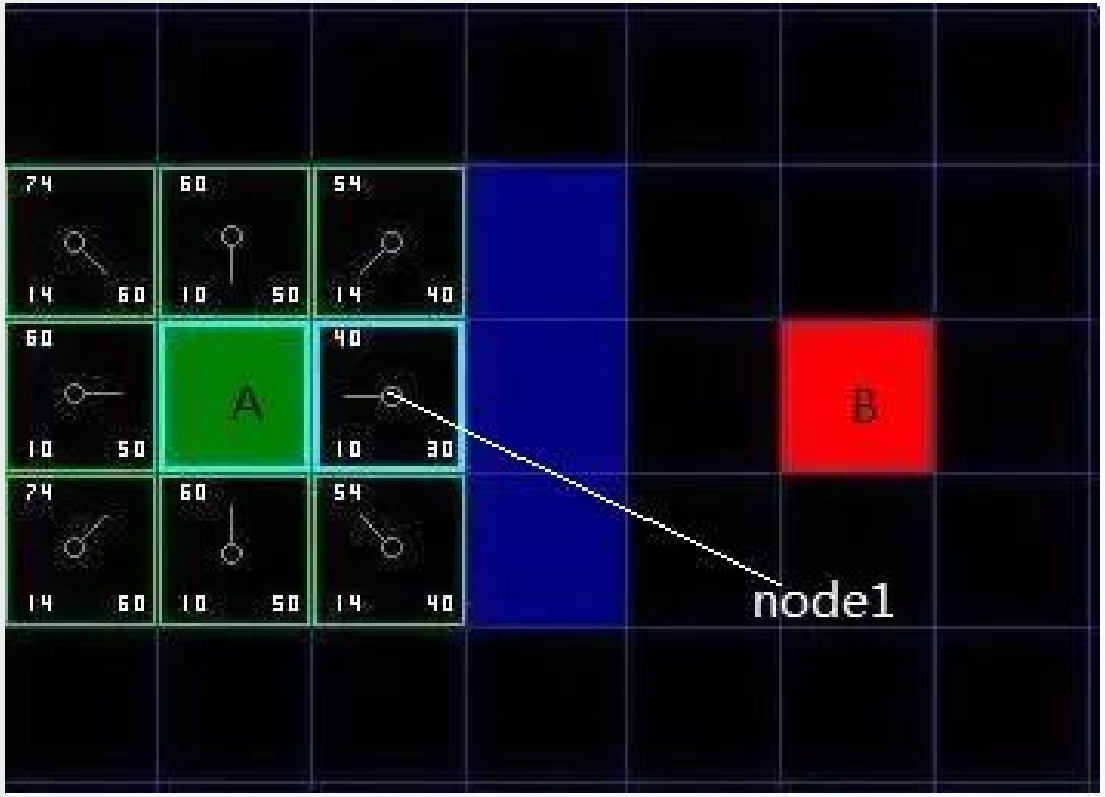
F = G + H

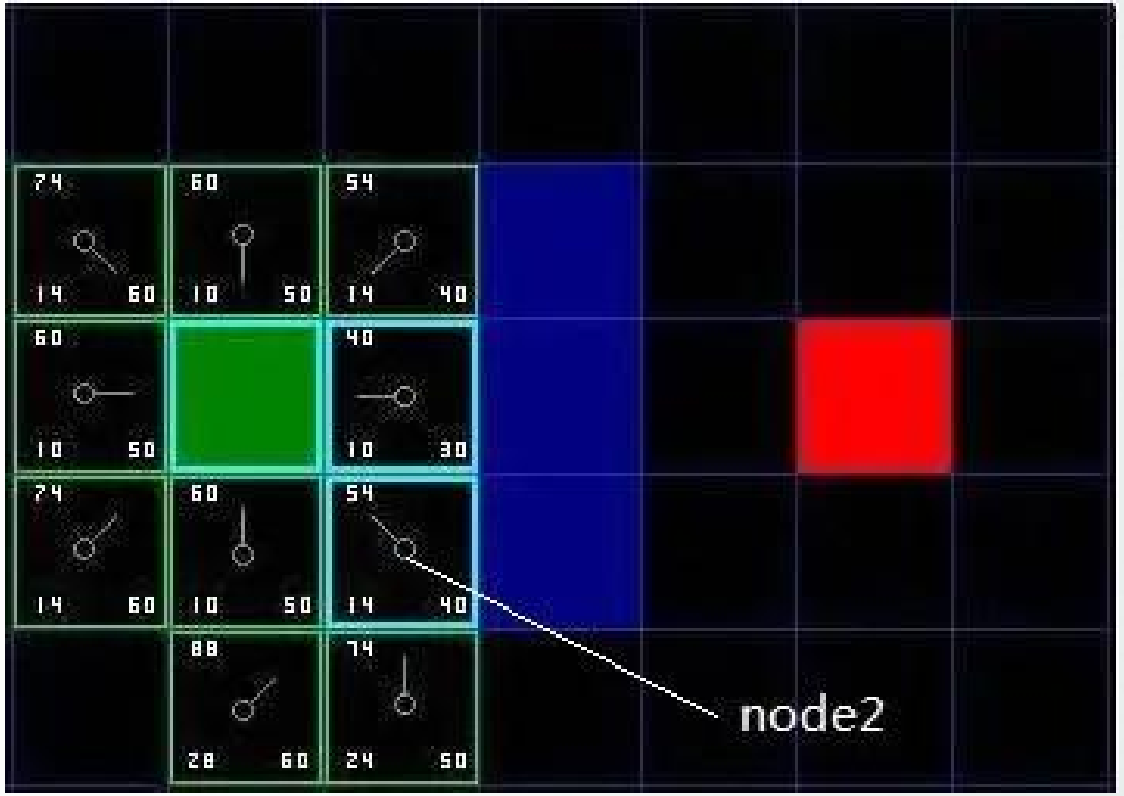
G:从起点网格移动到当前网格的路程

H：从当前网格到目标点的路程

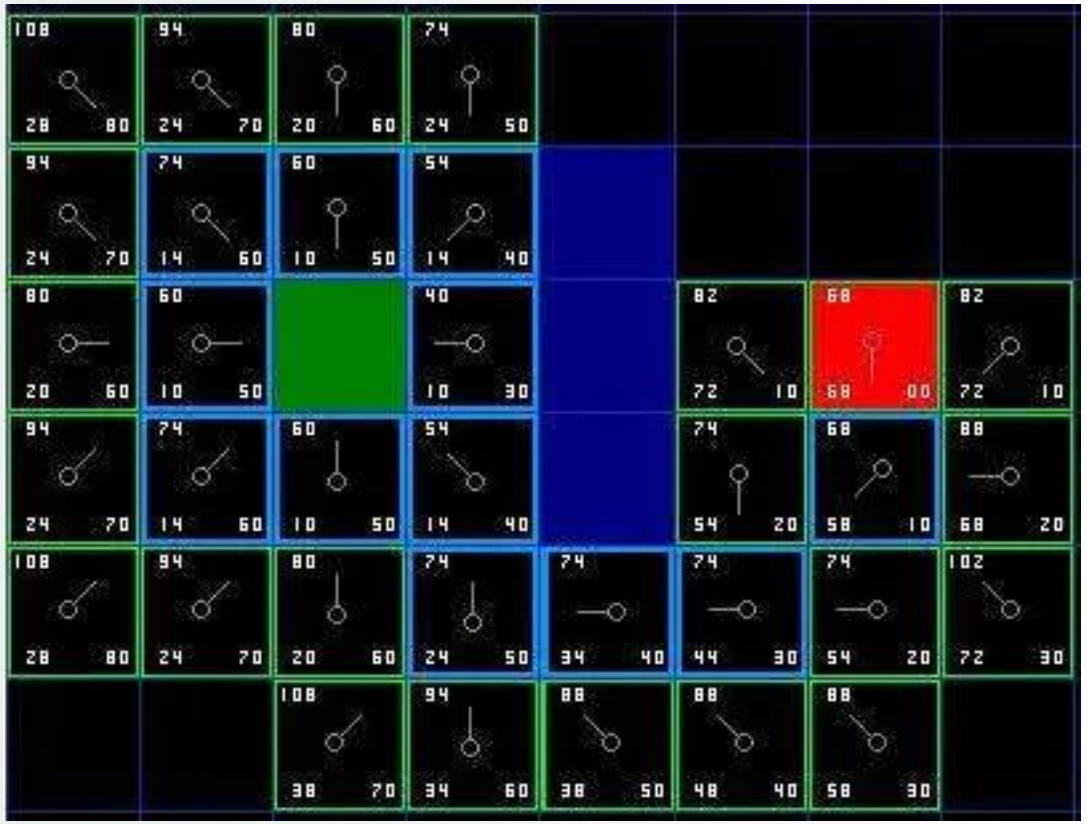
重复搜索排序过程

是一个不断修正的过程

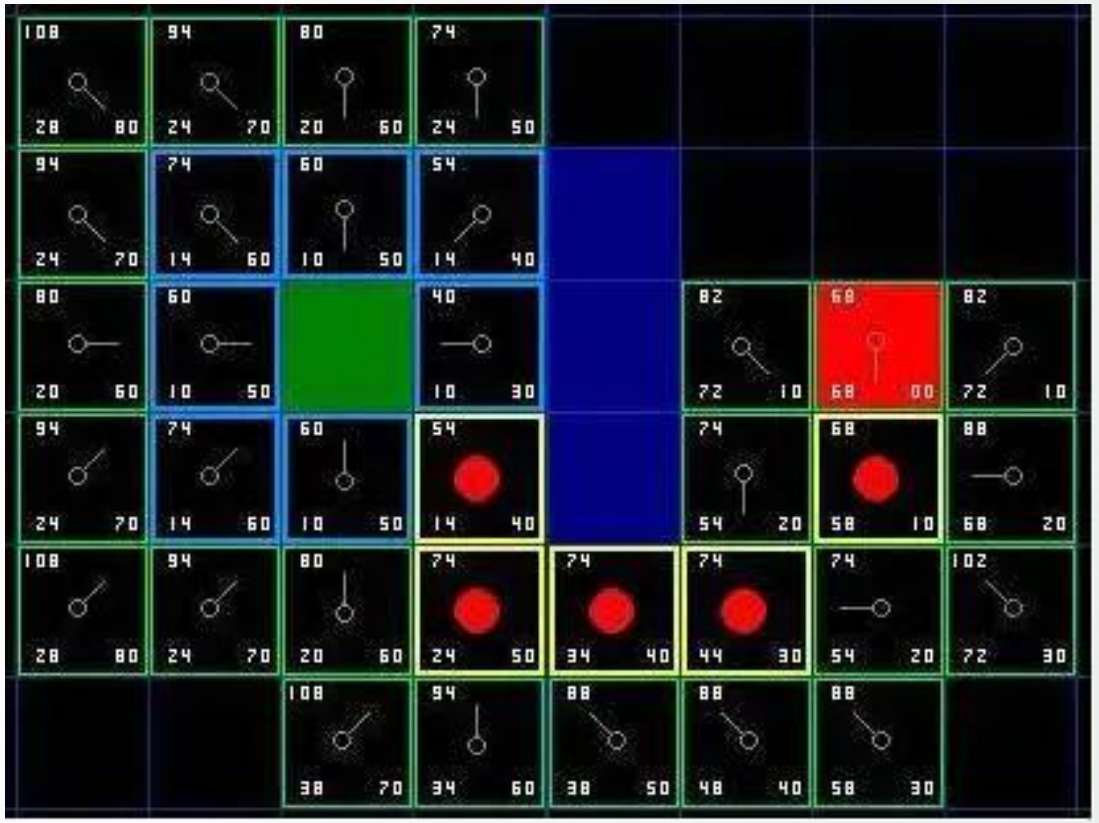




重复搜索排序过程



得到路径序列



本章作业

理解A*算法的搜索过程，自主实现A*算法。

作业相关资料在课程上线后发送

谢 谢 观 看