1. Demand：求解三维空间无碰撞的存续联通路径
2. Project Address：<https://github.com/bladesaber/MAPF_Pipeline>
3. Algorithm Structure:

算法组成：

1. 求解三维空间存续无碰撞路径
   1. 参考方案1: CBS[10] + A-star + CAT(Conflict Avoidance Table)[12]
   2. 参考方案2: Prioritized Planning[19, 20] + A-star

初步评价：方案1的求解路径为理论最短路径，但求解空间大，需要计算资源大，求解时间长。在方案初步结果确认后，可考虑添加Operator Decomposition[6,7,8]与Bypass[17]方法进行优化。方案2的求解路径为次优路径，但无法保证一定有求解结果。

1. 所得路径进行局部平滑
   1. 参考方案1：Hyprid A-star
   2. 参考方案2：Bezier Smoothing（以路径点为控制点）

初步评价：后续需要结合流体方面的函数设计

1. 管道效果可视化
   1. 参考方案1：基于PyVista库实现（参考https://docs.pyvista.org/）
   2. 参考方案2（候选）：基于Mayavi库实现
2. Plan：

2023-03-10：

1. 计划2023-04-01前完成算法组成（1）中两个方案（基于C++）。不确认在三维空间上A-star会不会由于搜索空间过大的问题导致崩溃，因此初期Grid空间设计为（50x50x50）先做尝试。
2. 之后需要一个粗糙的可视化代码（基于Python）。
3. 需要部分模拟应用场景的参数，对比以上两种算法求解该部分场景的Metric差异，以及对比人工设计与算法求解路径的差异（忽略局部路径平滑），已确认下一步是否继续进行。

2023-03-22：

一些优化的想法：

1. 将conflict检测更改为管道之间的距离阈值，当存在冲突时，使用Dijk（不需要Dijk，使用Max（X， Y）<=n即可）找出外层cell作为约束。因此与传统约束不同，的是一个集，而且与不是同一个集。
2. Theta\*是一个参考
3. Life-Long A\* 与 D\*，推荐Life-Long A\*
4. Paper Reference:

Survey：

1. A Survey of the Multi-Agent Pathfinding Problem, Erwin Lejeune
2. Multi-Agent Path Finding – An Overview , Roni Stern, 2022
3. Multi-Agent Pathfinding: Definitions, Variants, and Benchmarks, Roni Stern
4. Search-Based Optimal Solvers for the Multi-Agent Pathfinding Problem: Summary and Challenges(SoCS 2017)
5. T. Uras and S. Koenig. An Empirical Comparison of Any-Angle Path-Planning Algorithms. In Proceedings of the Annual Symposium on Combinatorial Search, 2015

MAPF：

Search Based Method:

1. WHCA-star：Silver, D. 2005. Cooperative pathfinding. In Artificial Intelligence and Interactive Digital Entertainment (AIIDE), 117–122
2. EPEA-star：Goldenberg, M., Felner, A., Sturtevant, N.R., Holte, R.C., Schaeffer, J.: Optimal generation variants of EPEA. In: SoCS (2013)
3. Independence Detection + OD：Standley, T. S. 2010. Finding optimal solutions to cooperative pathfinding problems. In AAAI
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5. Bnaya, Z., and Felner, A. 2014. Conflict-oriented windowed hierarchical cooperative A\*. In (ICRA). Online Algorithm, ignore

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1. CBS: G. Sharon, R. Stern, A. Felner, N. Sturtevant, Conflict-based search for optimal multi-agent path finding, in: Proceedings of the AAAI Conference on Artificial Intelligence, Toronto, Ontario, Canada, 2012
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1. From Multi-Agent Pathfinding to 3D Pipe Routing, Gleb Belov, SoCS 2020：
   1. Priority conflict-based search + A-star
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2. Position Paper: From Multi-Agent Pathfinding to Pipe Routing, Gleb Belov, 2019:
   1. ECBS + focal A-star

Path Smooth:

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2. A. Nash, K. Daniel, S. Koenig and A. Felner. [Theta\*: Any-Angle Path Planning on Grids](https://web.archive.org/web/20160528140046/http://idm-lab.org/bib/abstracts/Koen07f.html). In Proceedings of the AAAI Conference on Artificial Intelligence (AAAI), 1177-1183, 2007:

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1. Optimal Any-Angle Pathfinding In Practice. Daniel Harabor Journal of Artifificial Intelligence Research 56 (2016). (Anya algorithm):

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3. Code Reference:
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   2. Andreychuk, A., Yakovlev, K.: Two techniques that enhance the performance of multi-robot prioritized path planning. In: International Conference on Autonomous Agents and MultiAgent Systems (AAMAS). pp. 2177–2179 (2018)
   3. EECBS: A Bounded-Suboptimal Search for Multi-Agent Path Finding
   4. HCBS + RTC: Improved Heuristics for Multi-Agent Path Finding with Conflict-Based Search
   5. MAPF-LNS: Anytime Multi-Agent Path Finding via Large Neighborhood Search
   6. Dynamic A\* and Lifelong Planning A\* may be useful
   7. CL-MAPF: Multi-Agent Path Finding for Car-Like Robots with Kinematic and Spatiotemporal Constraints

记录：

2023-03-06：

这段时间可以完成low-level的搜索方法与high-level规划方法的确定就很好了，第二个比较麻烦的方面就是要找到合适的参考代码并进行移植。对于传统的搜索方法的改进主要体现在：（1）启发式（2）限制branch数目（3）independent detection（4）创建window移动窗体（4）Operator decomposition （5）Conflict Avoid Table

2023-03-08：

与多智体路径规划不同的是，管道规划中行走过的路径不允许再被占据，所以Prioritized Planning 才会比较占主导，不过CBS应该仍然是最优结果的求解器。但我估计在三维上使用CBS会比在二维上开销大得多。

1. M-star似乎不适合于管道路径问题，因为路径不允许二次占据

2023-03-09:

总结来说，与常规的多智慧体路径规划相对比，主要是agent merge的操作失效了，（1） Operator Decomposition（单纯作为branch发散的问题方案使用）（2）ByPass方法 （3）启发式 这部分仍然是有效的。我的计划：

1. 完成两个求解器：
   1. 基于CBS + Search 的求解器 (CBS+A\*, ECBS)
   2. 基于 Prioritized Planning 的求解器 (PBS)
2. 我需要对比一下人工设计与算法设计的纯路径的差异
3. 路径平滑还是一个大问题，我预估这是一个Motion Planning Problem，我可能需要参考一下Hybrid A\* 或 基于simulation 的方法（例如Model Predictive Control，RRT\*）

2023-03-10:

A\*-star的变种应该是有用的：A-star（wiki）

2023-03-22：

目前完成了简单的Space-Time Astar与CBS的基础。在确认了方向无误后，先考虑完成一个完整的应用，先在小的测试环境上完成对（1）不同尺寸（2）平滑路径（3）合并与交集，三个问题的处理。

我认为我之前参考multi-agent path finding是有一定的偏差的，因为agent path finding的冲突需要考虑运动时间，但管道不需要考虑运动时间，因此可能Any-Angel Path finding与CBS混合是一个更合适的选择。

两个思路：