Peter Nielsen

- Associate Professor, Department of Materials and Production, Aalborg University
  - Head of the Operations Research group
  - EU Expert on AI and unmanned systems for Defence
  - MoD EDF reference group member
- Artificial Intelligence for Autonomous Systems
  - Large scale NP-hard problems requiring solution in near real-time
  - Problems subject to stochastic conditions
  - Solution architecture design and implementation for complex problems

Operations Research

Industrial Partners

AIRBUS DEFENCE & SPACE

LEONARDO

MÆRSK

SIEMENS Gamesa RENEWABLE ENERGY

SAFRAN

HENSOLDT Detect and Protect.

SAAB

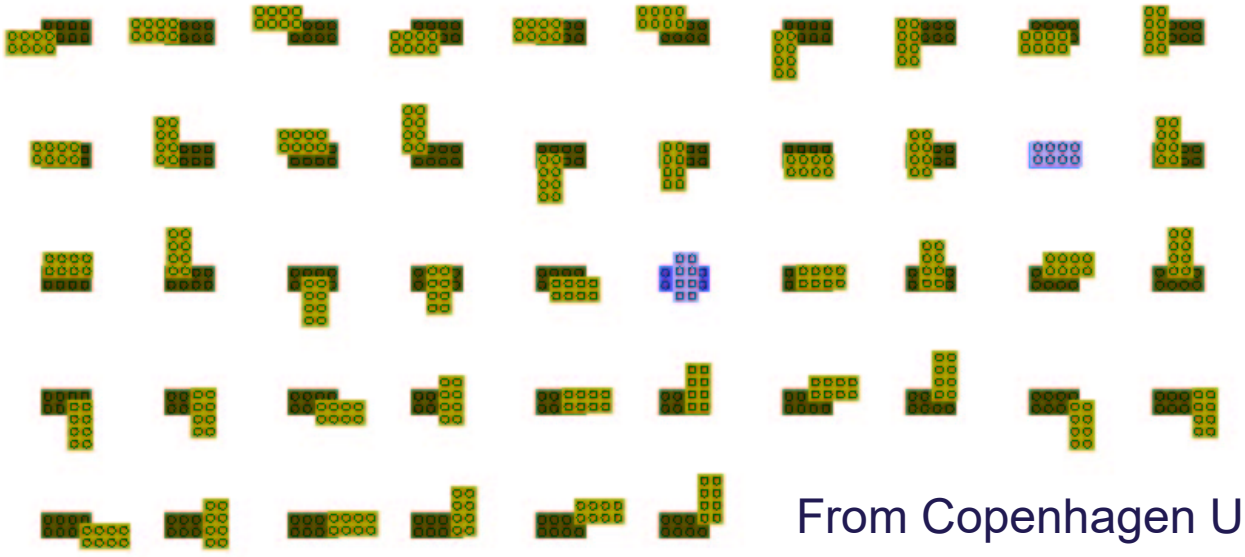
TELEDYNE MARINE Everywhereyoulook™

MBDA MISSILE SYSTEMS

Autonomous cyber-physical systems

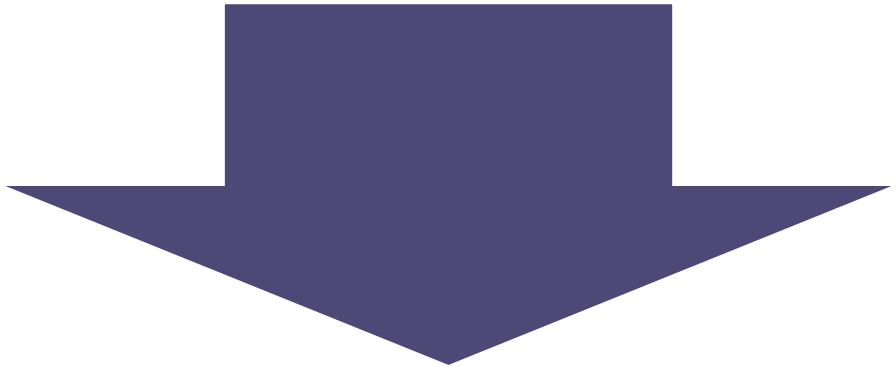
The fundamental nature of combinatorial complex problems

2 Lego bricks (2 x 4) can be combined in 46 different ways
3 can be combined in 1.060 ways
6 can be combined in +915 million ways



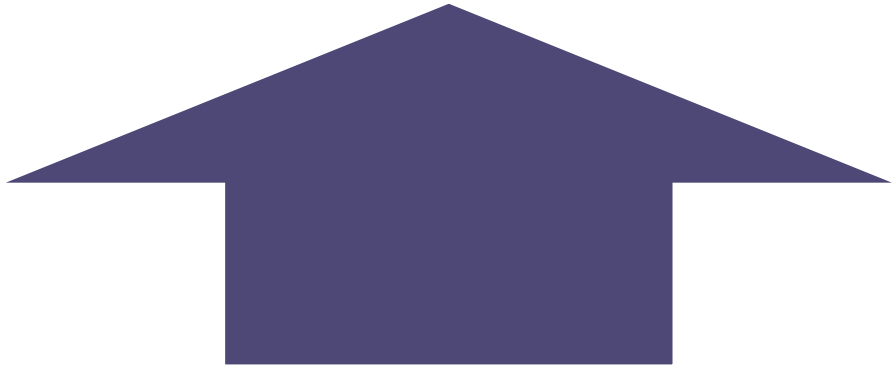
From Copenhagen University

Solution spectrum



100% design
solution to problem

100% adapt problem
to solution approach



Characteristics:
Fast – likely to succeed
Pay (potentially a hefty) price in terms of adaptation

Characteristics:
Slow – no guarantee of success
Fewer assumptions needed, close to the real problem

Standard approach

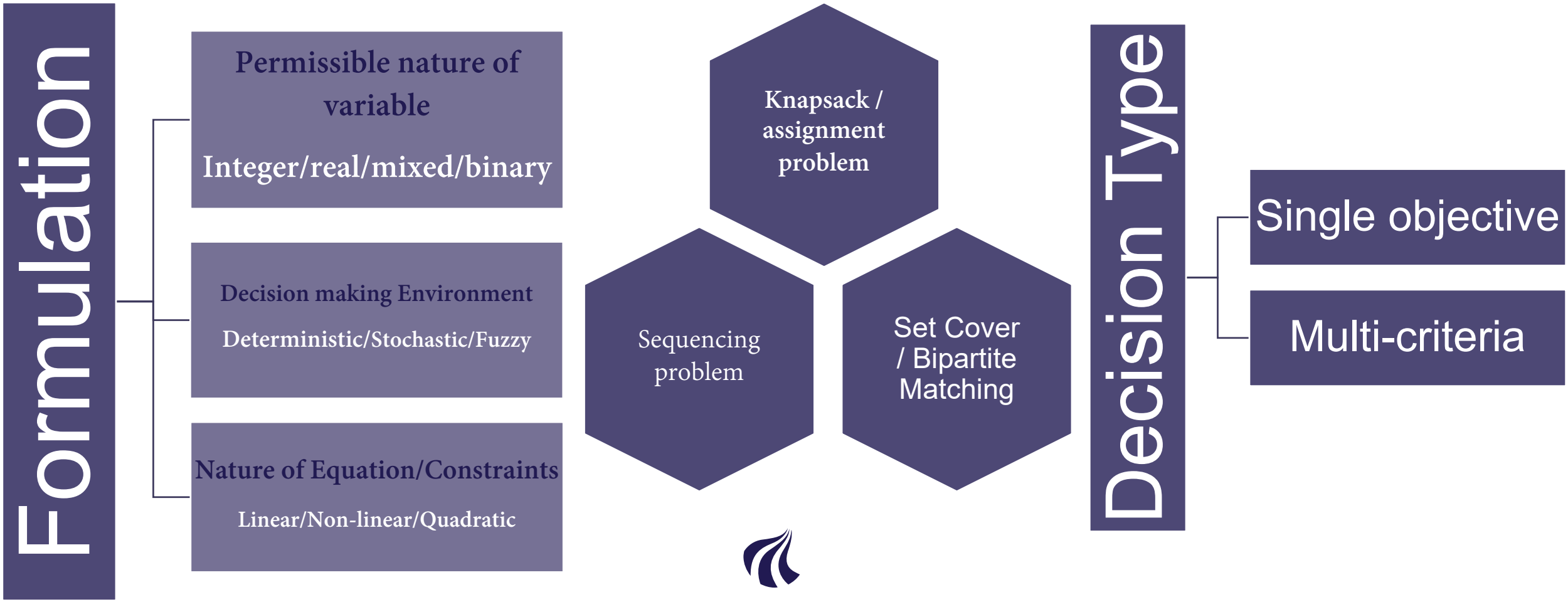
Matching generic solutions to generic problems

Identifying the generic problems in specific use cases

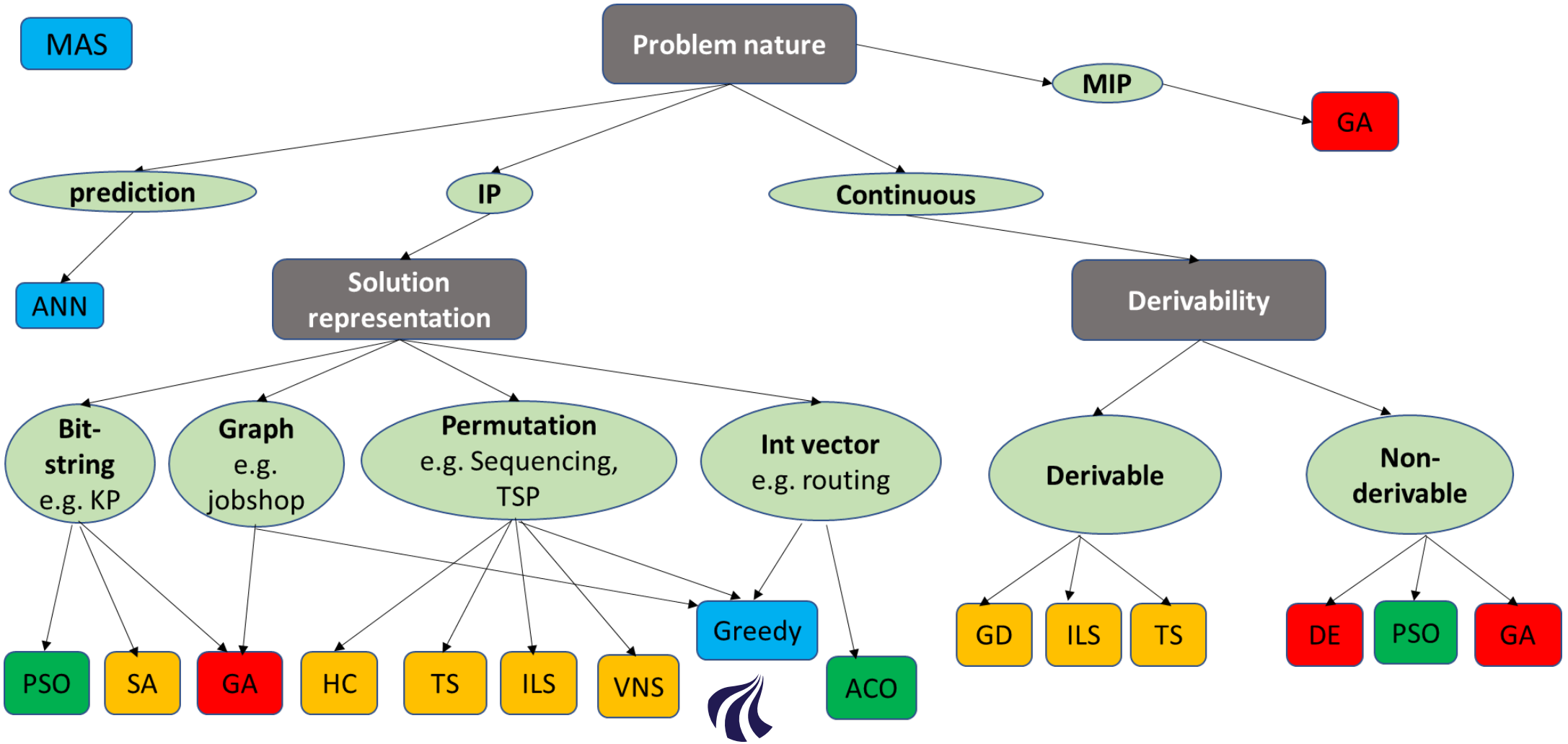
Ensuring the right match for the specific use case

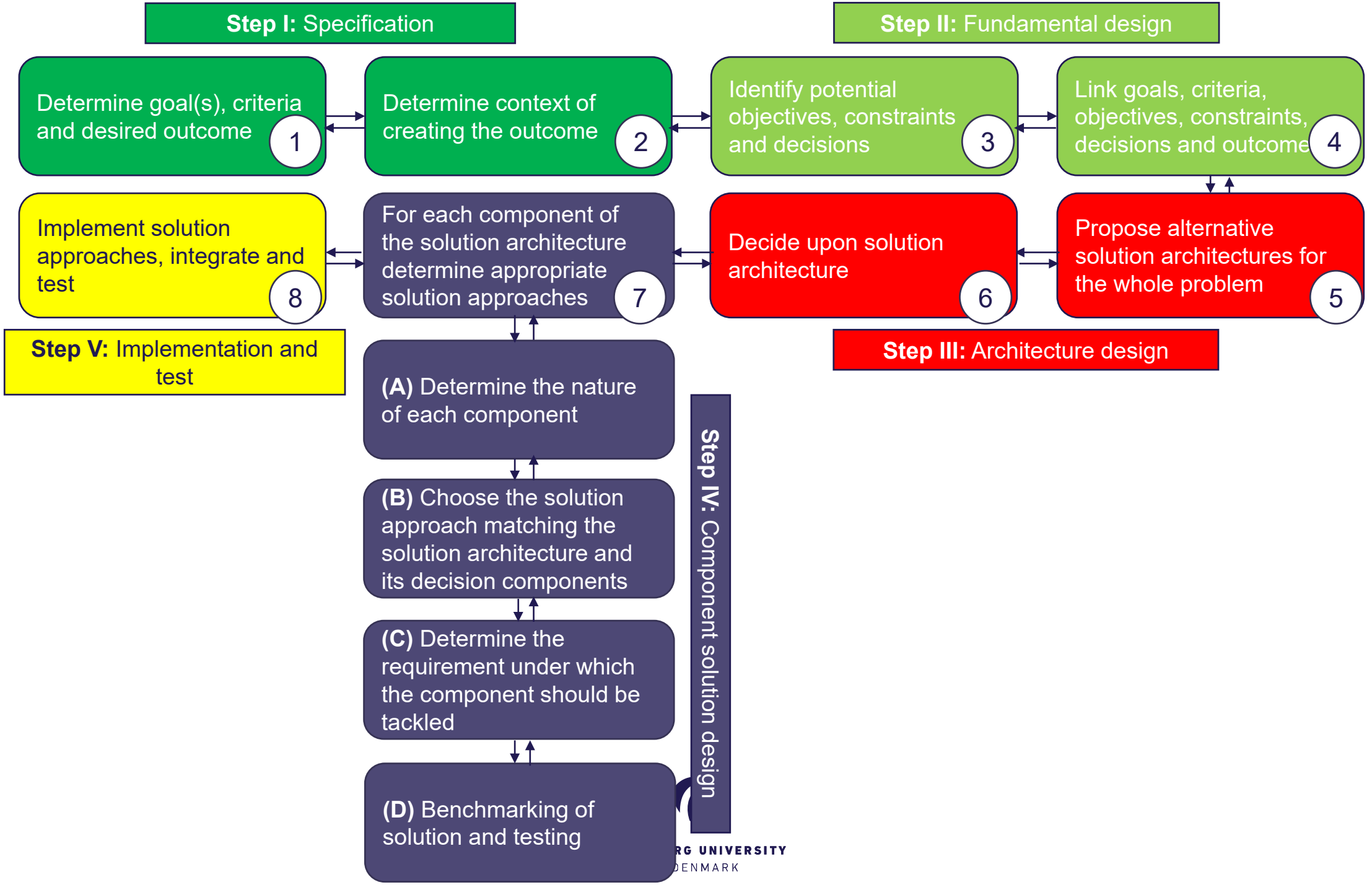
Always remember
No Free Lunch (theorem)

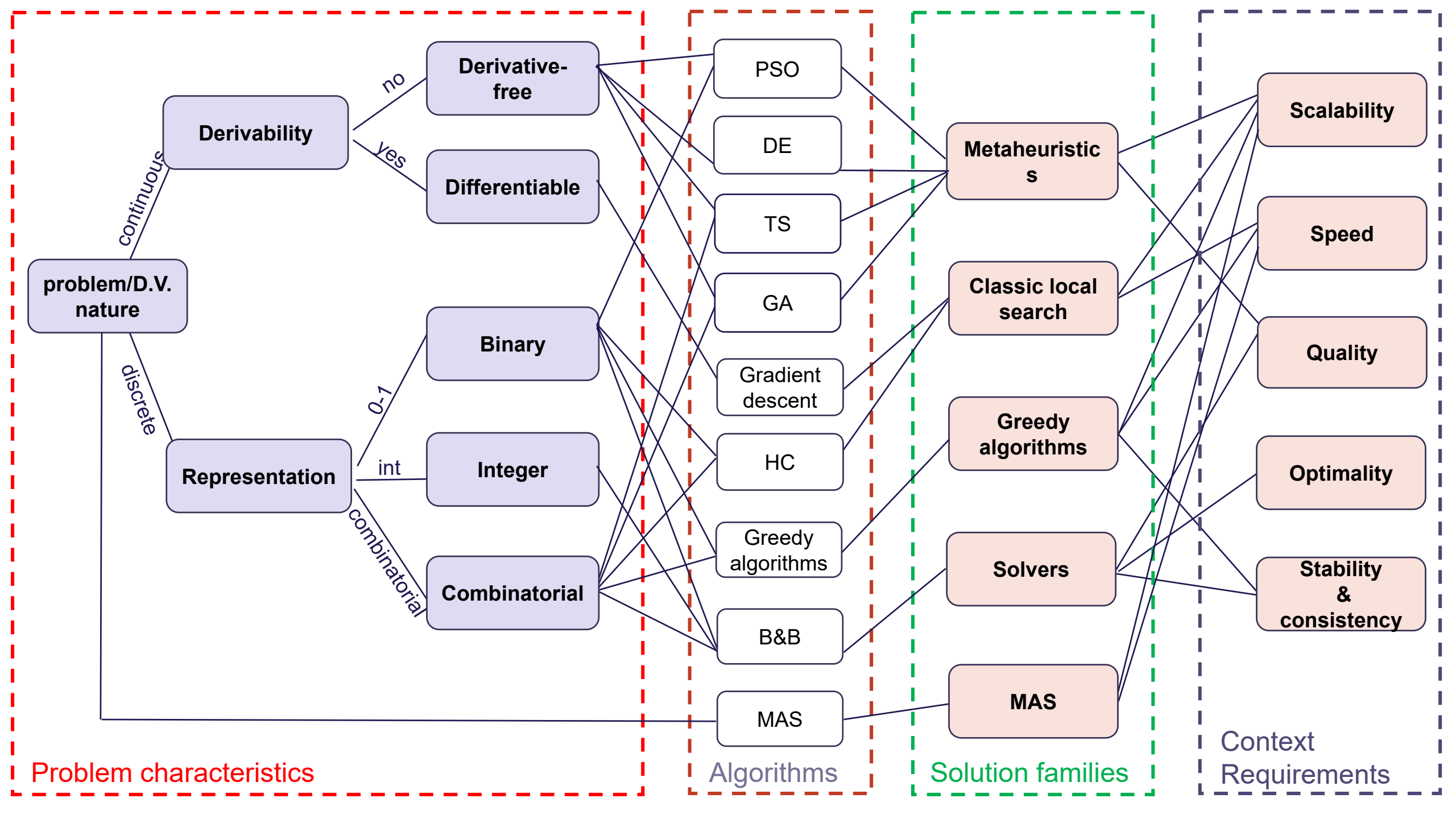
Identifying the generic problems in specific use cases



Matching generic solutions to generic problems




Step I: Specification
Step II: Fundamental design
Determine goal(s), criteria and desired outcome
1
Determine context of creating the outcome
2
Identify potential objectives, constraints and decisions
3
Link goals, criteria, objectives, constraints, decisions and outcome
4
Implement solution approaches, integrate and test
8
For each component of the solution architecture determine appropriate solution approaches
7
Decide upon solution architecture
6
Propose alternative solution architectures for the whole problem
5
Step V: Implementation and test
Step III: Architecture design
(A) Determine the nature of each component
(B) Choose the solution approach matching the solution architecture and its decision components
(C) Determine the requirement under which the component should be tackled
(D) Benchmarking of solution and testing
Step IV: Component solution design


problem/D.V. nature
continuous
discrete
Derivability
no
yes
Derivative-free
Differentiable
Representation
0-1
int
combinatorial
Binary
Integer
Combinatorial
PSO
DE
TS
GA
Gradient descent
HC
Greedy algorithms
B&B
MAS
Metaheuristics
Classic local search
Greedy algorithms
Solvers
MAS
Scalability
Speed
Quality
Optimality
Stability & consistency
Problem characteristics
Algorithms
Solution families
Context Requirements