Missions d'exploration multirobots décentralisée garantie

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LIX - Cosynus

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Introduction	Multi-agent exploration problem	мстѕ	Current directions	References
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# Table of contents

#### 1 Introduction

2 Multi-agent exploration problem

#### **3 MCTS**

- Definition
- Variations

**4** Current directions



5900

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E 2 / 15 April 19, 2023

Introduction ●	Multi-agent exploration problem O	<b>MCTS</b> 0000 000	Current directions	References
Introduction				

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems



596

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Seminaire AID

April 19, 2023 3 / 15

Introduction ●	Multi-agent exploration problem O	<b>MCTS</b> 0000 000	Current directions	References
Introduction				

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:



596

Mathilde Jeannin (LIX)

Seminaire AID

April 19, 2023 3 / 15

<ロ> (四) (四) (三) (三) (三)

Introduction ●	<b>Multi-agent exploration problem</b> O	<b>MCTS</b> 0000 000	Current directions	References
Introduction				

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:

• Distributed multirobots exploration



590

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April 19, 2023 3 / 15

Introduction ●	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References
Introduction				

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:

- Distributed multirobots exploration
- Unknown environment



590

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April 19, 2023 3 / 15

Introduction •	<b>Multi-agent exploration problem</b> O	MCTS 0000 000	Current directions	References

Problem:

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:

- Distributed multirobots exploration
- Unknown environment
- Partial communication



590

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April 19, 2023 3 / 15

Introduction •	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References

Problem:

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:

- Distributed multirobots exploration
- Unknown environment
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Current directions:

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▲ 重 ▶ 重 *√ Q (*~) April 19, 2023 <u>3 / 15</u>

Introduction ●	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References

Problem:

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:

- Distributed multirobots exploration
- Unknown environment
- Partial communication

Current directions:

- Probabilistic solutions:
  - Monte Carlo Tree Search (MCTS)
  - Variations

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Seminaire AID

Э April 19, 2023 3/15

590

Introduction •	<b>Multi-agent exploration problem</b> O	MCTS 0000 000	Current directions	References

Problem:

• Find a robust solution under realistic assumptions (communication...) to multi-agents exploration problems

Assumptions:

- Distributed multirobots exploration
- Unknown environment
- Partial communication

Current directions:

- Probabilistic solutions:
  - Monte Carlo Tree Search (MCTS)
  - Variations
- (Use knowledge:
  - Epistemic logic
  - Assumption on the map)

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-00

April 19, 2023

590

3/15

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Introduction O	Multi-agent exploration problem ●	<b>MCTS</b>	Current directions	References
		000		

Multi-agent exploration problem

Assumptions:

- Distributed multirobots exploration
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590

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Seminaire AID

April 19, 2023 4 / 15

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Introduction	Multi-agent exploration problem	мстѕ	Current directions	References
0	•	<u> </u>	000	

## Multi-agent exploration problem

Assumptions:

- Distributed multirobots exploration
- Unknown environment
- Partial communication

- Possible directions:
  - Objectives
    - Auction methods
    - Allocation tasks
    - ...
  - Planification
    - Heuristic methods (A\*)

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- Frontier methods
- ...
- Global
  - Learning methods
  - MCTS
  - ...

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E April 19, 2023 4 / 15

500

Introduction O	Multi-agent exploration problem O	MCTS ●000 ○○○	Current directions	References
Definition				
MCTS - Exa	mple			

$$UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$$

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₹ April 19, 2023 5 / 15

Introduction O	<b>Multi-agent exploration problem</b> O	MCTS 0●00 000	Current directions	References
Definition				
MCTS				

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Mathilde Jeannin (LIX)	Seminaire AID	April 19, 202	3 6/15

Introduction O	Multi-agent exploration problem O	MCTS 00●0 000	Current directions	References
Definition				
MCTS				





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Mathilde Jeannin (LIX)	Seminaire AID		April 19,	2023	7 / 1

Introduction O	<b>Multi-agent exploration problem</b> O	MCTS 00●0 000	Current directions	References
Definition				
MCTS				



• Tree policy: Upper Confidence Bound  $UCB = \bar{X} + \sqrt{\frac{2ln(n_{parent})}{n}}$ 

	4		500
Mathilde leannin (LIX)	Seminaire AID	April 19 2023	7 / 15

Introduction O	Multi-agent exploration problem O	MCTS 00●0 000	Current directions	References
Definition				
MCTS				



• Tree policy: Upper Confidence Bound  $UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$  $\rightarrow$  exploitation term + exploration term

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▲□▶ ▲圖▶ ▲厘▶ ▲厘▶ April 19, 2023 7 / 15

500

Introduction O	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References
Definition				
MCTS				



- Tree policy: Upper Confidence Bound  $UCB = \bar{X} + \sqrt{\frac{2ln(n_{parent})}{n}}$  $\rightarrow$  exploitation term + exploration term
- Default policy: random choice

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Introduction O	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References
Definition				
МСТЅ				

$$UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$$



590

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Seminaire AID

电 April 19, 2023 8 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References
Definition				
мстѕ				

 $UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$ Selection





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₹ April 19, 2023 8 / 15

< 日 > < 回 > < 回 > < 回 > < 回 >

Introduction O	Multi-agent exploration problem O	MCTS 000● 000	Current directions	References
Definition				
MCTS				

 $UCB = \bar{X} + \chi$ Expansion  $\frac{2ln(n_{parent})}{n}$ 





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₹ April 19, 2023 8 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 000● 000	Current directions	References
Definition				
MCTS				

 $UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$ Simulation



Introduction O	Multi-agent exploration problem O	MCTS 000● 000	Current directions	References
Definition				
мстѕ				

Example:  $UCB = \bar{X} + \sqrt{\frac{2In(n_{parent})}{n}}$ Backpropagation + Selection





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April 19, 2023 8 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 0000 000	Current directions	References
Definition				
MCTS				

 $UCB = \bar{X} + \chi$ Expansion  $\frac{2ln(n_{parent})}{n}$ 





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₹ April 19, 2023 8 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 000● 000	Current directions	References
Definition				
MCTS				

 $UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$ Simulation



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Mathilde Jeannin (LIX)	Seminaire AID	April 19, 2023	8 / 15

Introduction O	<b>Multi-agent exploration problem</b> O	MCTS 000● 000	Current directions	References
Definition				
MCTS				

 $UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$ Backpropagation





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Seminaire AID

April 19, 2023 8 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 000● 000	Current directions	References
Definition				
MCTS				

 $UCB = \bar{X} + \sqrt{\frac{2\ln(n_{parent})}{n}}$ If end of rollout, choice of the real action  $\rightarrow$  several criteria





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Seminaire AID

April 19, 2023 8 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 0000 ●00	Current directions	References
Variations				
MCTS				

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Mathilde Jeannin (LIX)	Seminaire AID	April 19, 2023	9 / 15

Introduction O	Multi-agent exploration problem O	MCTS 0000 ●00	Current directions	References
Variations				
MCTS				

- Can usually demonstrate that UCB converges toward an optimal solution
- Easily parallelizable
- Robust to the mission
- Online and offline solution



590

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Seminaire AID

April 19, 2023 9 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 0000 ●00	Current directions	References
Variations				
MCTS				

- Can usually demonstrate that UCB converges toward an optimal solution
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- Online and offline solution

- Computing power
- UCB performs poorly in domains with many trap states

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500

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Seminaire AID

April 19, 2023 9 / 15

Introduction O	Multi-agent exploration problem O	MCTS 0000 ●00	Current directions	References
Variations				
MCTS				

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- Computing power
- UCB performs poorly in domains with many trap states

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#### Variations

- Decentralized MCTS : use communication to optimize its own tree and reduce computating
- Partially Observable environment : use the inherent properties (random) of MCTS and particle filter

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April 19, 2023 9 / 15

590

Introduction O	Multi-agent exploration problem O	MCTS 0000 0●0	Current directions	References
Variations				
MCTS				

Decentralized MCTS

Problem: Multi-robot exploration mission + Decentralized

Best et al. 2019



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Mathilde Jeannin (LIX)	Seminaire AID	April 19, 2023	10 / 15

Introduction O	Multi-agent exploration problem O	MCTS ○○○○ ○●○	Current directions	References
Variations				
MCTS				

#### Decentralized MCTS

Problem: Multi-robot exploration mission + Decentralized

- 1 robot = 1 tree
- root = actual state
- 1 tree = sample of possible sequences of actions over a time horizon

Best et al. 2019

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 April 19, 2023
 10 / 15

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Introduction O	Multi-agent exploration problem O	MCTS ○○○○ ○●○	Current directions	References
Variations				
MCTS				

#### Decentralized MCTS

Problem: Multi-robot exploration mission + Decentralized

- 1 robot = 1 tree
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Introduction O	Multi-agent exploration problem O	MCTS ○○○○ ○●○	Current directions	References
Variations				
MCTS				

# Decentralized MCTS Problem: Multi-robot exploration mission + Decentralized 1 robot = 1 tree root = actual state 1 tree = sample of possible sequences of actions over a time horizon if communication is possible, share their trees Optimization of the set of possibles actions = prune the tree

Best et al. 2019



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April 19, 2023 10 / 15

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Introduction O	Multi-agent exploration problem O	MCTS ○○○○ ○○●	Current directions	References
Variations				
MCTS				

#### Partially Observable MCTS

Problem: Exploration mission + partially observable

 $\rightarrow$  Particle filter = compute random posterior distributions of a partially observable state to find the most accurate.

 $\rightarrow$  MCTS = compute random posterior actions to find the optimal one. Idea :



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April 19, 2023 11 / 15

Introduction O	Multi-agent exploration problem O	MCTS 0000 00●	Current directions	References
Variations				
MCTS				

#### Partially Observable MCTS

Problem: Exploration mission + partially observable

 $\rightarrow$  Particle filter = compute random posterior distributions of a partially observable state to find the most accurate.

 $\rightarrow$  MCTS = compute random posterior actions to find the optimal one.

Idea :

- Mix MCTS and particle filter
- I node = either an action or on observation
- 1 simulation = update 1 particle

Silver and Veness 2010

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Seminaire AID

April 19, 2023 11 / 15

3

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Introduction O	Multi-agent exploration problem O	MCTS 0000 00●	Current directions	References
Variations				
MCTS				

#### Partially Observable MCTS

Problem: Exploration mission + partially observable

 $\rightarrow$  Particle filter = compute random posterior distributions of a partially observable state to find the most accurate.

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- Mix MCTS and particle filter
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Silver and Veness 2010

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Seminaire AID

April 19, 2023 11 / 15

3

▲□▶ ▲□▶ ▲三▶

Introduction O	Multi-agent exploration problem O	MCTS 0000 00●	Current directions	References
Variations				
MCTS				

Partially Observable MCTS	
$\begin{array}{l} \underline{\text{Problem:}} \ \text{Exploration mission} + \text{partially observable} \\ \rightarrow \ \text{Particle filter} = \text{compute random posterior distribution} \\ \text{to find the most accurate.} \\ \rightarrow \ \text{MCTS} = compute random posterior actions to relate in the second second$	e ibutions of a partially observable state find the optimal one.
<ul> <li>Mix MCTS and particle filter</li> <li>1 node = either an action or on observation →</li> <li>1 simulation = update 1 particle</li> </ul>	Update belief state and find optimal action
Silver and Veness 2010	<u>Il</u>

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Ę April 19, 2023 11 / 15

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Introduction O	Multi-agent exploration problem O	MCTS 0000 000	Current directions ●○○	References

- How to use knowledge of the environment to make exploration more efficient ?
- Where are we according what we see ? Building ? Outdoor ?
- What we will probably see next ?



Introduction	Multi-agent exploration problem	мстѕ	Current directions	References
0	0	0000 000	000	

# **Current directions**

#### **Temporal Logic**

- Specify tasks :
  - Rendez-vous/ gathering
  - Communication
  - Get back the info to the operator
- If lots of robots :
  - Specify density of the swarm (Djeumou, Xu, and Topcu 2020; Djeumou, Xu, Cubuktepe, et al. 2021)
  - Control if that they are not too far from each other

#### **Epistemic Logic**

- Task to do only when we know something
- Consensus over a leader, a task, an information, ...
- Way to modelize communication

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Seminaire AID

April 19, 2023 13 / 15

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Thank you !



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April 19<u>, 2023 15 / 15</u>

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