



Hybrid algorithm development for production applications



POWERED BY VOLKSWAGEN GROUP

Qubits Europe 2019, Milan, Italy
Sheir Yarkoni



Quantum Computing Applications at **VOLKSWAGEN**

AKTIENGESELLSCHAFT



Quantum Computing Applications at Volkswagen

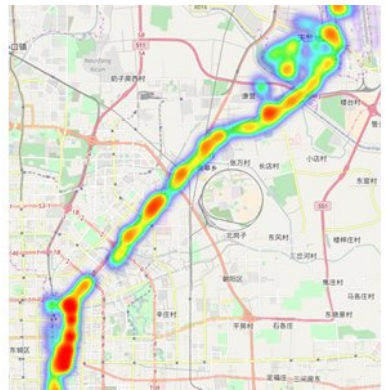
- Assembly line optimization
- Packing, logistics, and distribution
- Material simulation and design
- Smart mobility solutions
- ...



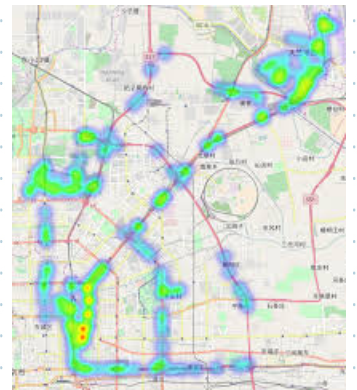
Smart Mobility solutions



Prototype application for quantum computing: Traffic flow optimization (PoC)



$$\begin{bmatrix} [-2918 & 5864 & 12 & \dots & 0 & 0 & 0] \\ [0 & -2908 & 8 & \dots & 0 & 0 & 0] \\ [0 & 0 & -2920 & \dots & 0 & 0 & 0] \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ [0 & 0 & 0 & \dots & -2925 & 5854 & 5854] \\ [0 & 0 & 0 & \dots & 0 & -2924 & 5856] \\ [0 & 0 & 0 & \dots & 0 & 0 & -2924] \end{bmatrix}$$





How do we work in a production environment?





How do we work in a production environment?

- Processes generate data continuously
- Objectives needs to be optimized as conditions change
- Waiting time must be minimized (can't stop production)
- Requests and responses are sporadic and irregular



Hybrid algorithm design: requirements and specifications

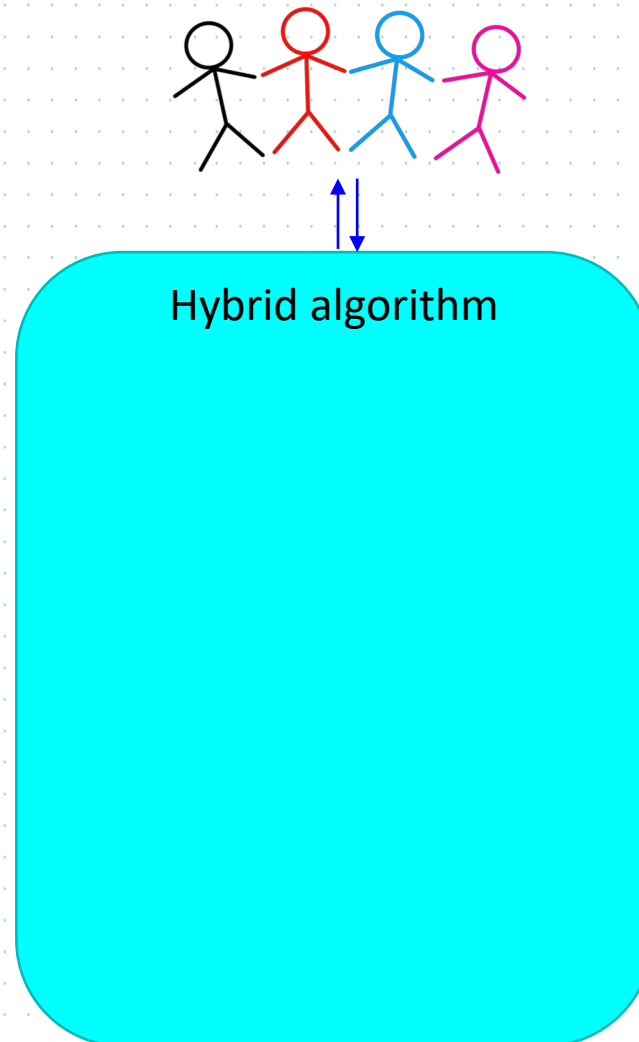
- Processes generate data continuously ← Algorithm must run continuously
- Objectives needs to be optimized as conditions change ← BQM construction
- Waiting time must be minimized (can't stop production) ← Maximum QPU throughput
- Requests and responses are sporadic and irregular ← Algorithm must listen & respond on demand





Hybrid algorithm design: requirements and specifications

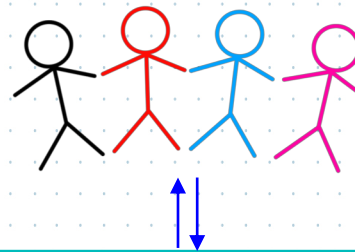
- Hosted on AWS
- Written in Python
- Exposed using Flask
- Containerized using Docker



Hybrid algorithm design: requirements and specifications

- Traffic flow optimization
- Ocean tools (dimod)

$$\text{Obj} = \sum_{s \in S} \text{cost}(s) + \lambda \sum_i \left(\sum_j q_{ij} - 1 \right)^2.$$



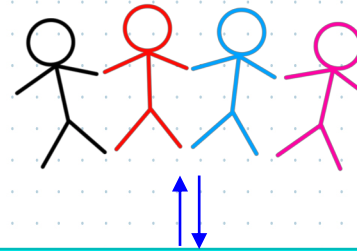
Hybrid algorithm

① BQM
Construction



Hybrid algorithm design: requirements and specifications

- Live traffic information
- Road network map



② External data supplier

Hybrid algorithm

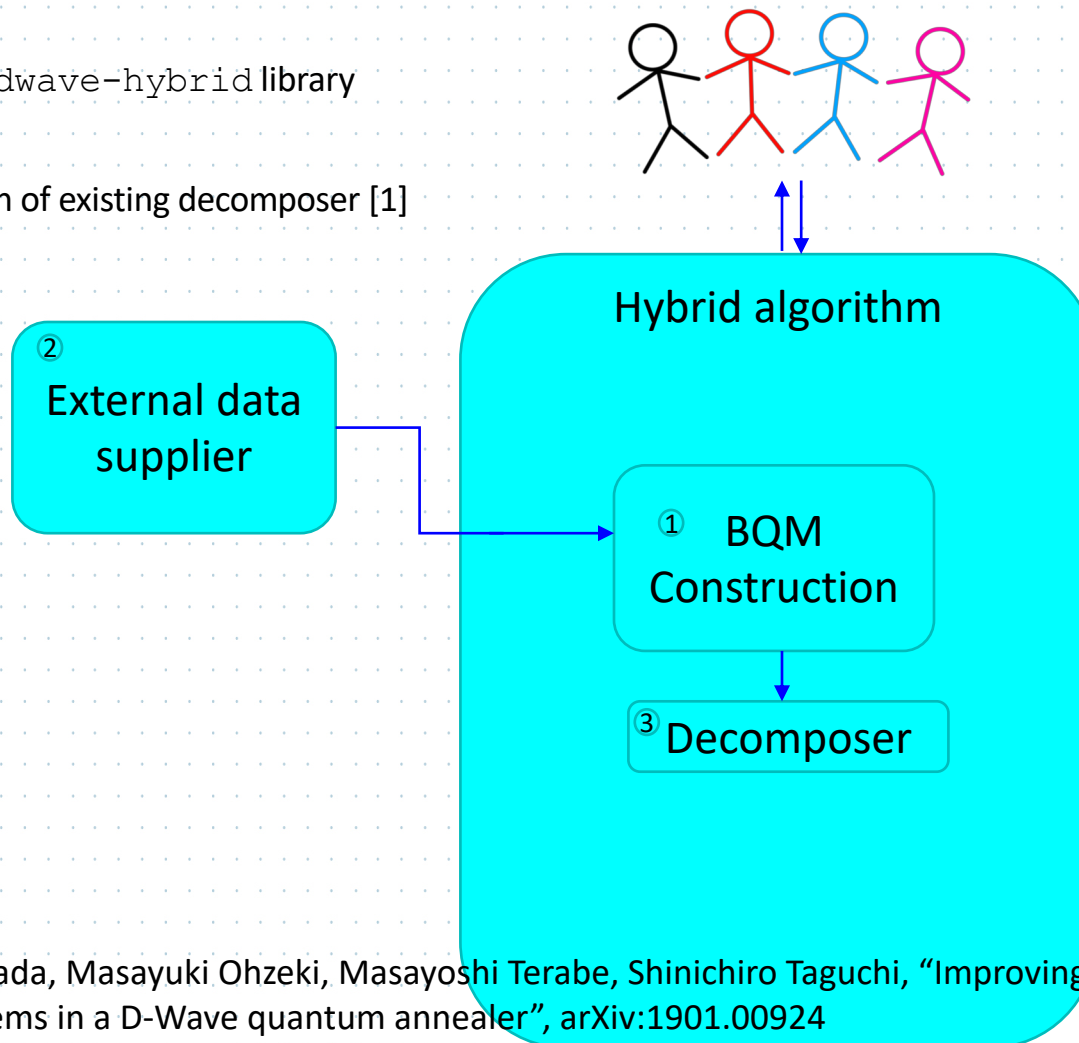
① BQM Construction



- www.here.com

Hybrid algorithm design: requirements and specifications

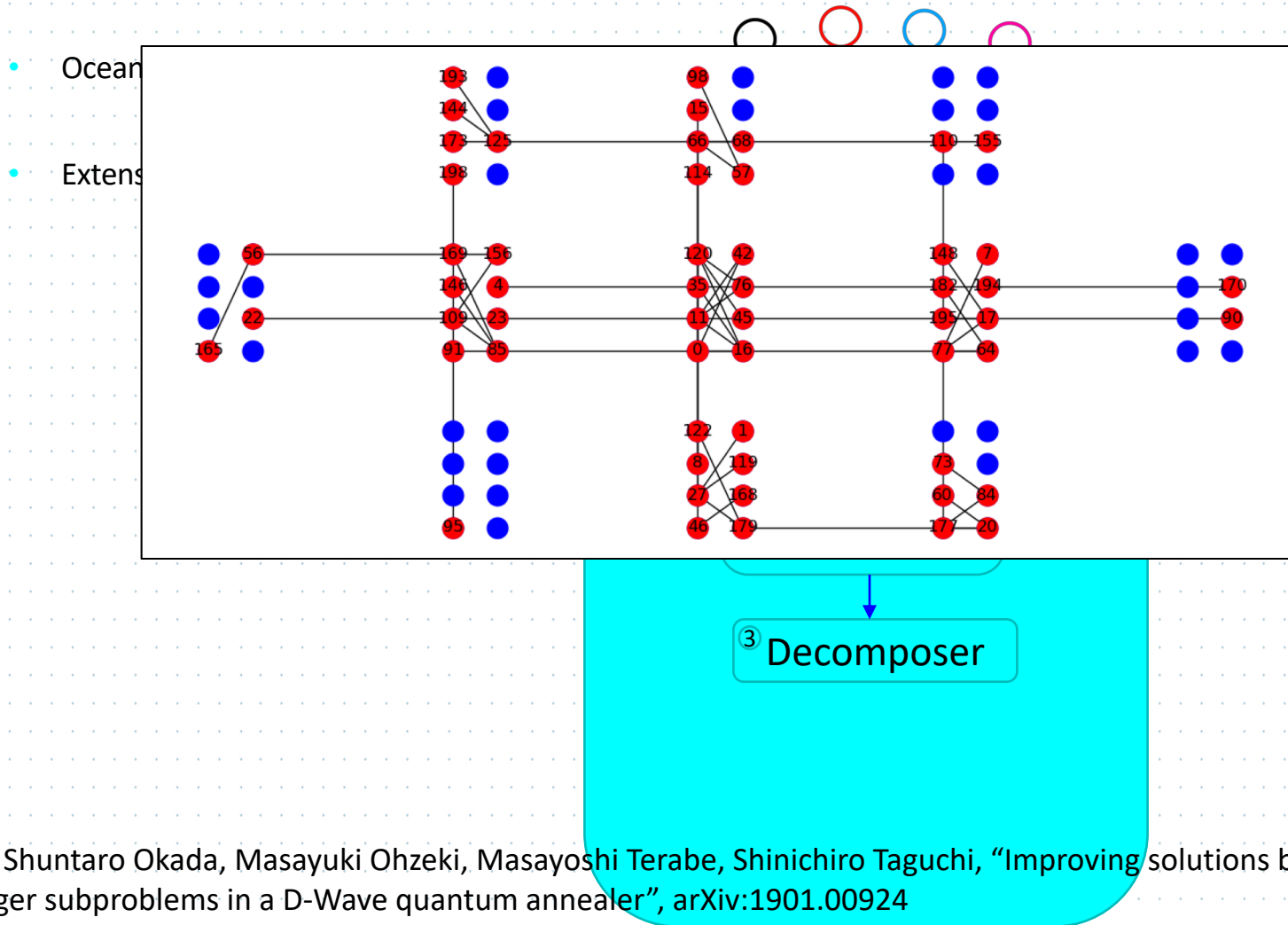
- Ocean's dwave-hybrid library
- Extension of existing decomposer [1]



[1] Shuntaro Okada, Masayuki Ohzeki, Masayoshi Terabe, Shinichiro Taguchi, "Improving solutions by embedding larger subproblems in a D-Wave quantum annealer", arXiv:1901.00924



Hybrid algorithm design: requirements and specifications

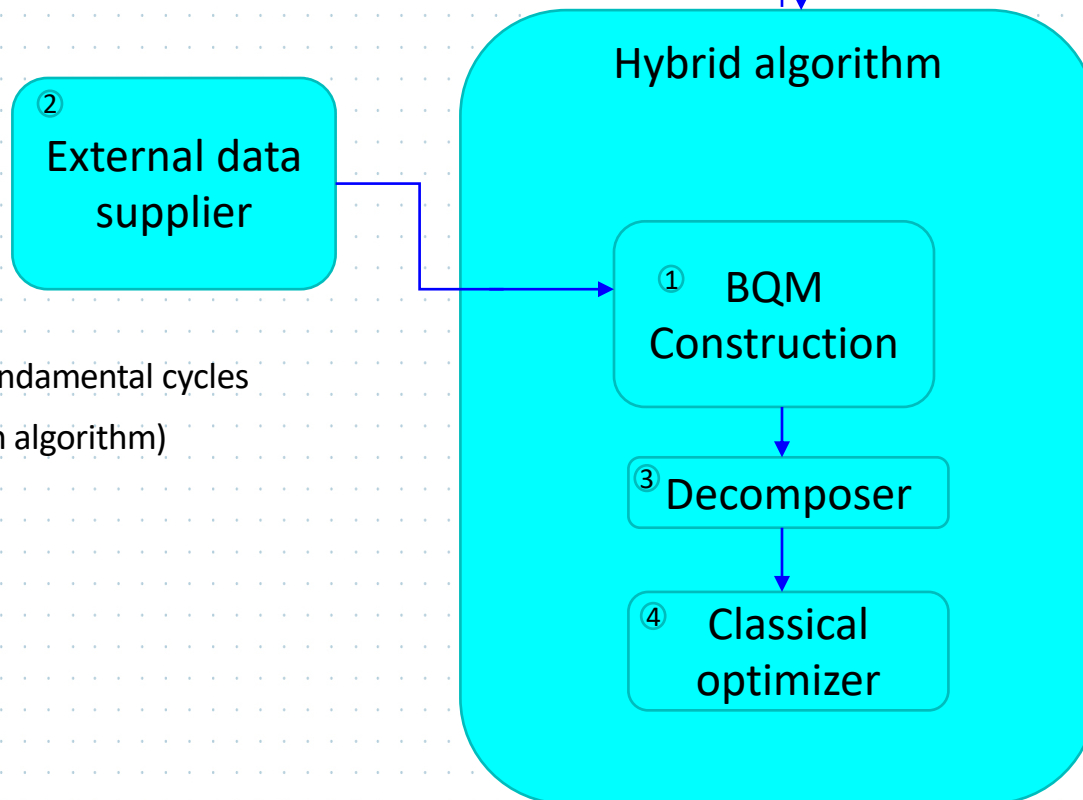
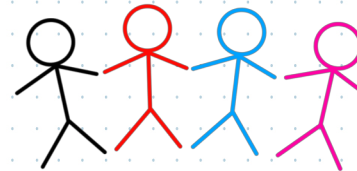


[1] Shuntaro Okada, Masayuki Ohzeki, Masayoshi Terabe, Shinichiro Taguchi, "Improving solutions by embedding larger subproblems in a D-Wave quantum annealer", arXiv:1901.00924



Hybrid algorithm design: requirements and specifications

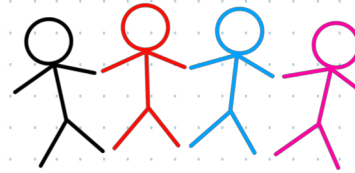
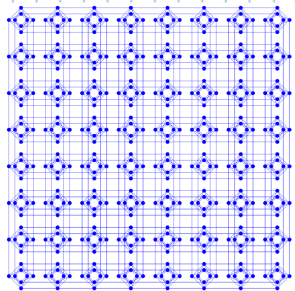
- QPU should be used for “hard” problems, “easy” problems solved classically



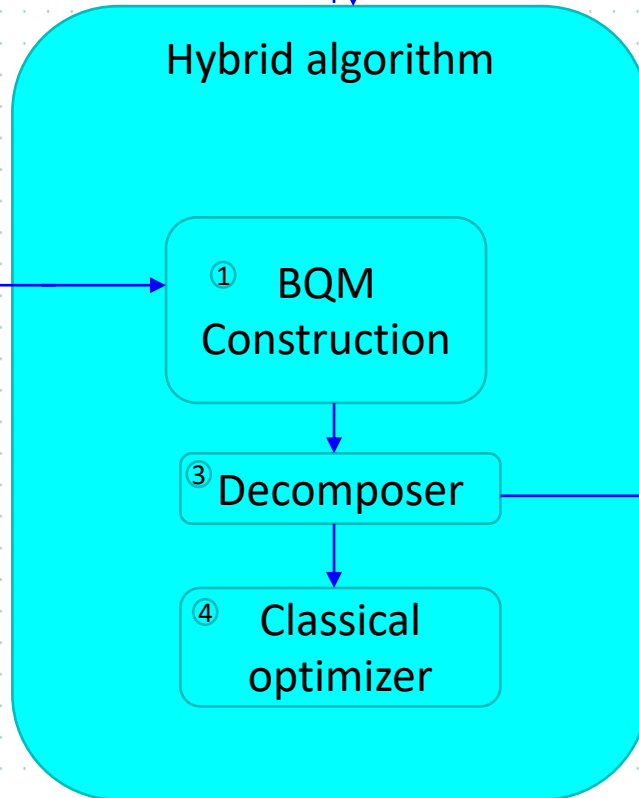
- Count fundamental cycles (min-sum algorithm)



Hybrid algorithm design: requirements and specifications



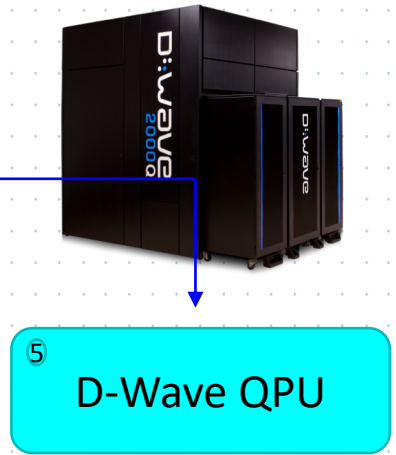
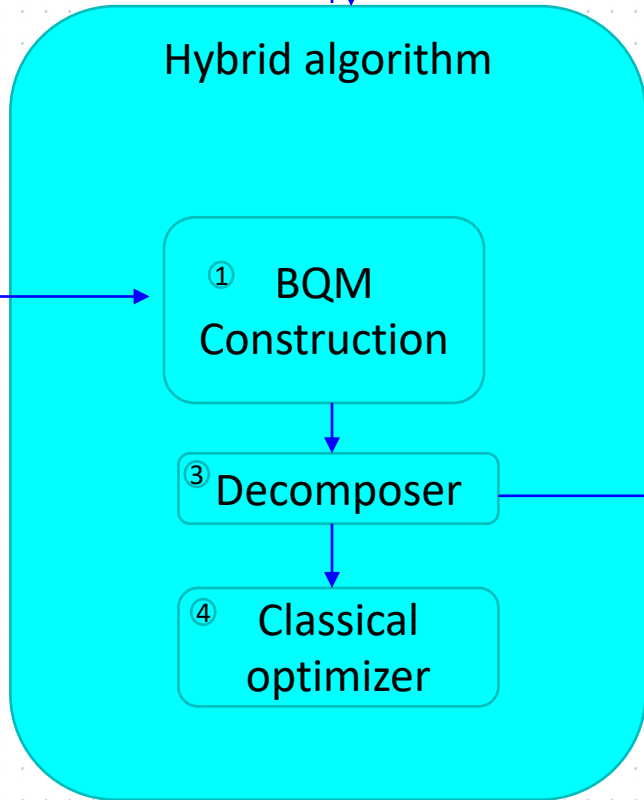
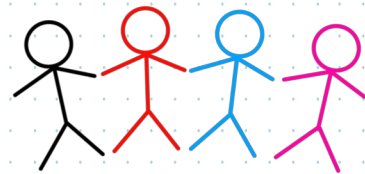
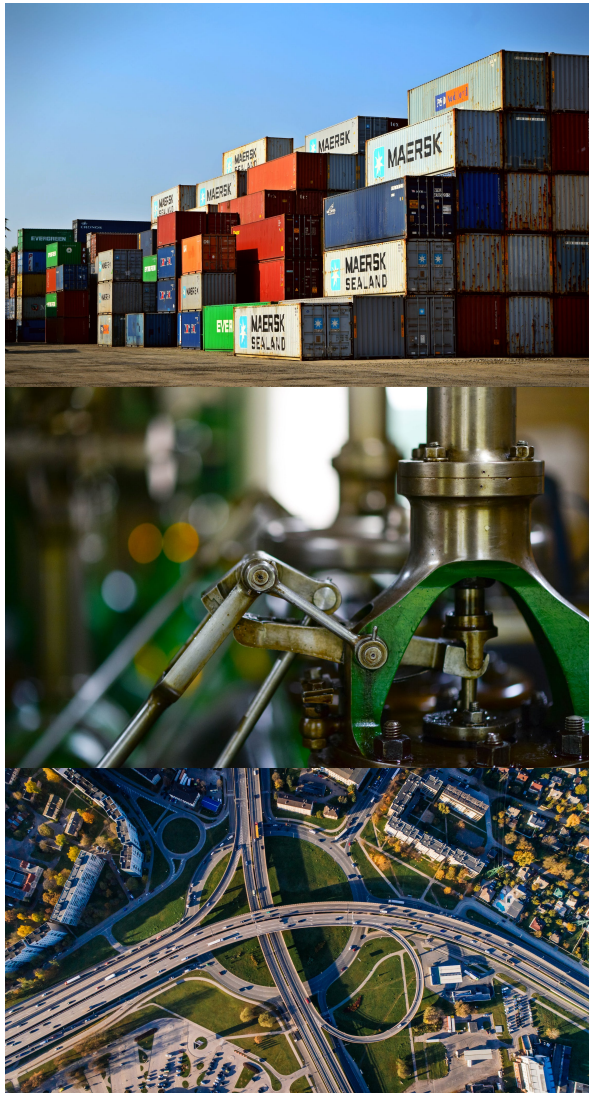
② External data supplier



⑤ D-Wave QPU



Hybrid algorithm design for use in practice





Thank you! Questions?