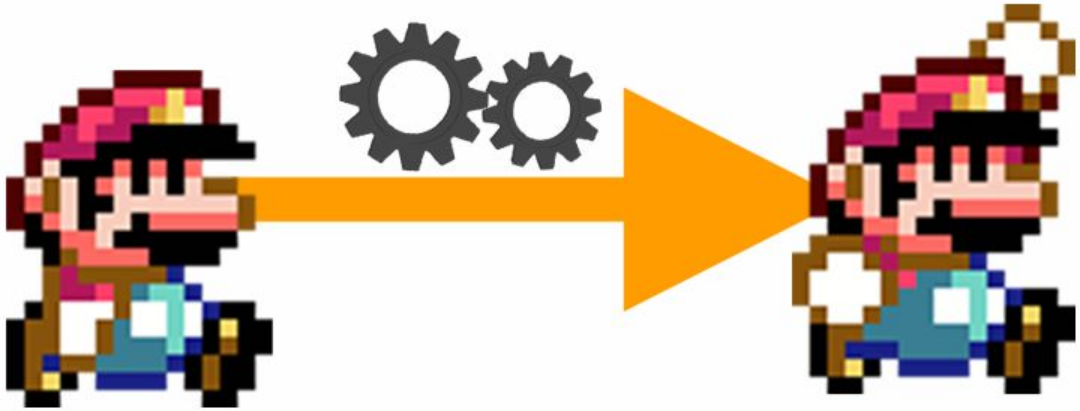
Operational Transformation

and its Relevance in Games



by Felix Pauck, Patrick Steffens

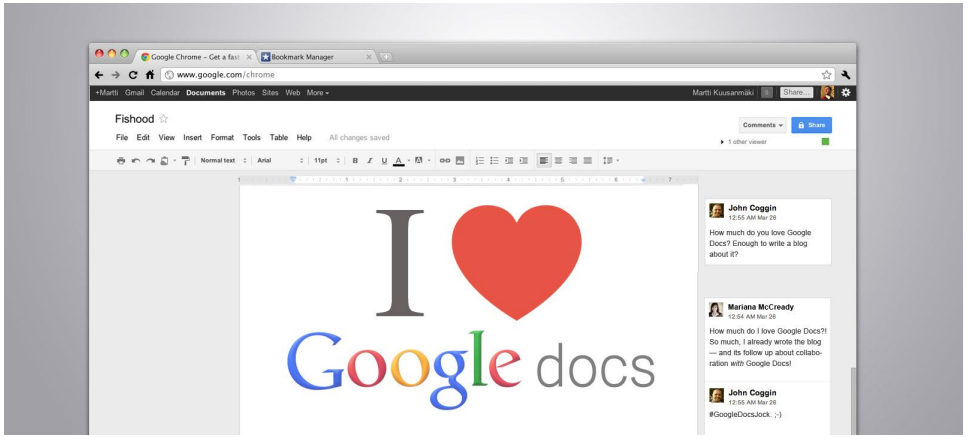
Outline

- **Introduction**
- **Solitaire**
  - Simplified Solitaire
  - Execution Scenario
- **Consistency Models**
  - CC Model
  - CCI Model
- **OT Algorithm**
  - OT Functions
- **Collaborative Games**

Introduction

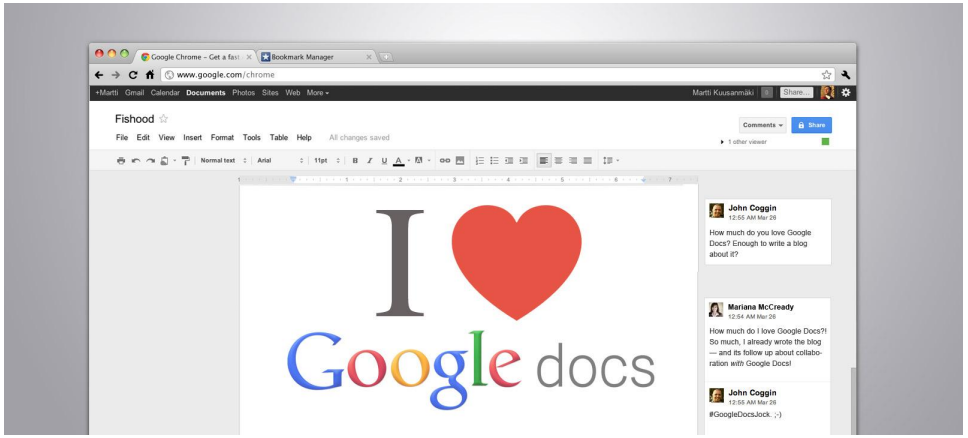
Google Docs

- Collaborative real-time editor
- Effects of operation instantly available



Introduction

Google Docs



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- Solution: **Operational Transformation**

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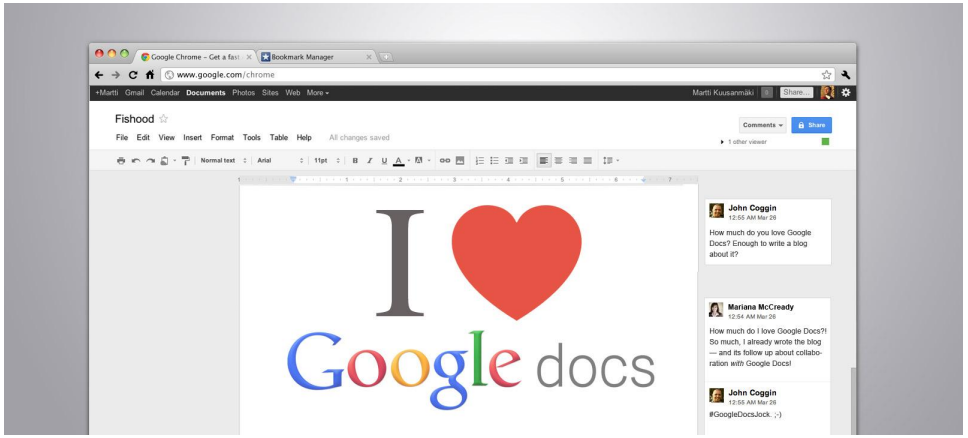

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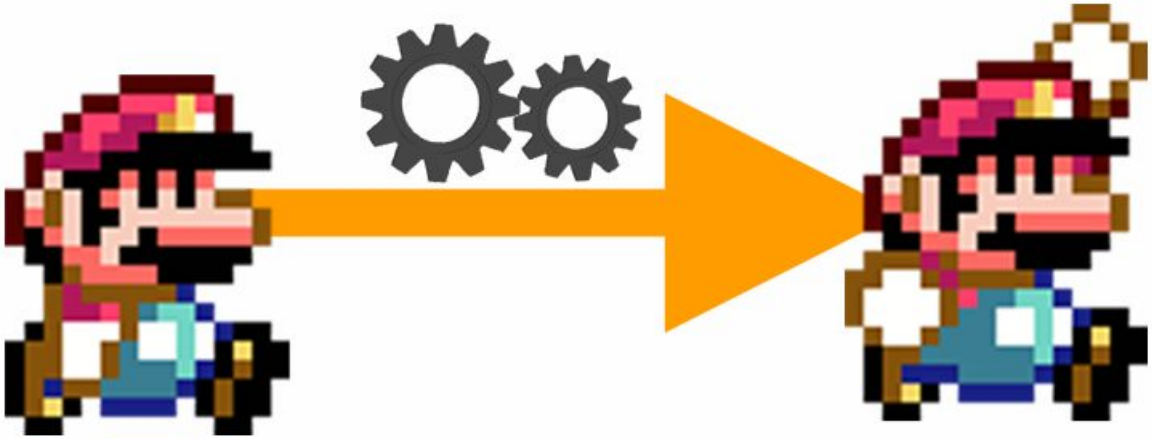
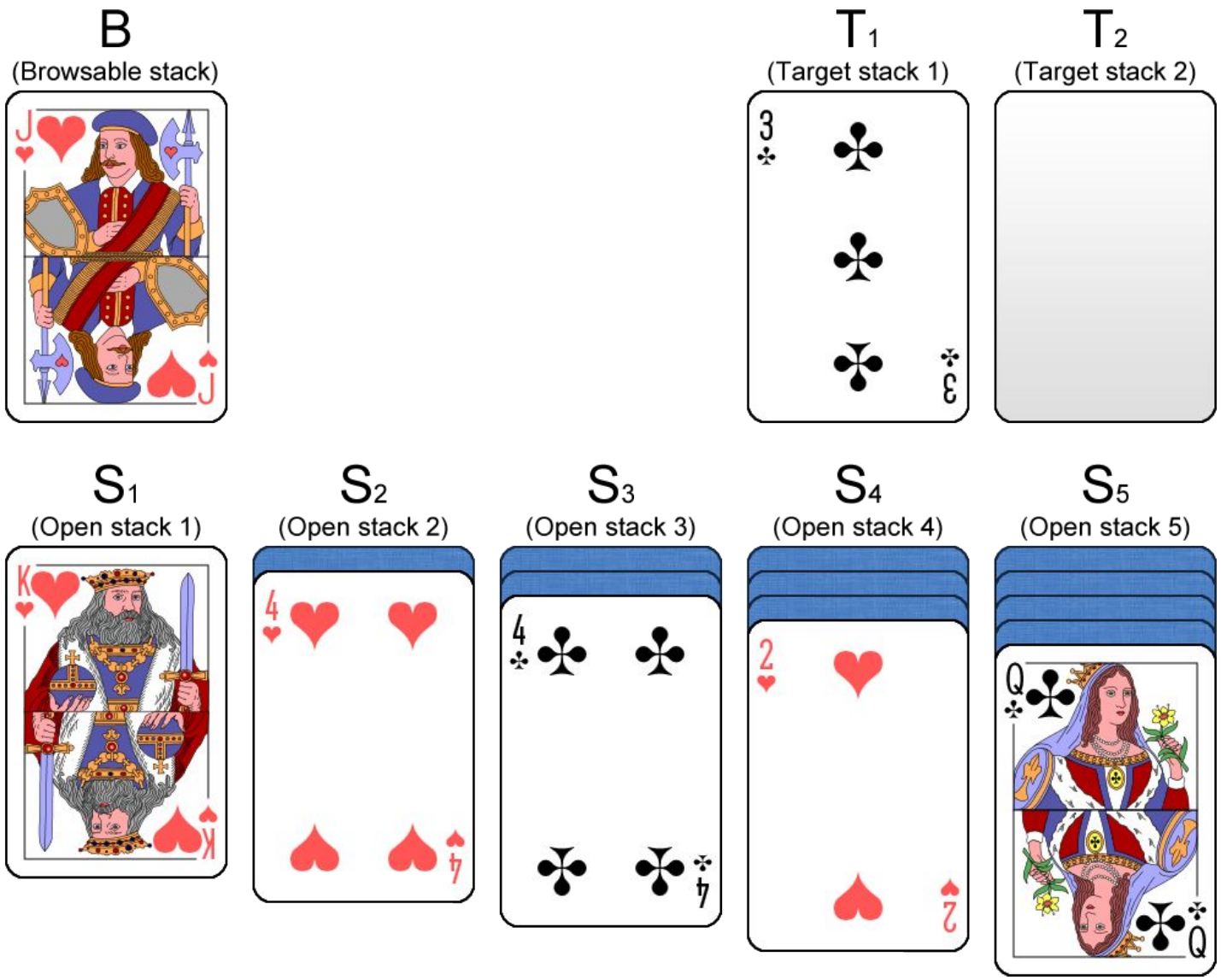


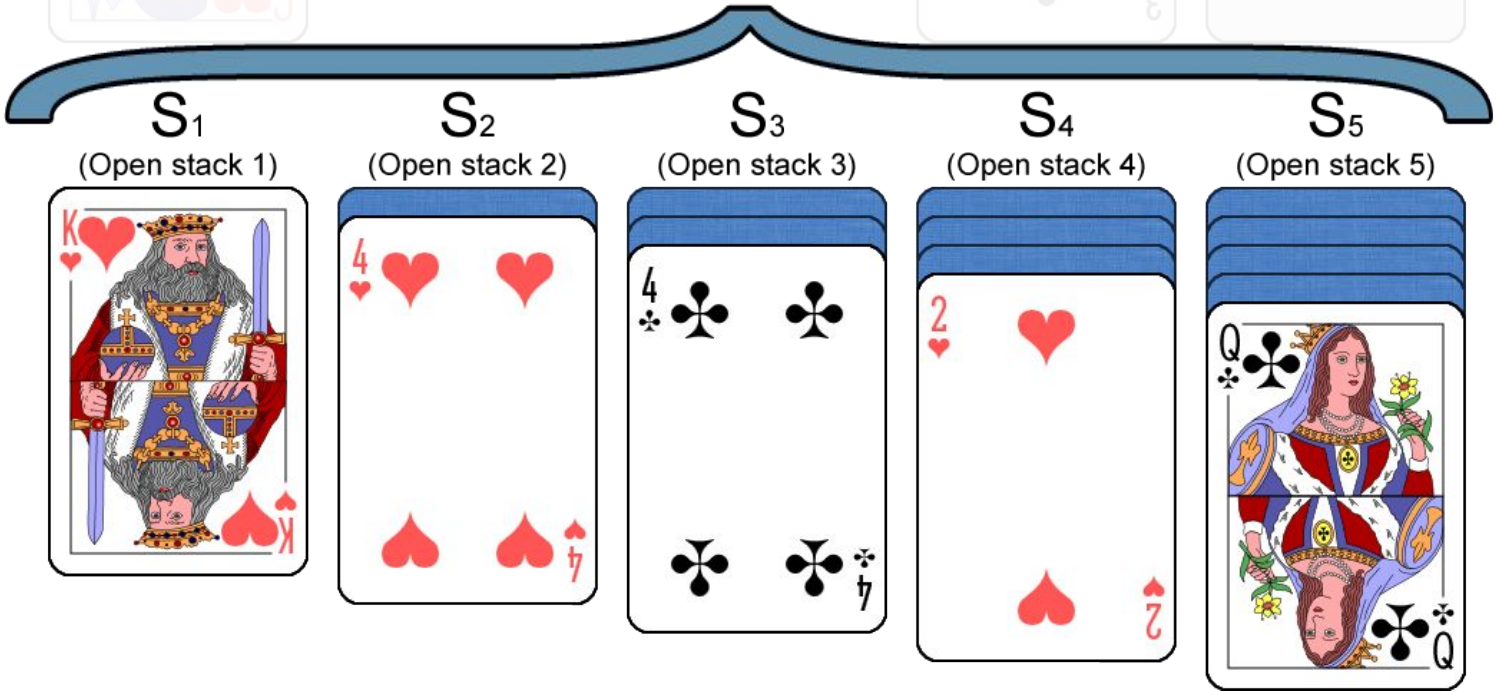
Simplified Solitaire



Simplified Solitaire

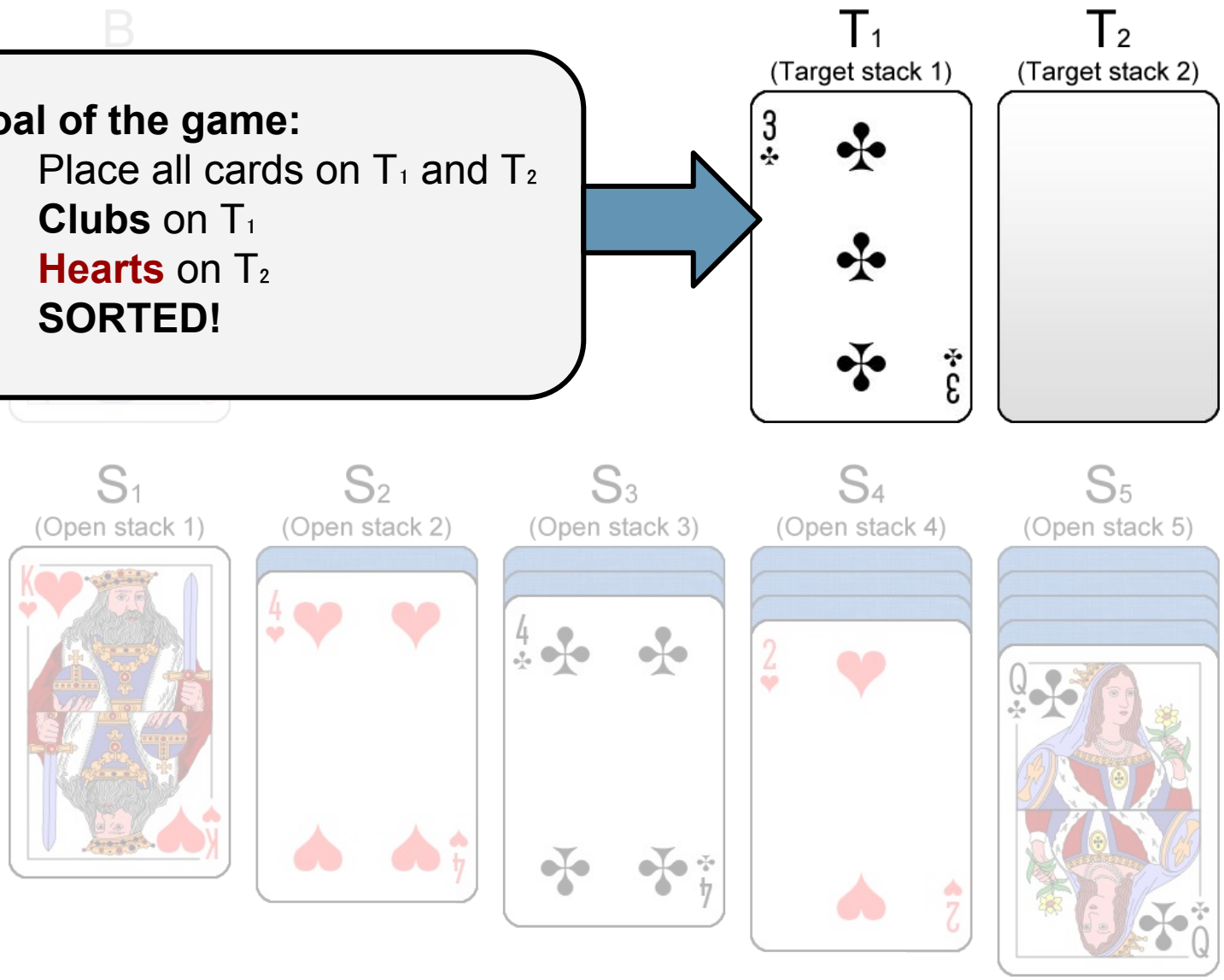
- **Clubs** on **Hearts**
- **Hearts** on **Clubs**

- Hidden cards
  (can only be uncovered if they are on top)



Simplified Solitaire

- **Goal of the game:**
  - Place all cards on T_1 and T_2
  - **Clubs** on T_1
  - **Hearts** on T_2
  - **SORTED!**



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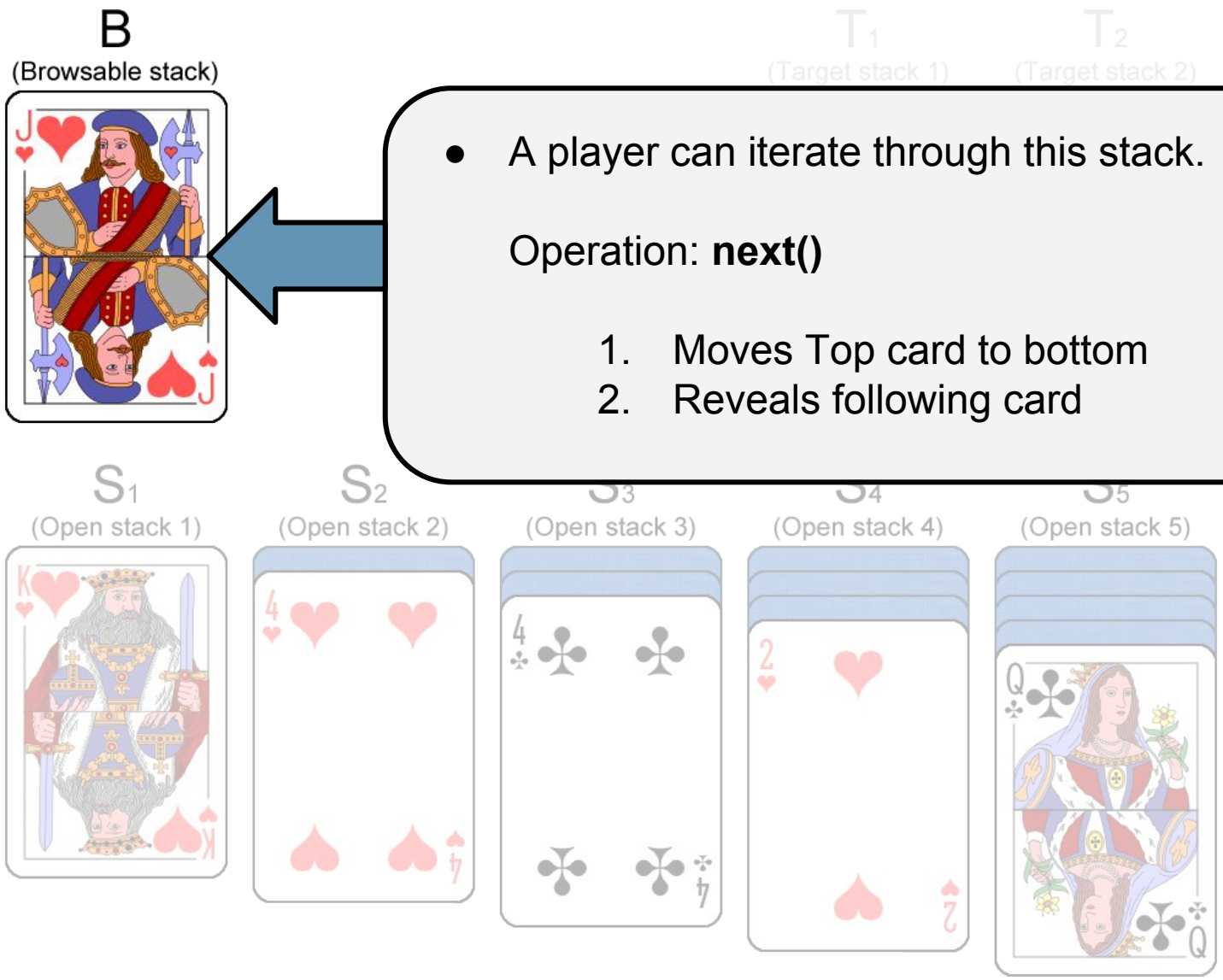
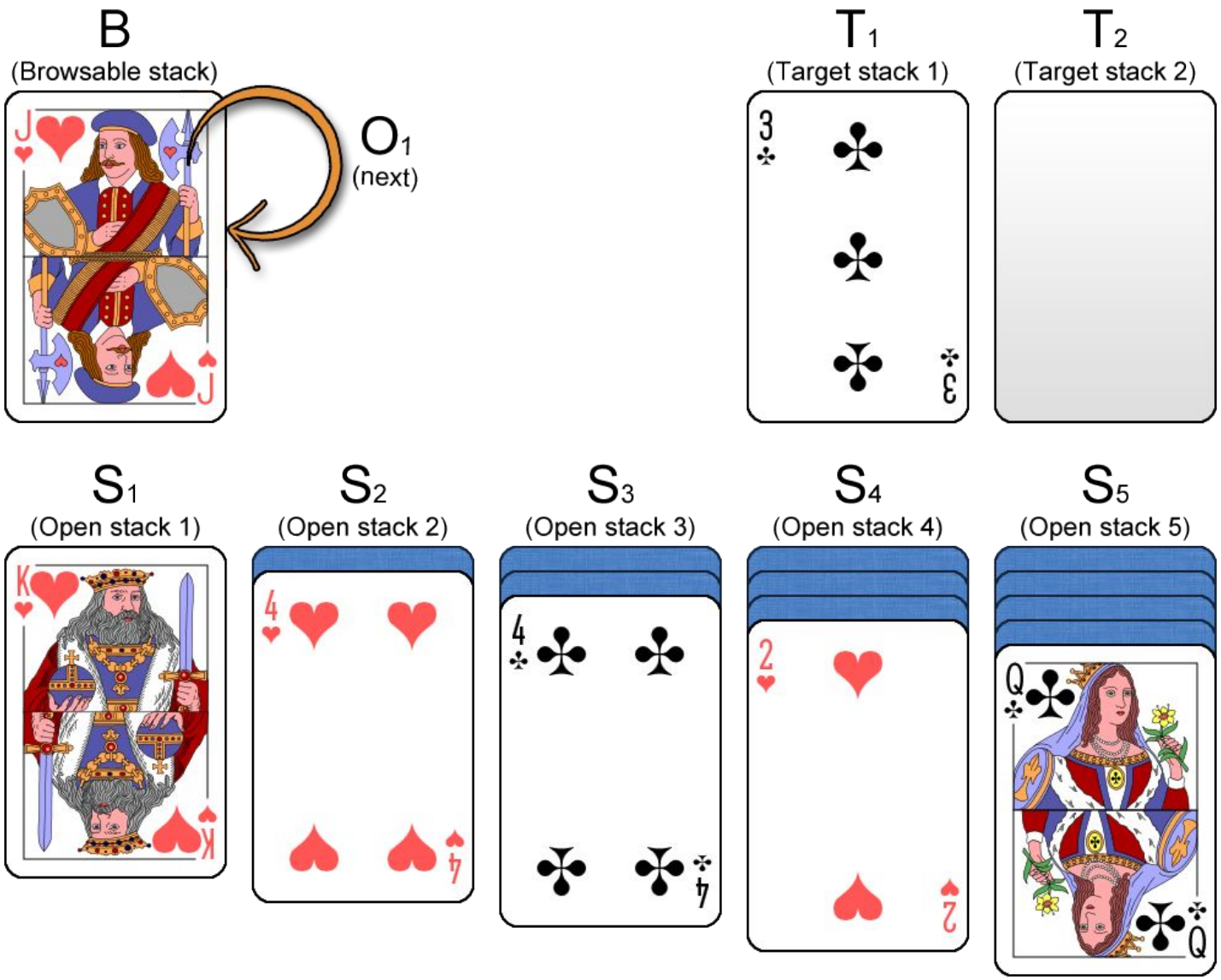


- A player can iterate through this stack.

  Operation: **next()**

  1. Moves Top card to bottom
  2. Reveals following card

Simplified Solitaire



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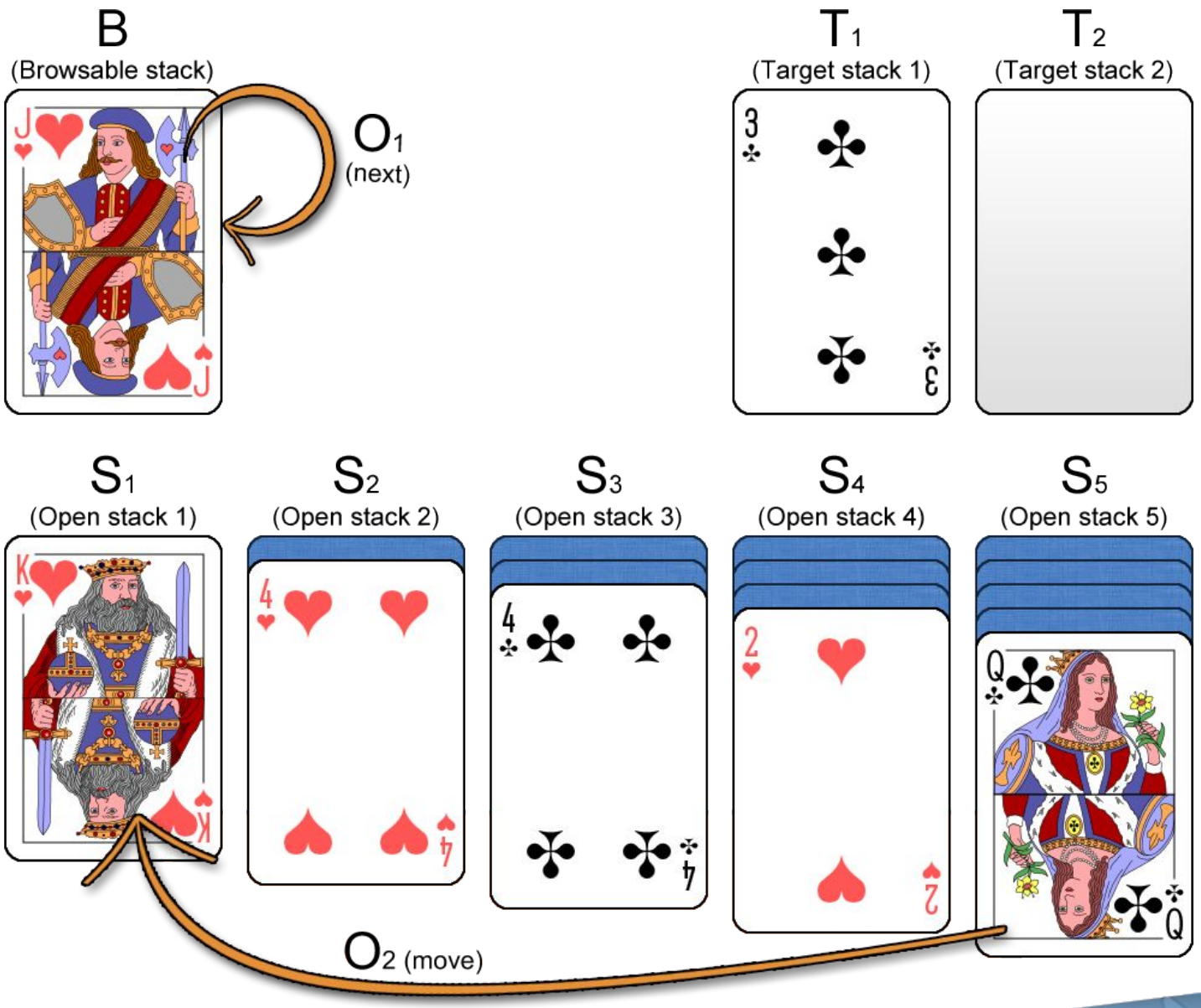

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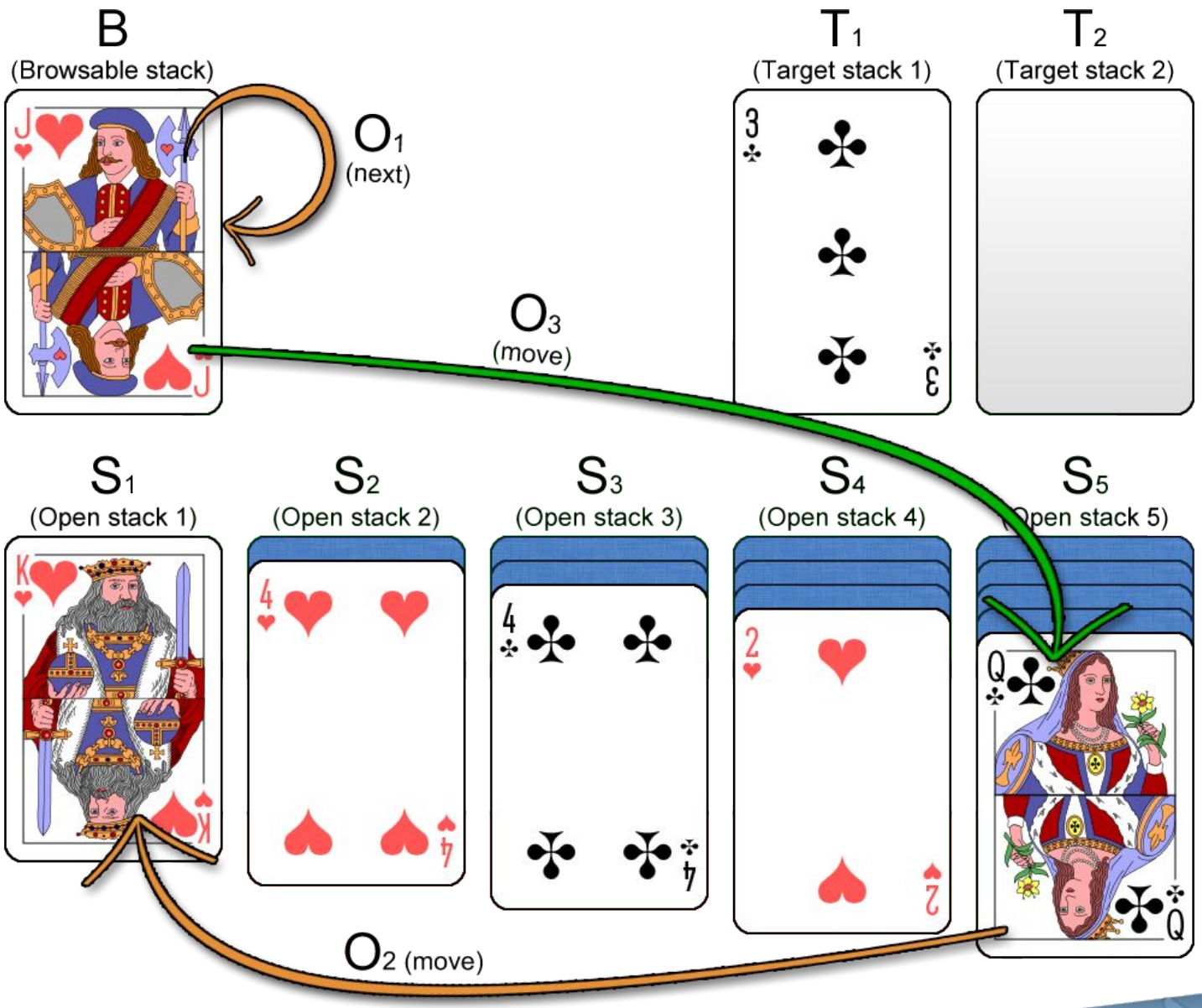

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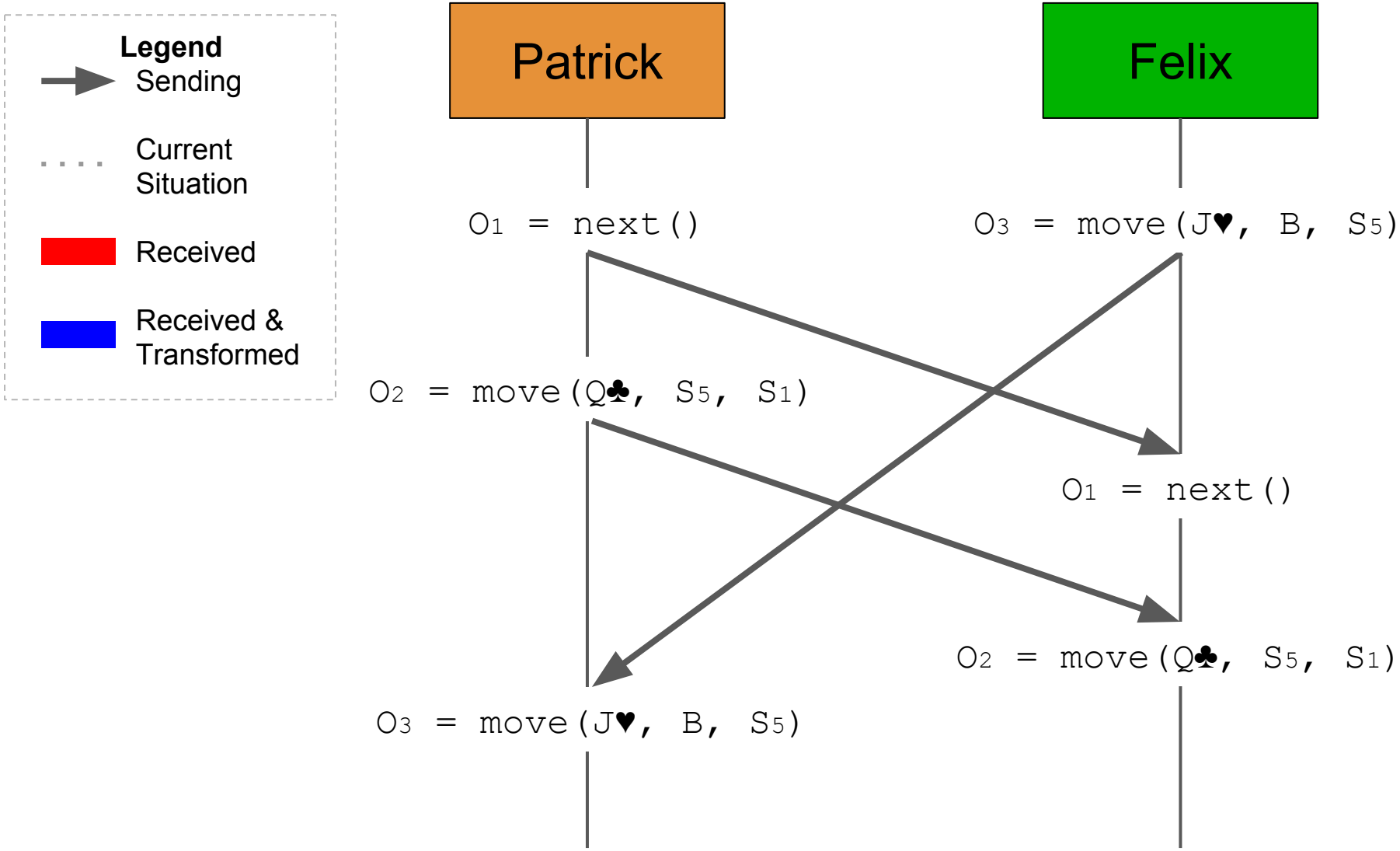

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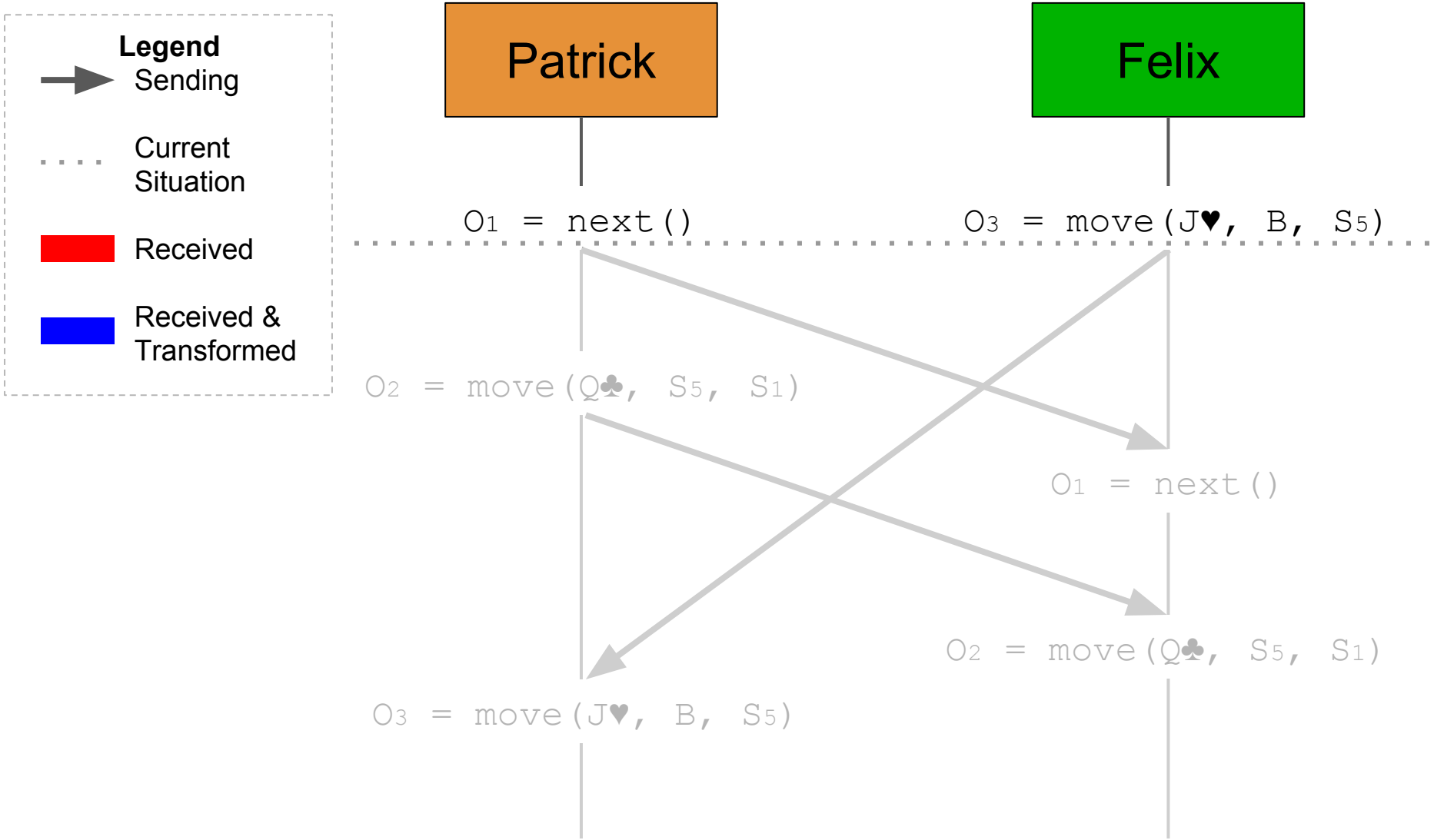

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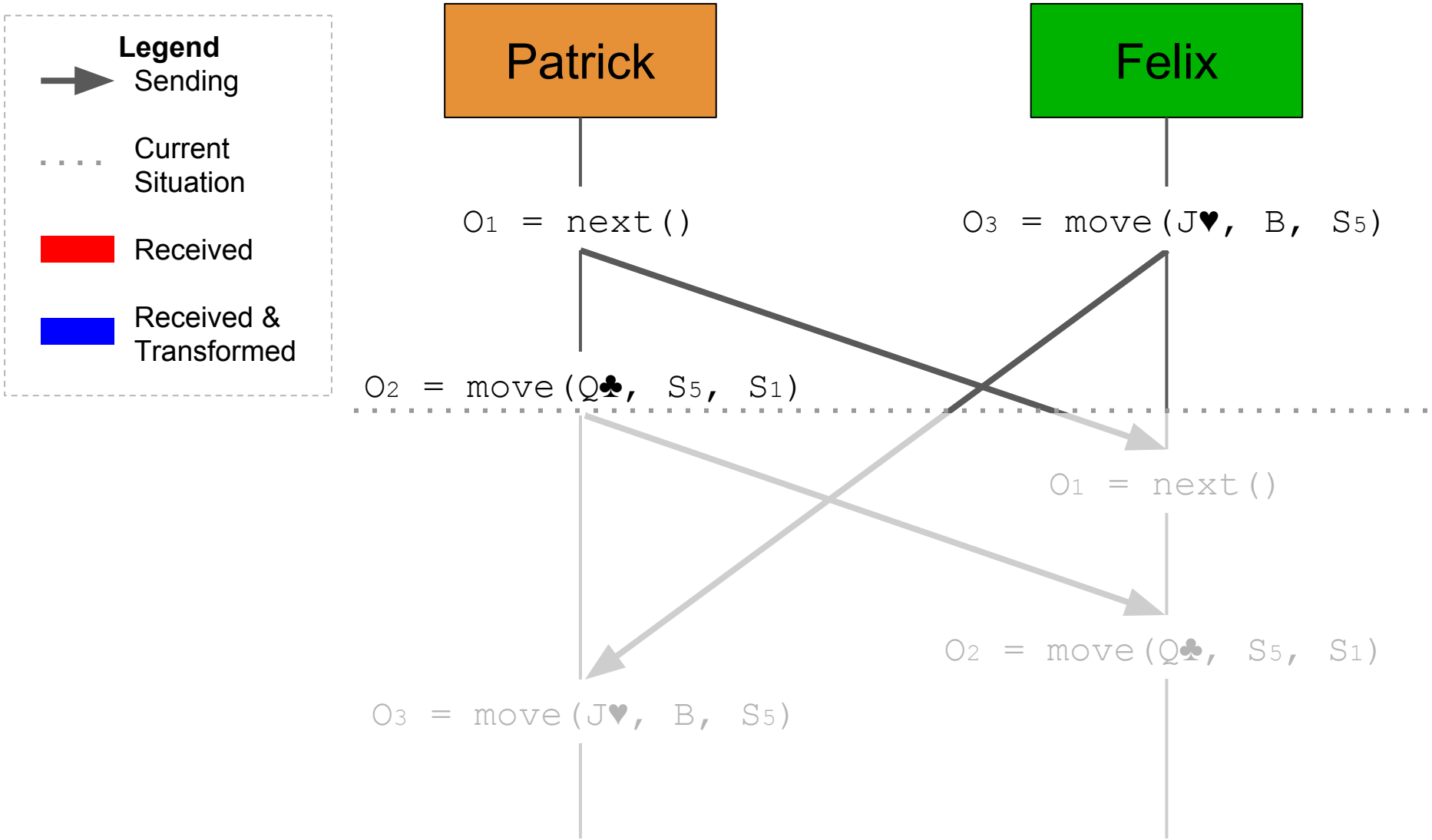

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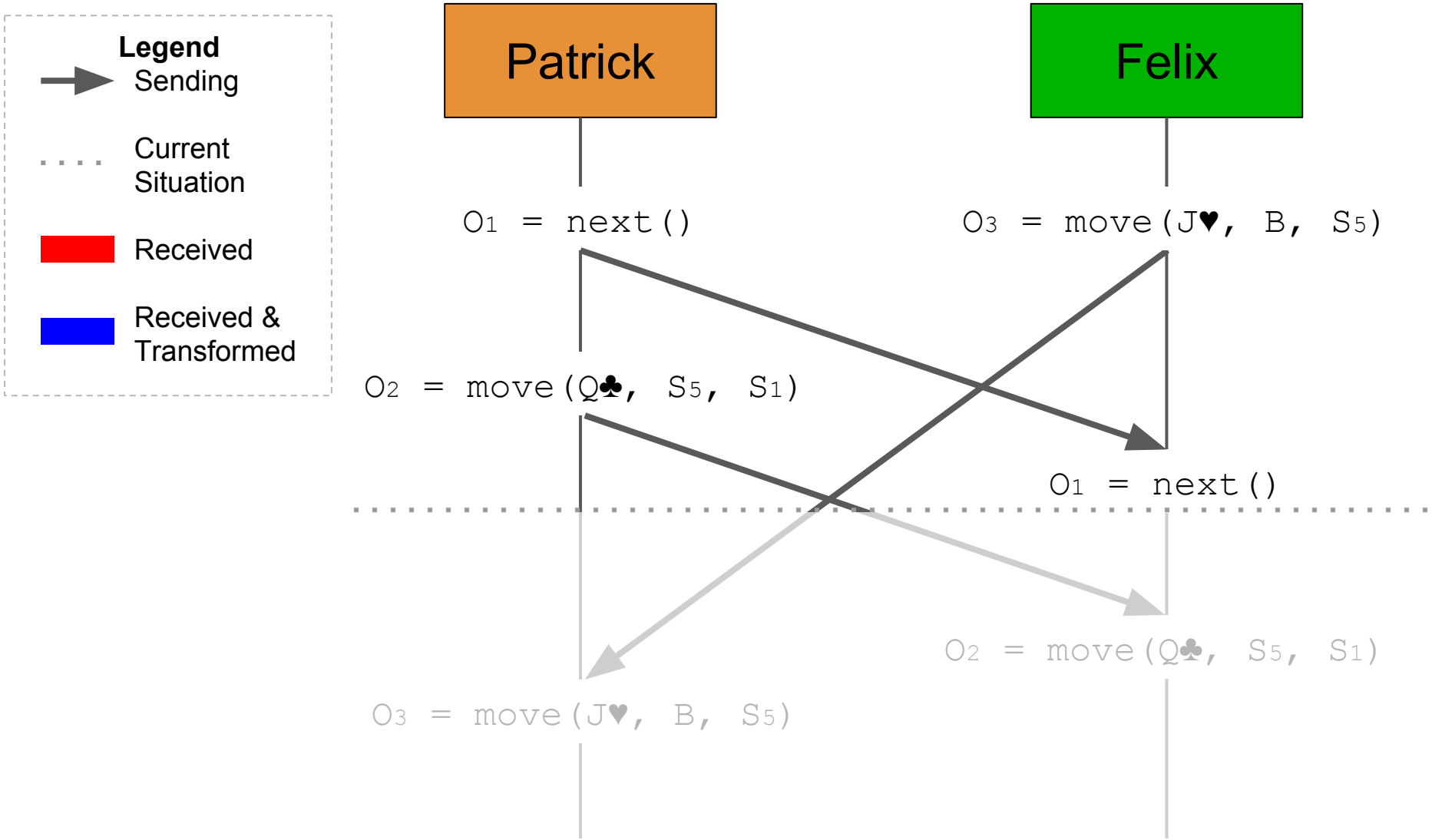

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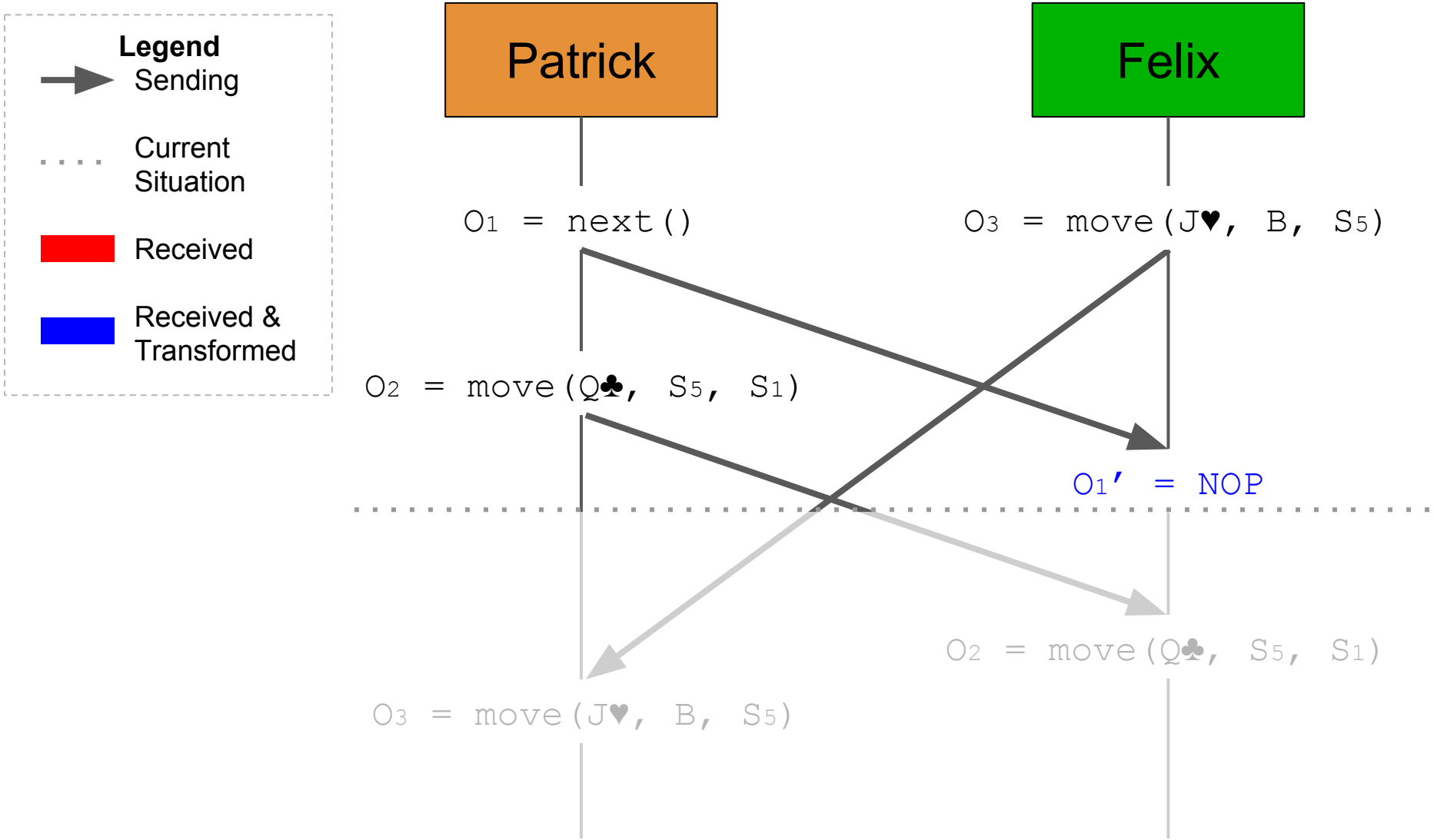

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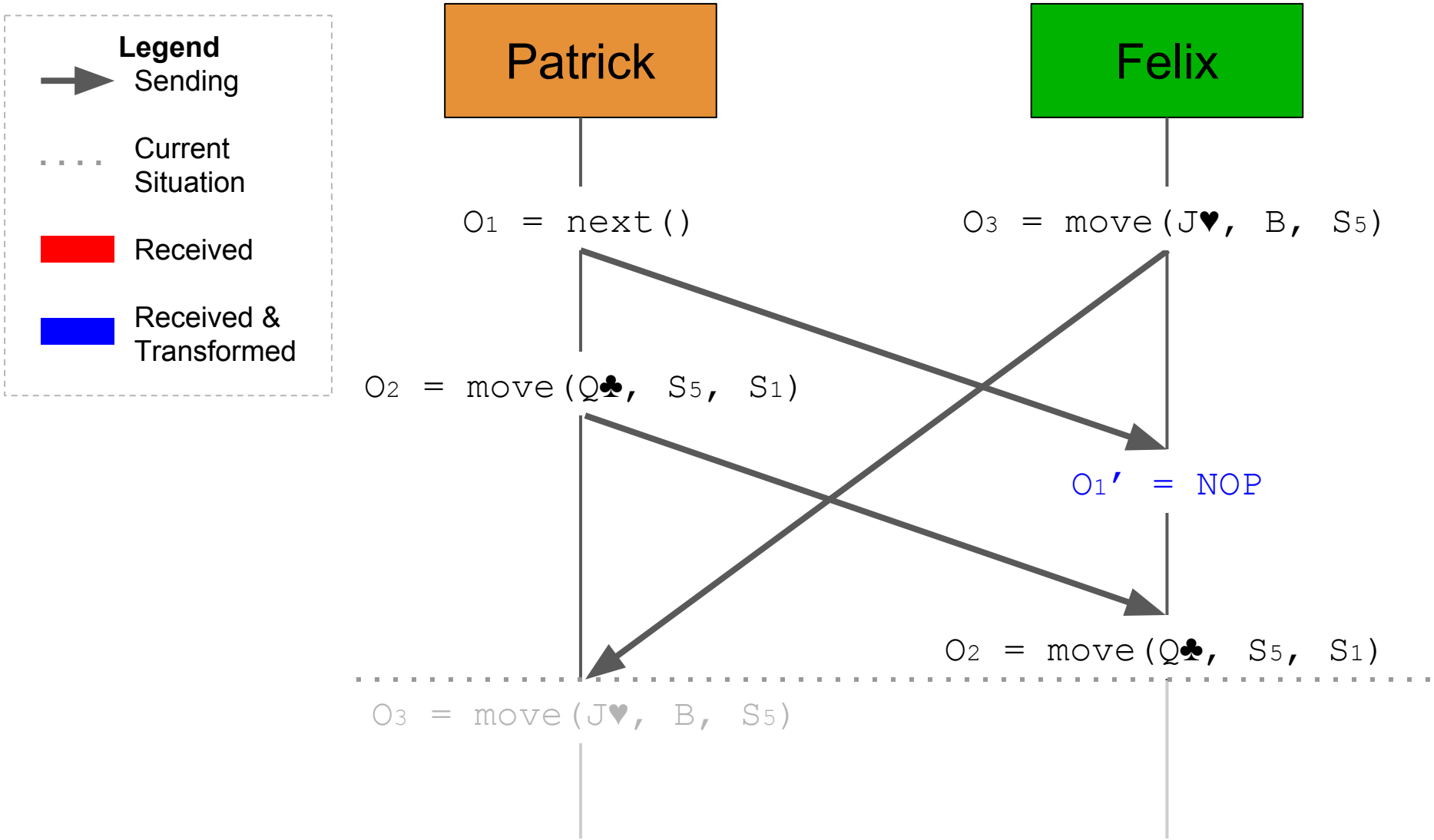

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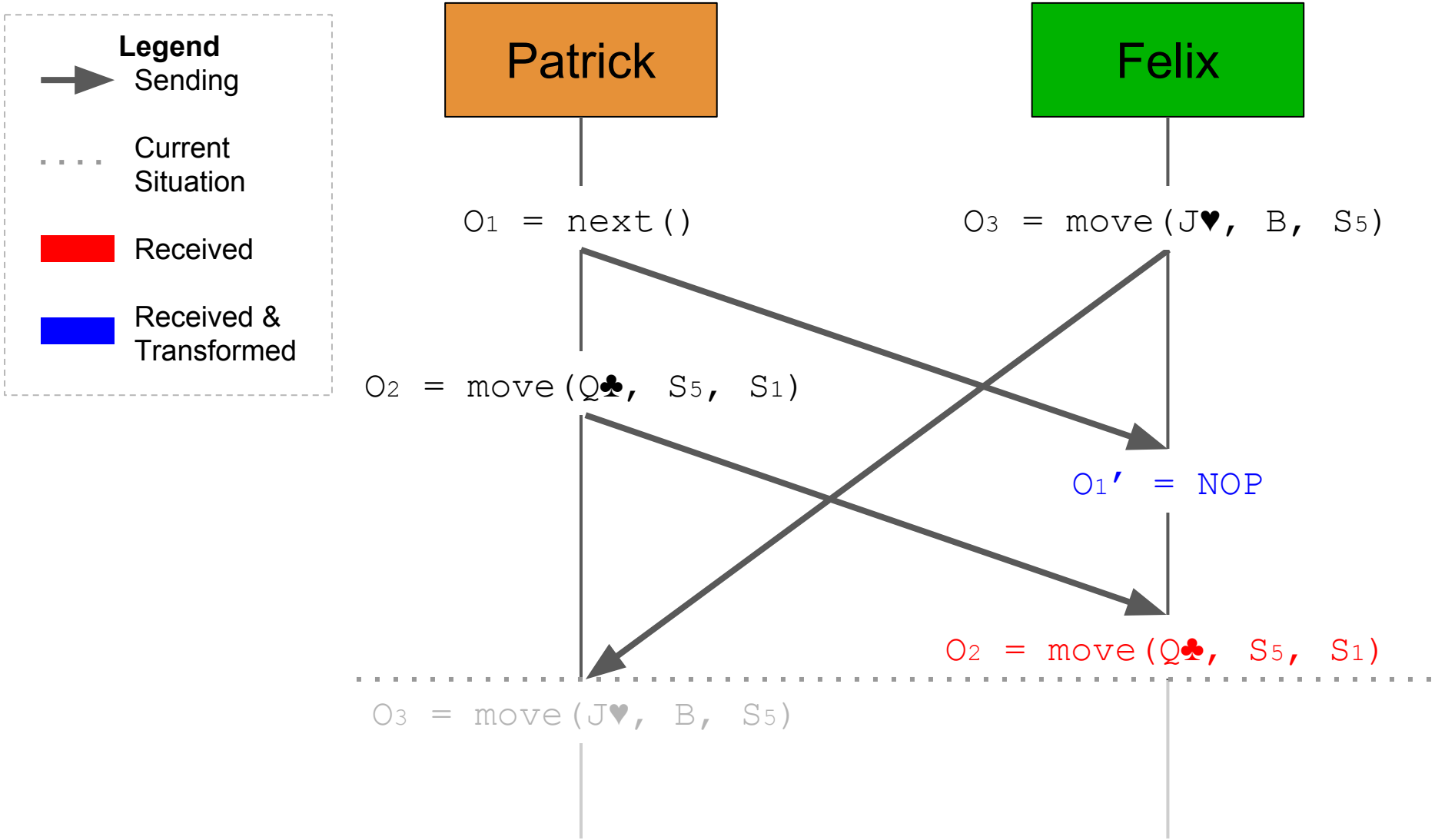

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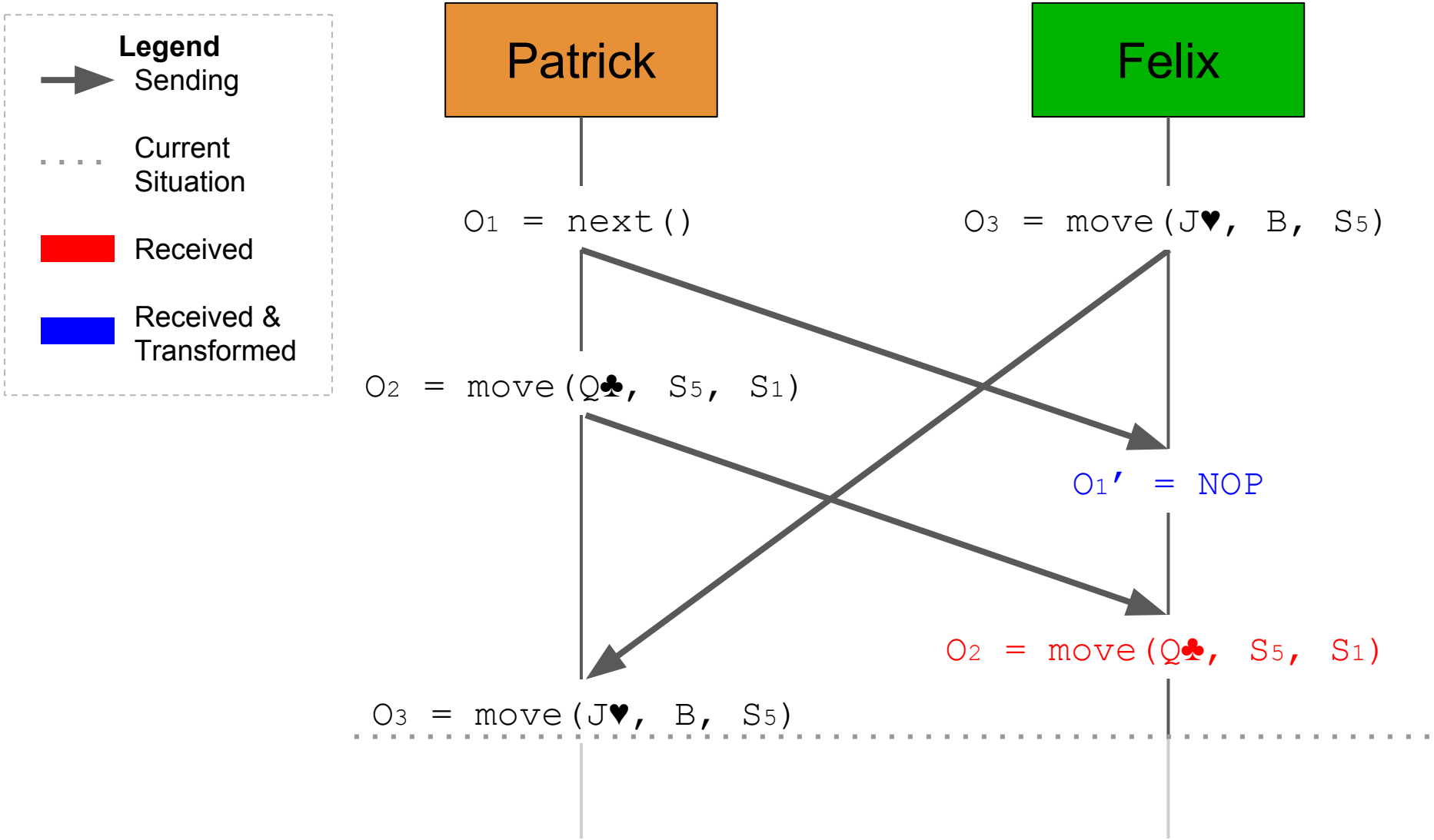

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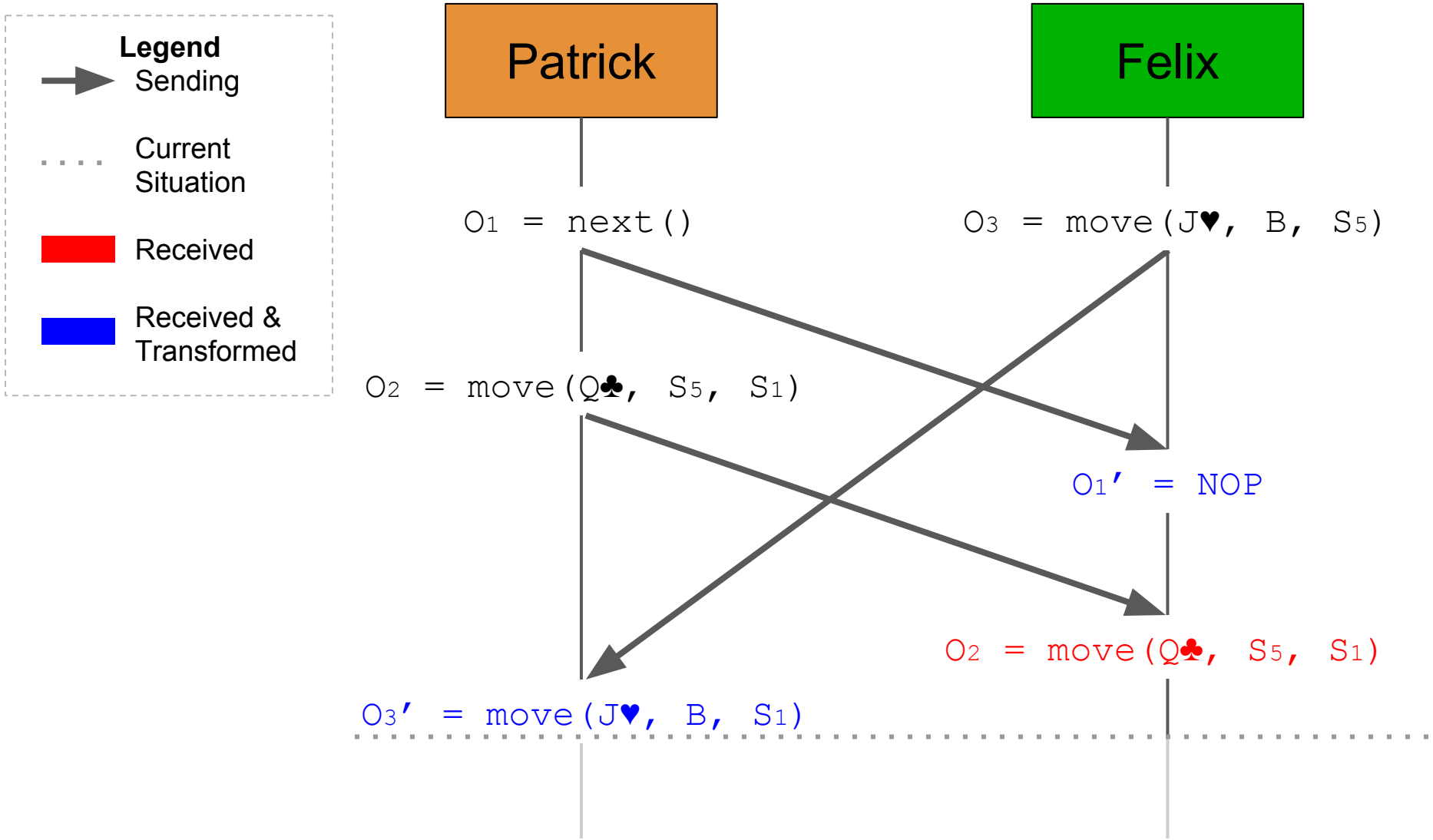

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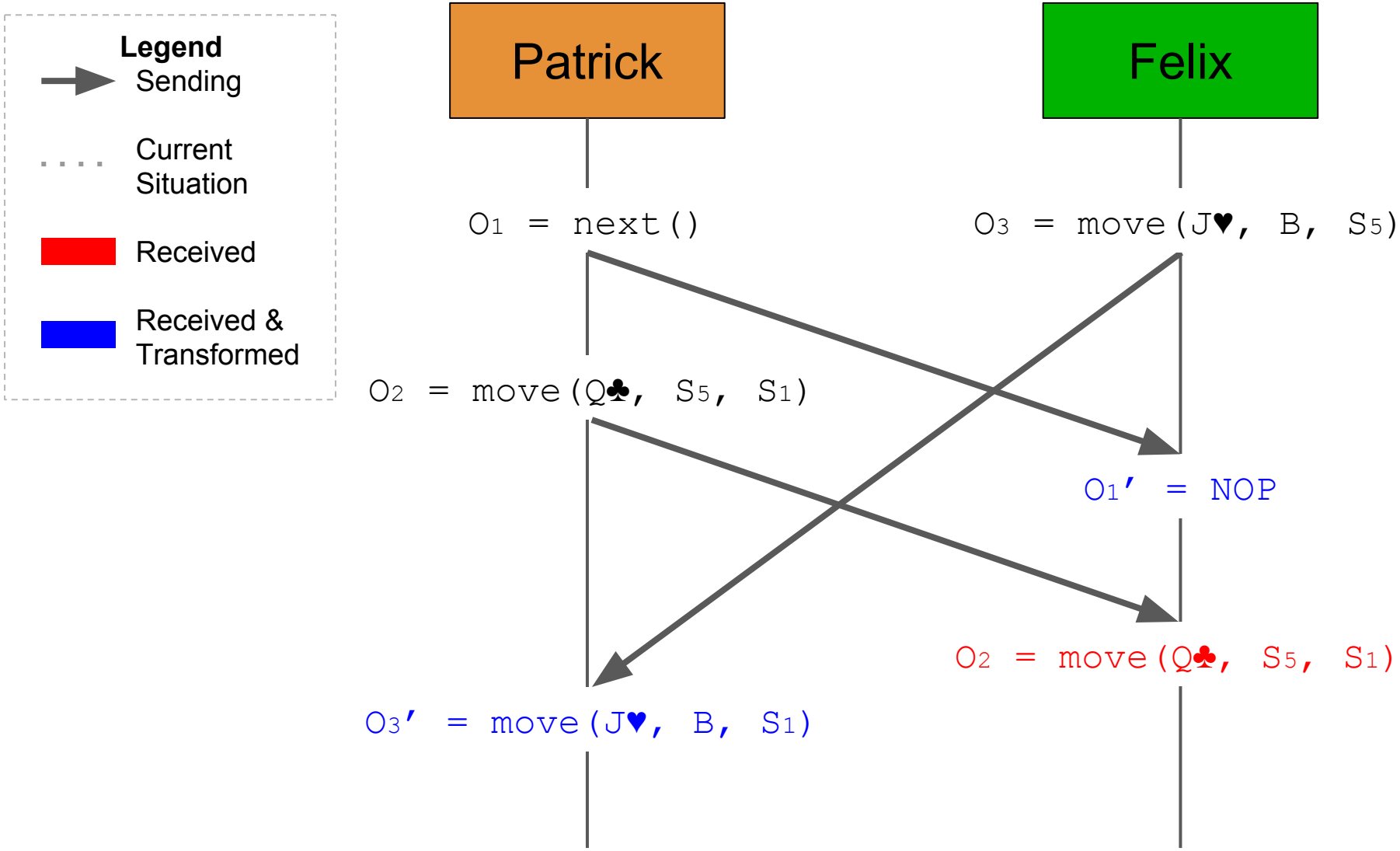

Consistency Models

- **CC Model**
  - **C**ausality (Precedence): All dependent operations are executed in the same order at all sites.
  - **C**onvergence: The configuration reached after the execution of a set of operations is the same at all sites.

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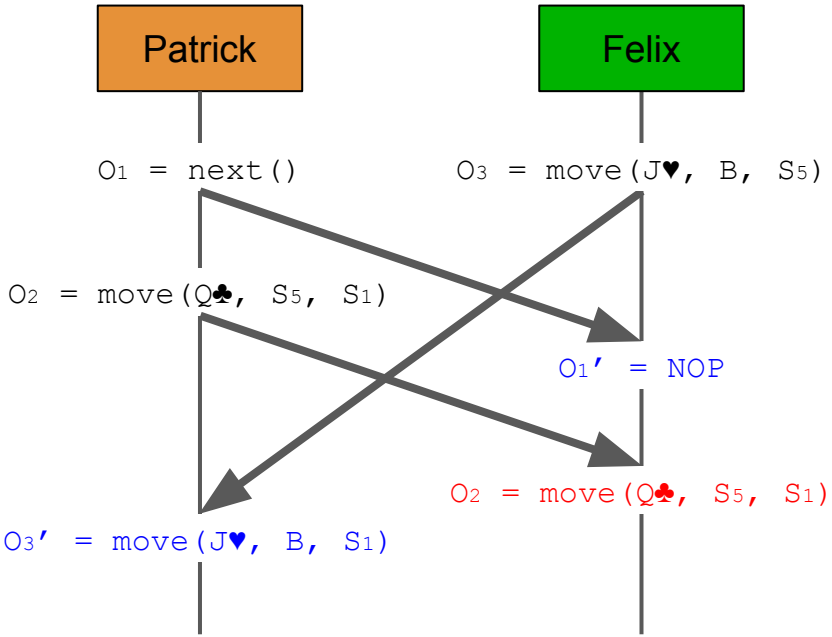

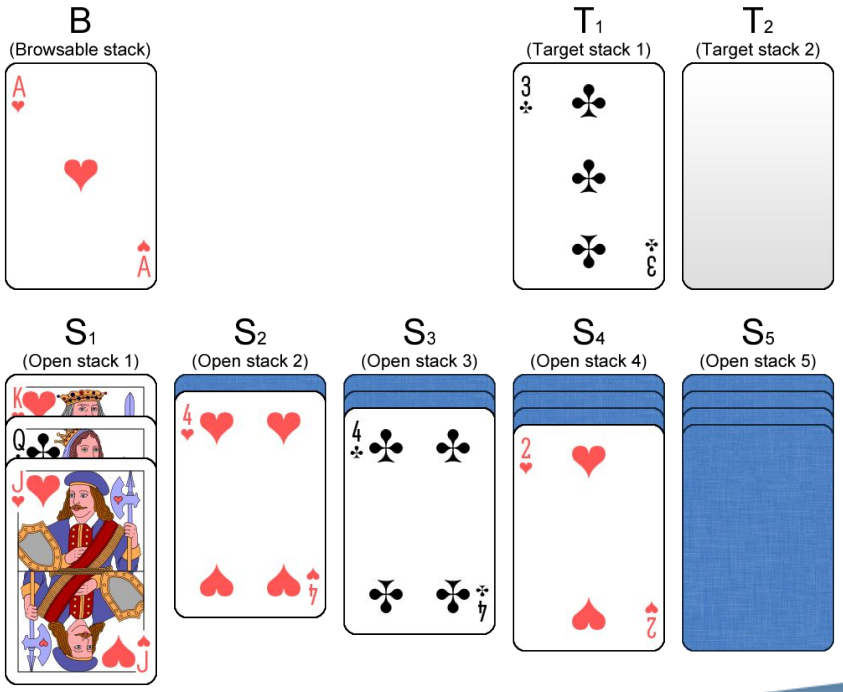

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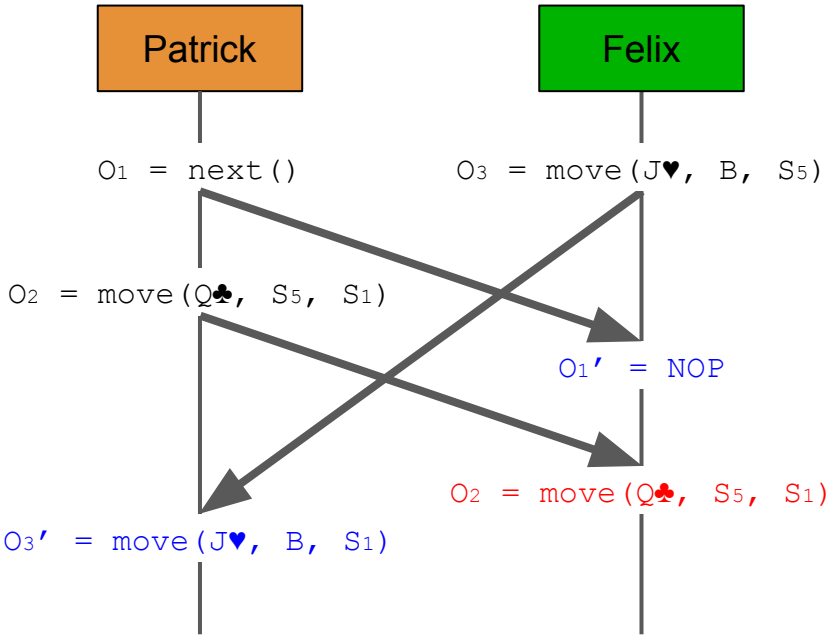

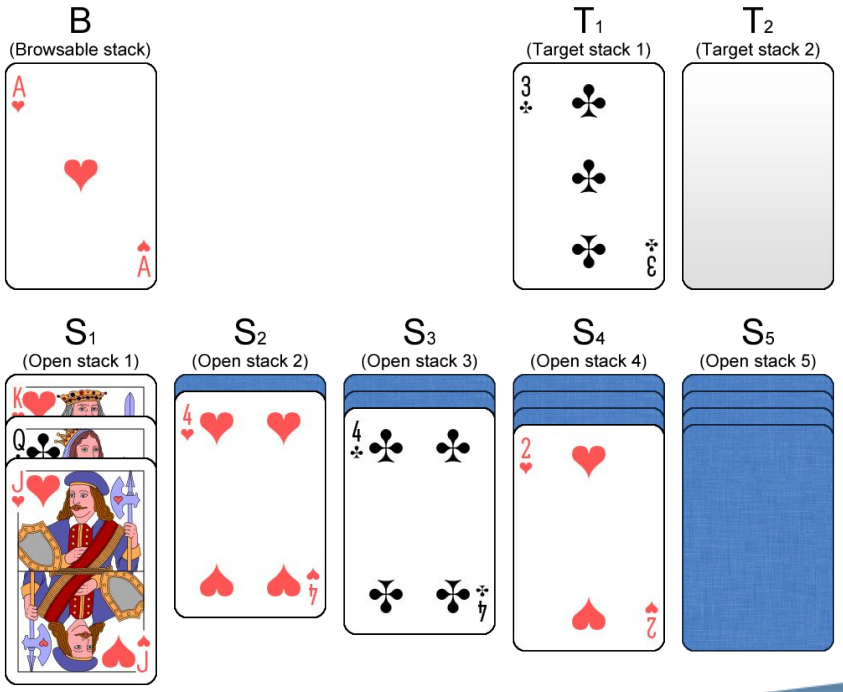

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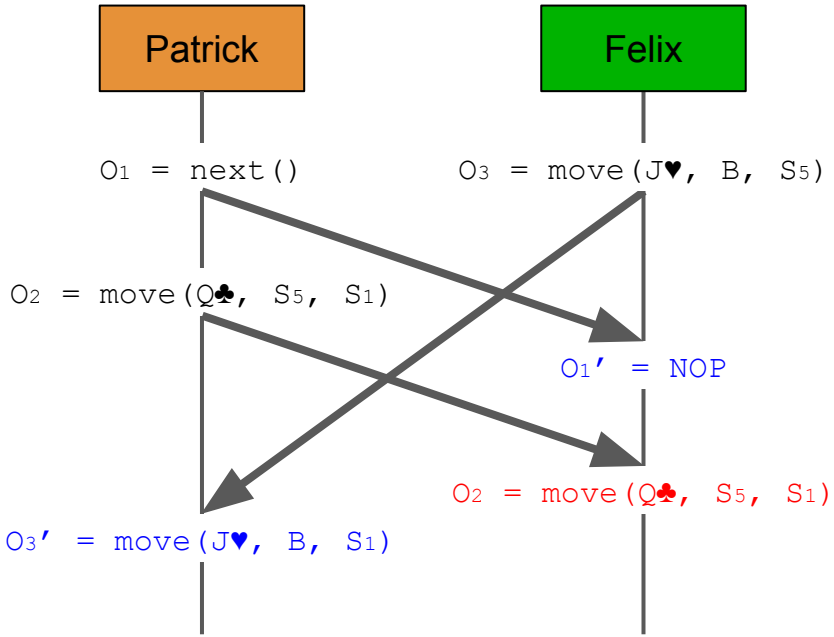

$$O_1 \rightarrow O_2$$

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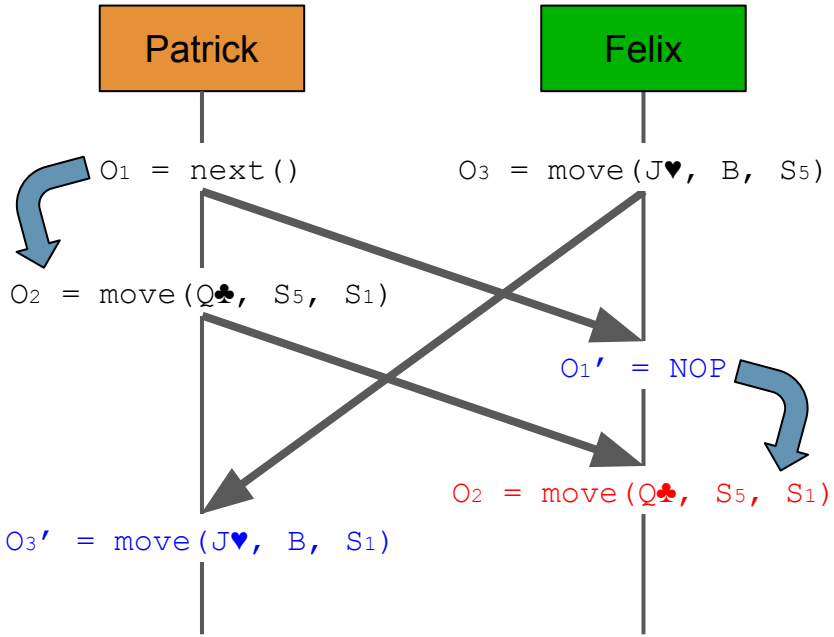

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All properties satisfied.

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All properties satisfied.

BUT: What happens if...

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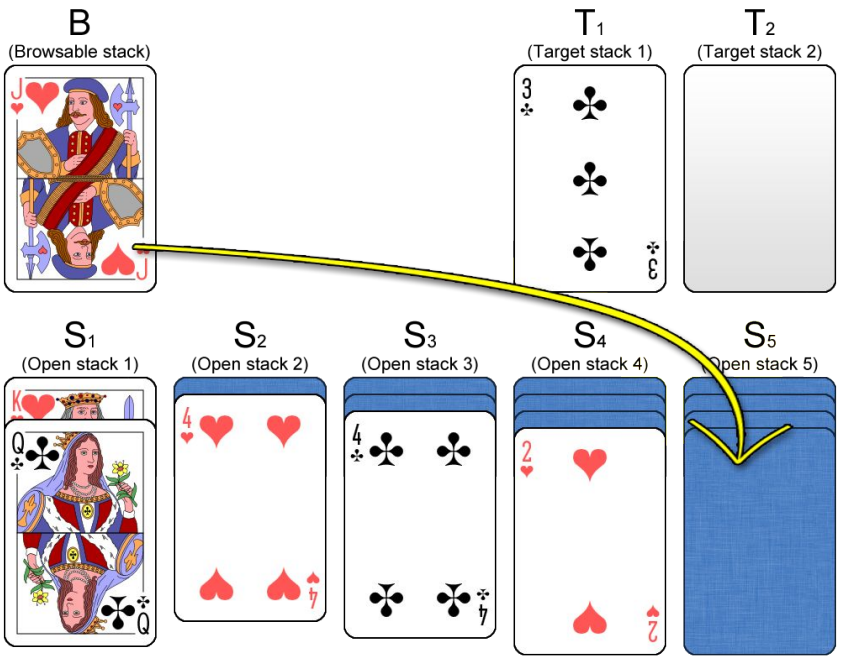
- Patrick moved the **Queen of Clubs** to **S_1**
- Felix moves the **Jack of Hearts** to **S_5**



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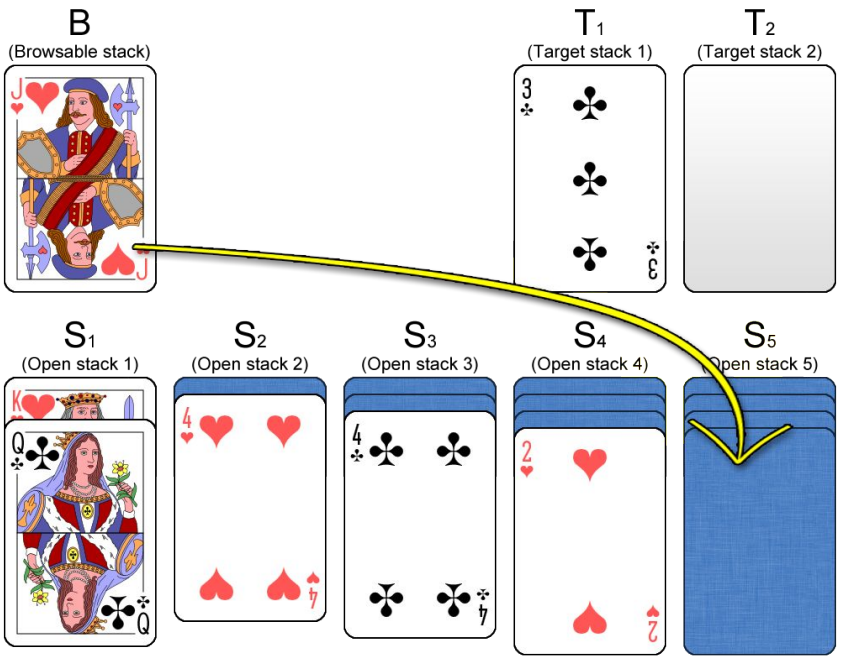
Violates game rules



Consistency Models

- **CCI Model** (Extension of CC Model)

  Intention Preservation: The Intention of any executed operation is always the same

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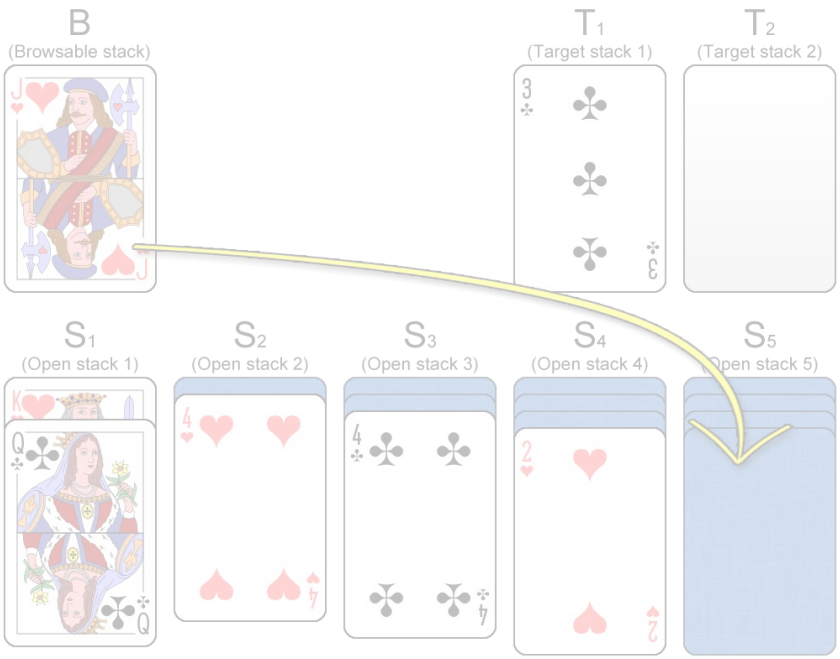

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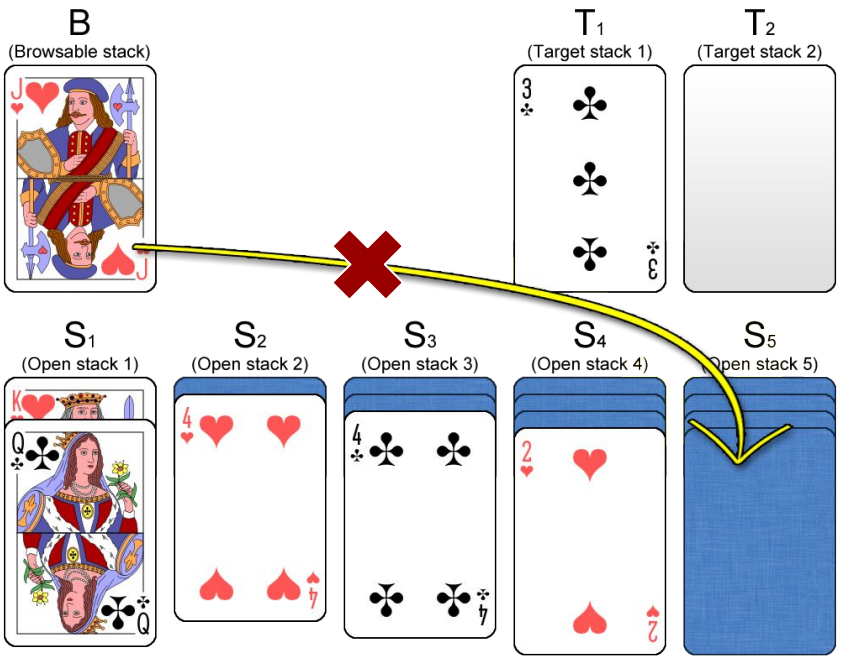

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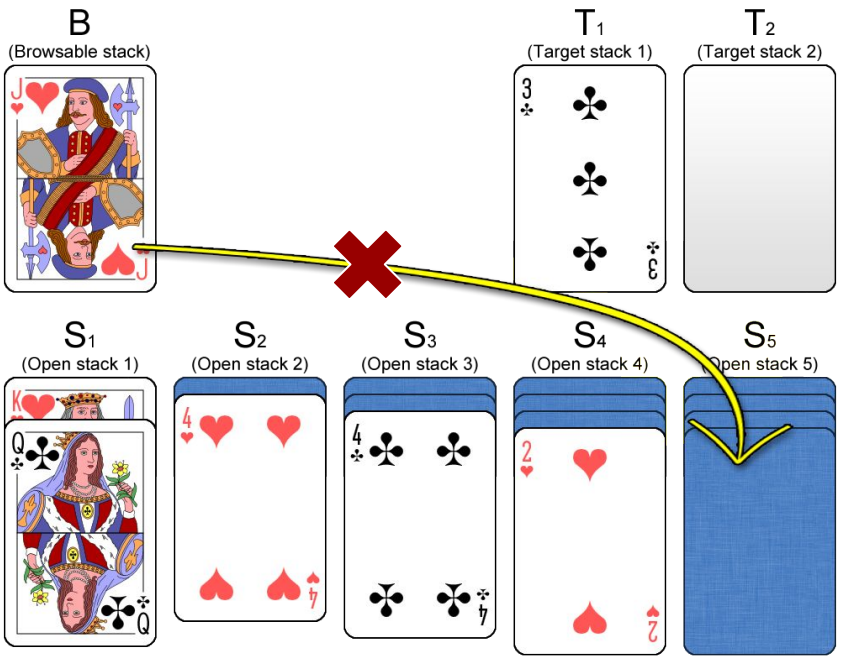
Transformation



OT Algorithm

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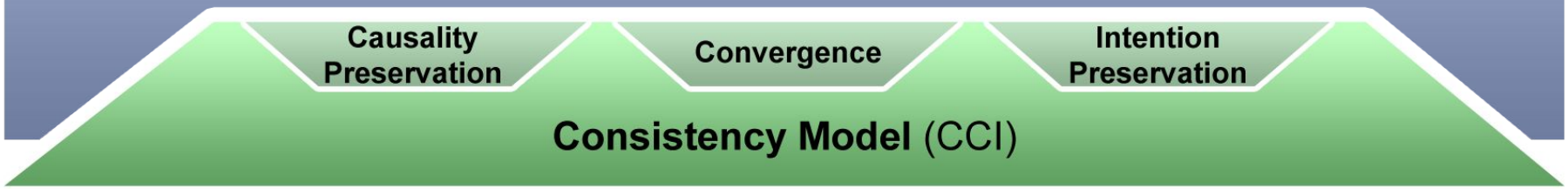

OT Algorithm

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Causality Preservation

Convergence

Intention Preservation

Consistency Model (CCI)

Properties

OT Algorithm

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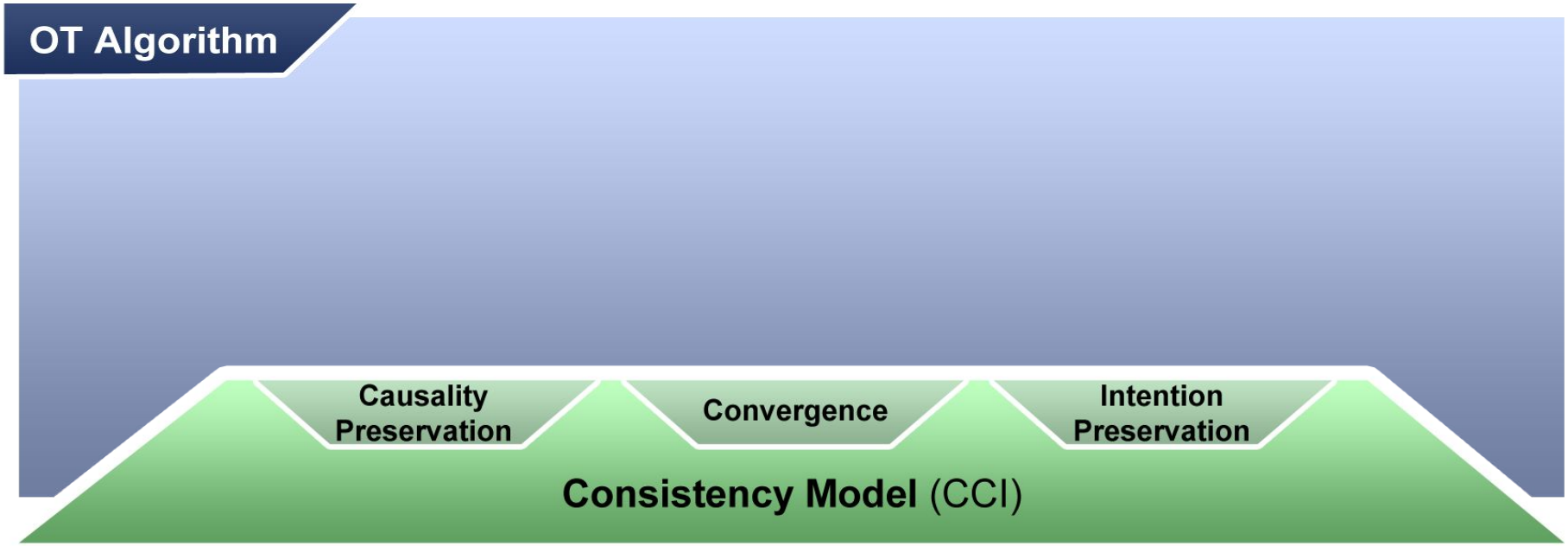

Properties → **Immediate results**

OT Algorithm

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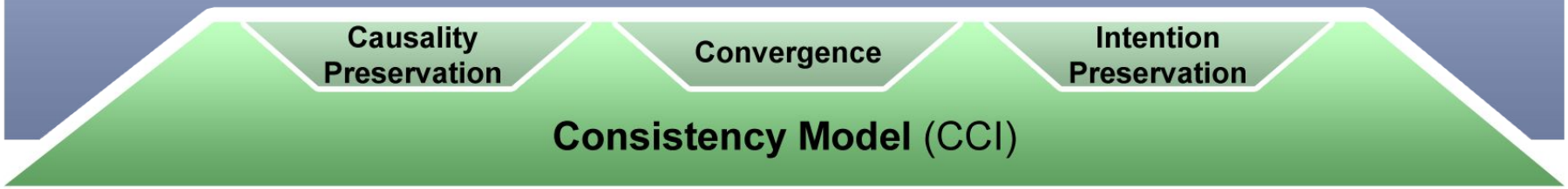

Properties

- **Immediate results**
- **No locking**

OT Algorithm

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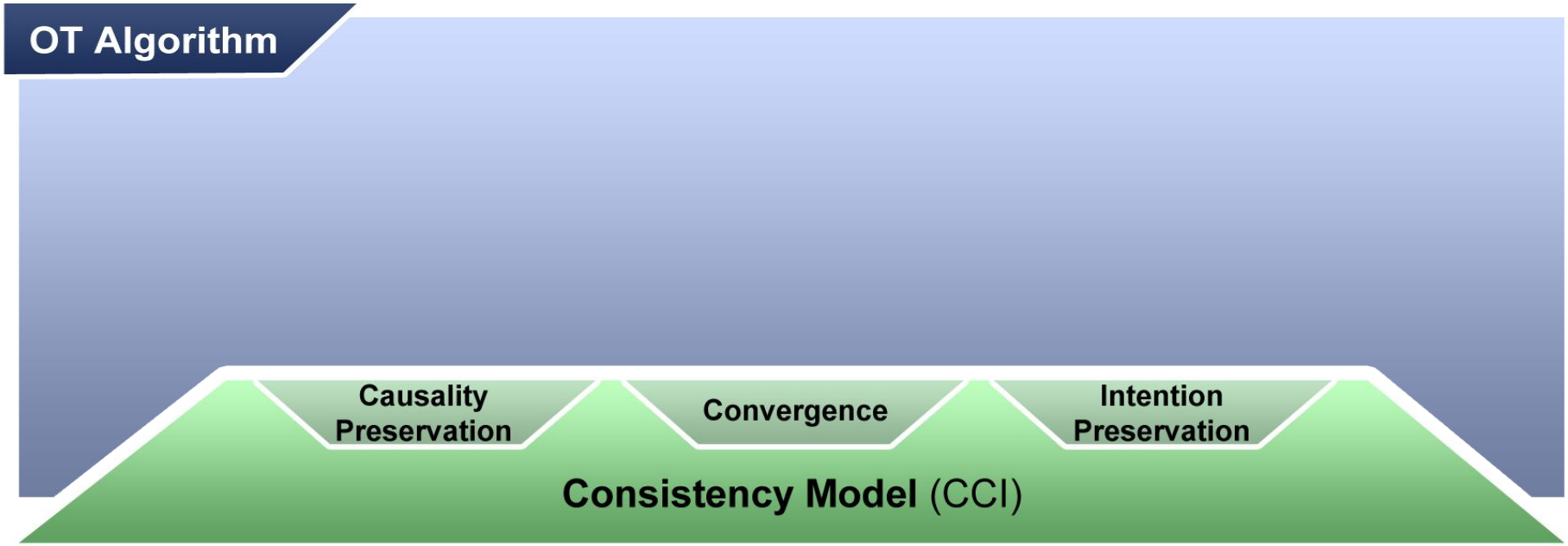

Properties

- **Immediate results**
- **No locking**
- **Fully distributive**

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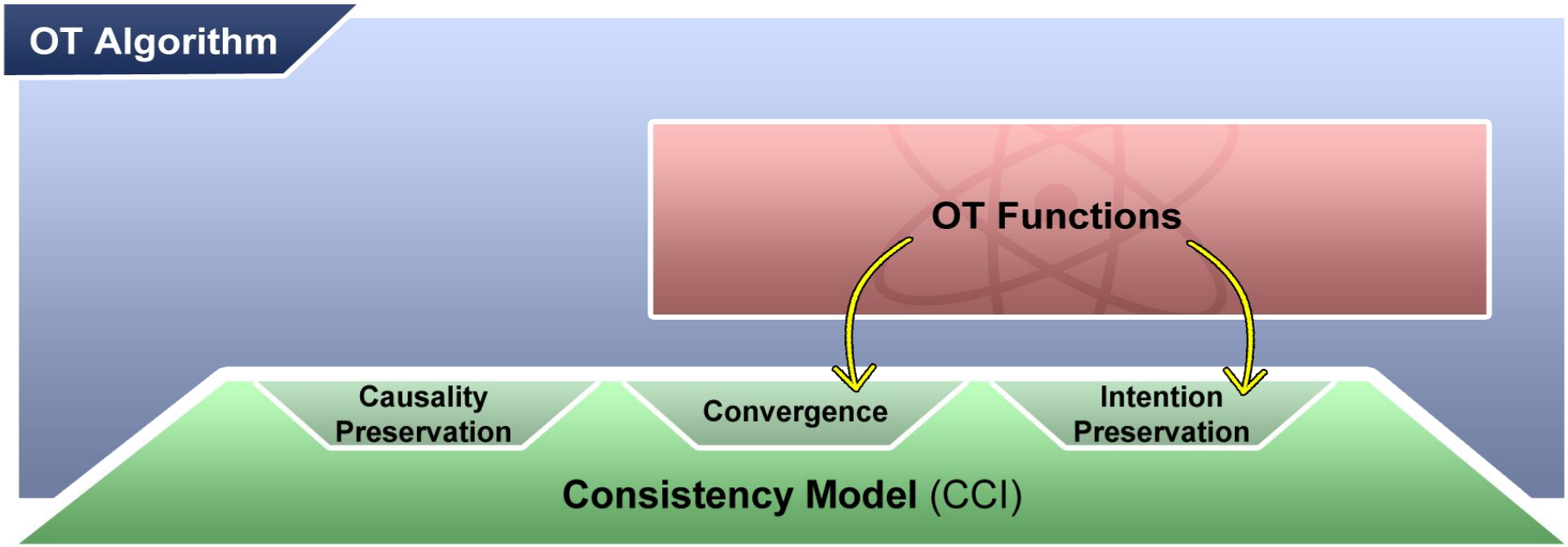

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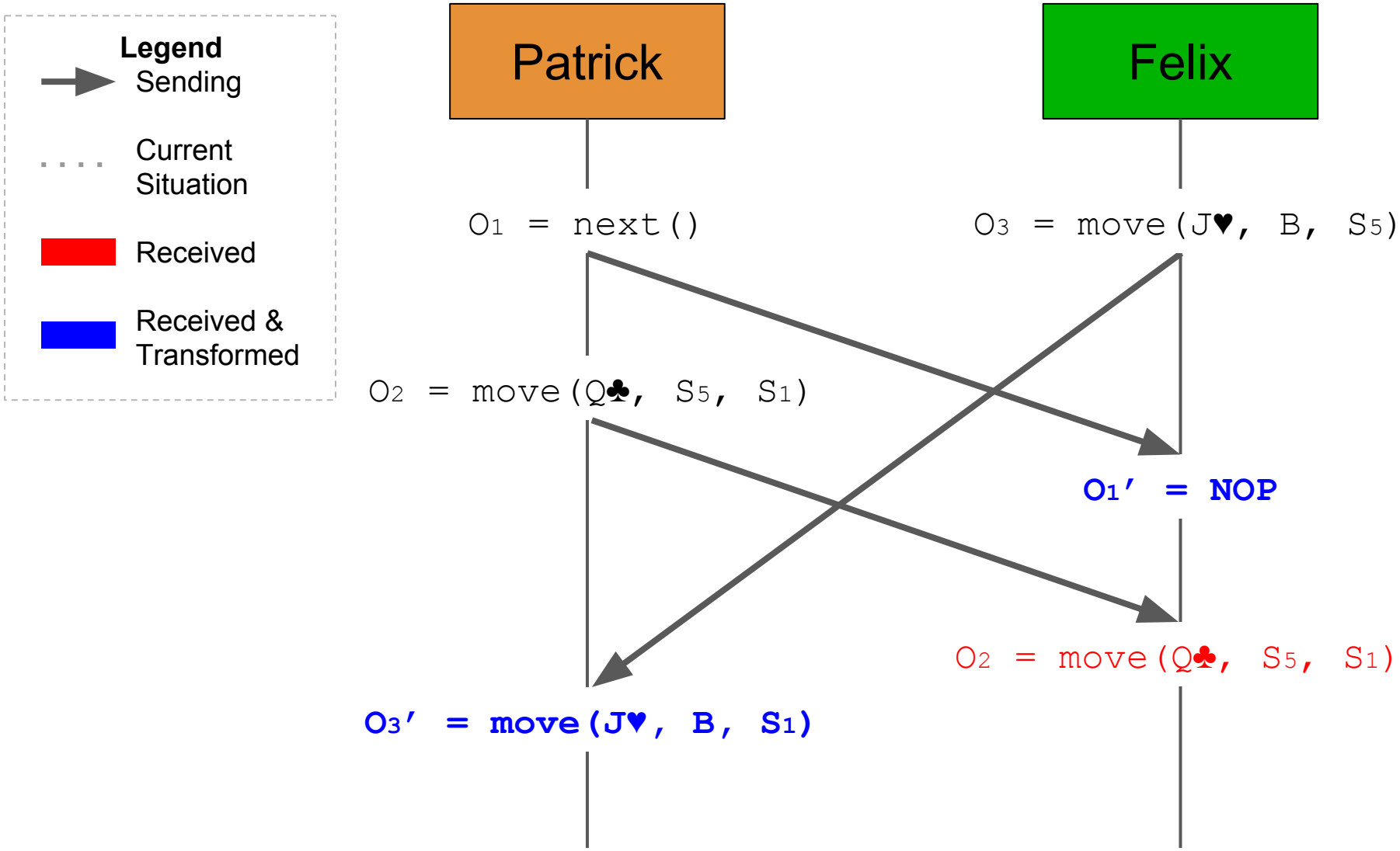

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- Function call:

$\mathbf{T}_{\mathtt{next,move}}$`(next(), move(J♥, B, S5))`

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- Function call:

```
Tnext,move(next(), move(J♥, B, S5))
```

- Function definition:

```
Tnext_move(next(), move(card, from, to)):
    if(from = B)
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OT Functions: Example 2

`move(J♥, B, S5)` → Transform against → `move(Q♣, S5, S1)`

- Transformation Matrix:

	move	**next**
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- Function call:

- Function definition:

OT Functions: Example 2

`move(J♥, B, S5)` → Transform against → `move(Q♣, S5, S1)`

- Transformation Matrix:

	move	next
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next	$T_{next,\ move}$	$T_{next,\ next}$

- Function call:

$T_{move,move}$(`move(J♥, B, S5)`, `move(Q♣, S5, S1)`)

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        //      move( J♥   ,       ,     )
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	move	next
move	$T_{move,\ move}$	$T_{move,\ next}$
next	$T_{next,\ move}$	$T_{next,\ next}$

- Function call:

$T_{move,move}$(move(J♥, B, S5), move(Q♣, S5, S1))

- Function definition:

```
Tmove,move(move(card1, from1, to1), move(card2, from2, to2)):
    if(to1 = from2)
        return move(card1, from1, to2)
        //      move( J♥   , B     ,     )
```

OT Functions: Example 2

`move(J♥, B, S5)` → Transform against → `move(Q♣, S5, S1)`

- Transformation Matrix:

	move	next
move	$T_{move,\ move}$	$T_{move,\ next}$
next	$T_{next,\ move}$	$T_{next,\ next}$

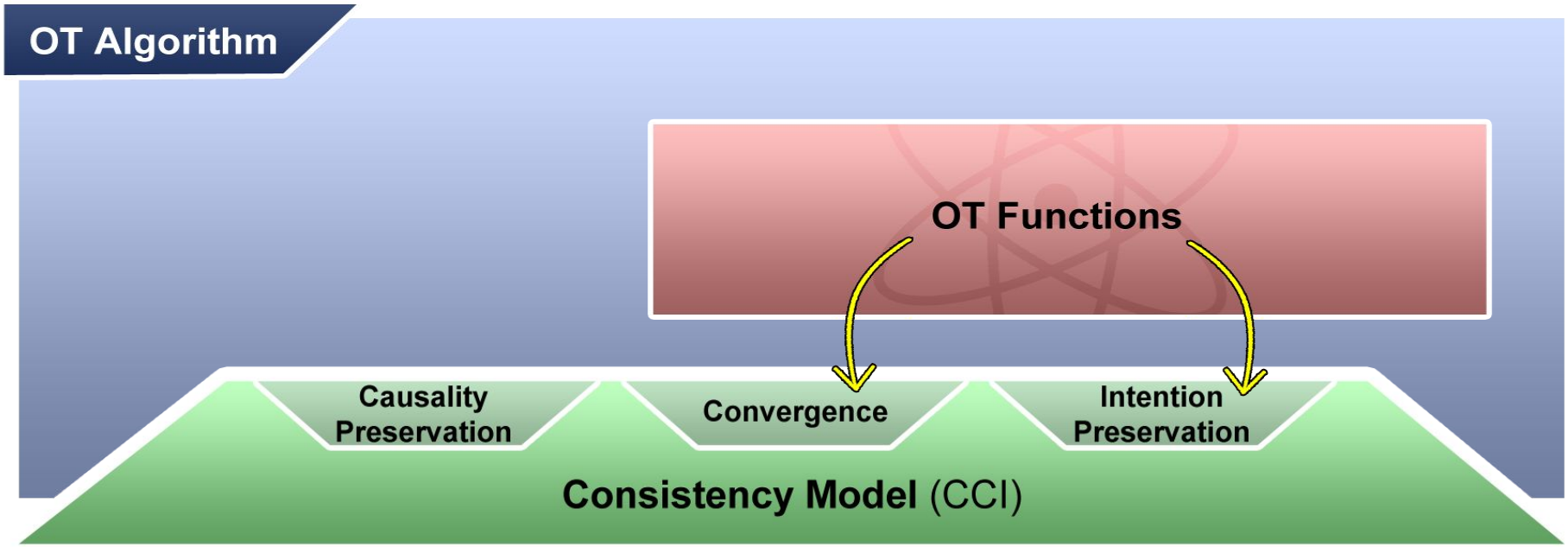
- Function call:

$T_{move,move}$(move(J♥, B, S5), move(Q♣, S5, S1))

- Function definition:

```
Tmove,move(move(card1, from1, to1), move(card2, from2, to2)):
    if(to1 = from2)
        return move(card1, from1, to2)
        //      move( J♥  , B     , S1 )
```

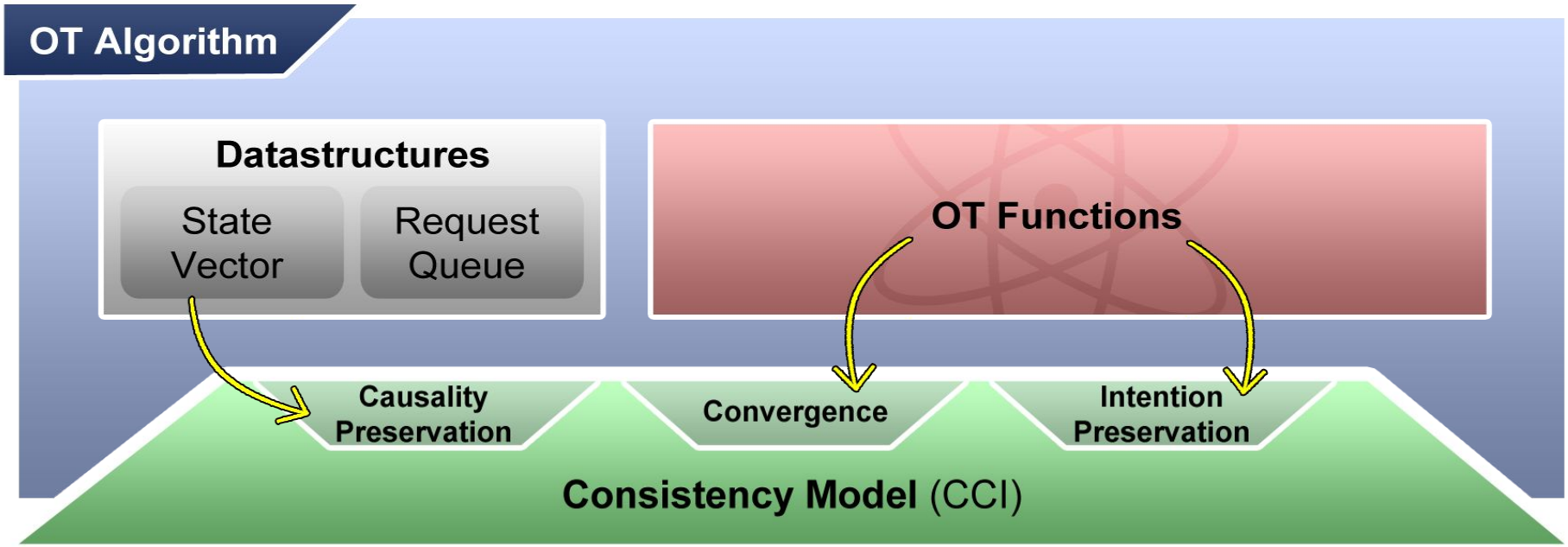
OT Algorithm



Properties

- Immediate results
- No locking
- Fully distributive

OT Algorithm



Properties

- **Immediate results**
- **No locking**
- **Fully distributive**

Collaborative Games

Collaborative games

One goal solved by **many**

VS

Cooperative games

Many goals each solved by **one**

Collaborative Games

Collaborative games *VS* **Cooperative** games

One goal solved by **many**

Many goals each solved by **one**

Are such games available at all?

Collaborative Games

Turn-Based	Single-Object	Multi-Object
No		
Yes		

Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	
Yes		

Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	
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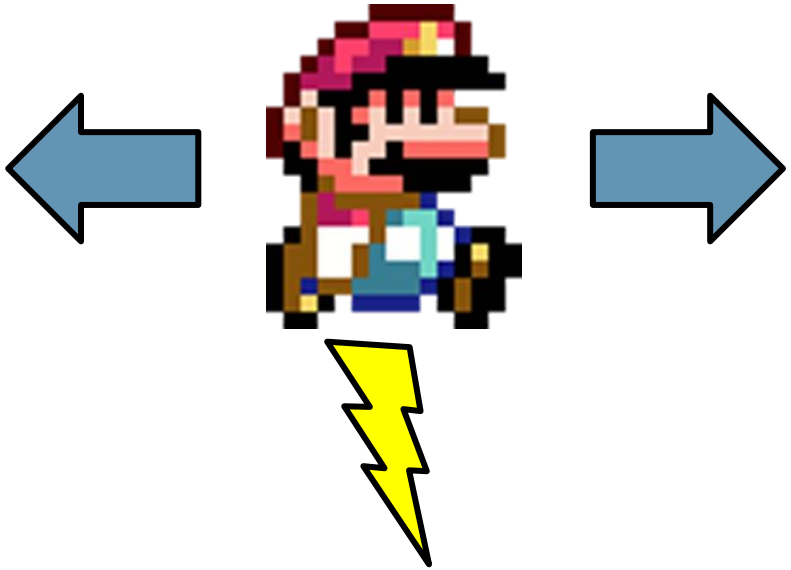
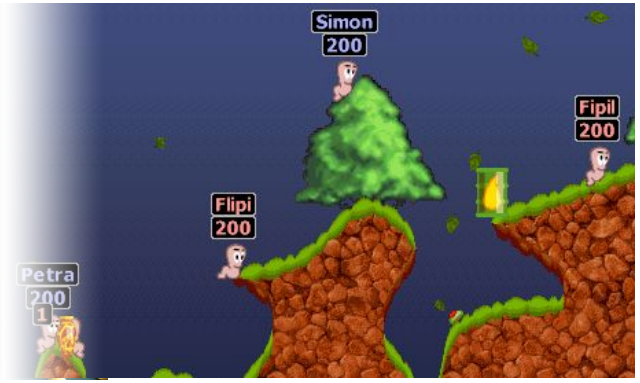


Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	
Yes	- Chess, Monopoly, Worms, ...	



Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	
Yes	- Chess, Monopoly, Worms, ...	

Only 1 Operation at a time

Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	
Yes	- Chess, Monopoly, Worms, ...	0 Scrabble, Rummy, ...

Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	
Yes	- Chess, Monopoly, Worms, ...	0 Scrabble, Rummy, ...

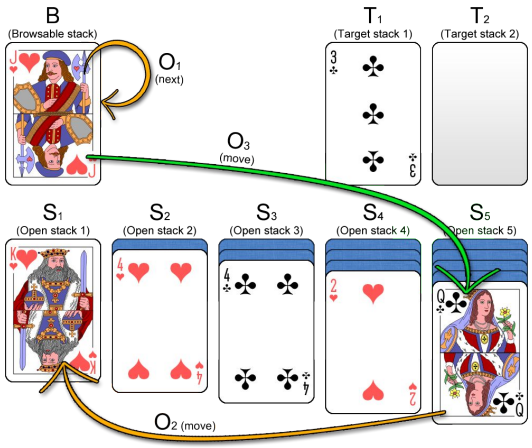
Only collaboratively playable during 1 of X phases

Collaborative Games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	+ Solitaire, Puzzles, Strategy and Tycoon Games, ...
Yes	- Chess, Monopoly, Worms, ...	0 Scrabble, Rummy, ...

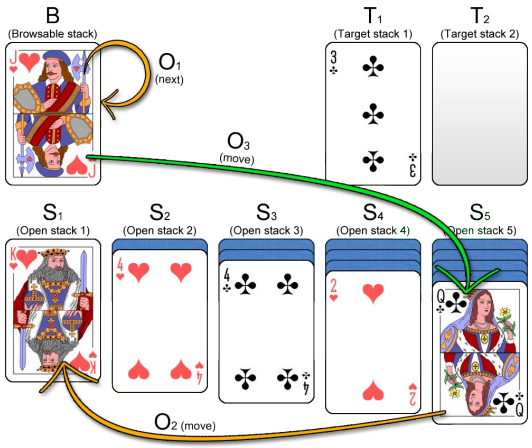
Conclusion

- **OT in games** (Example: Simplified Solitaire)



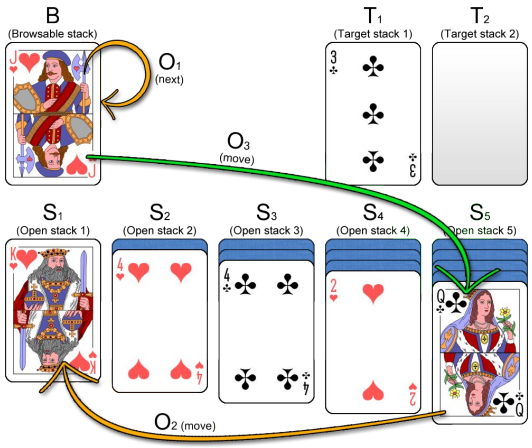
Conclusion

- **OT in games** (Example: Simplified Solitaire)
  ➡ Feasible



Conclusion

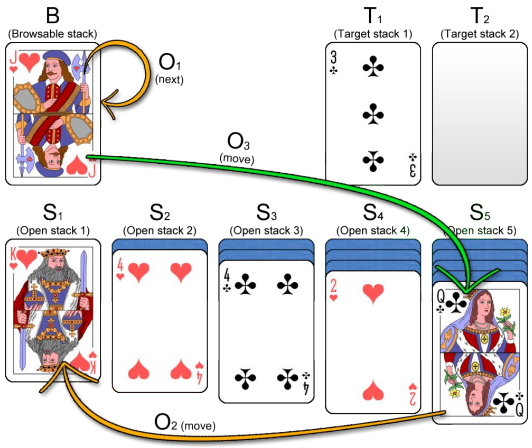
- **OT in games** (Example: Simplified Solitaire)
  ➡ Feasible
- Requires **consistency model**

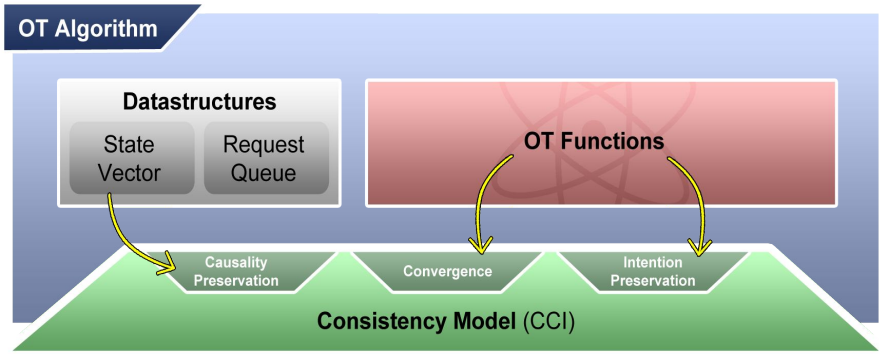


Conclusion

- **OT in games** (Example: Simplified Solitaire)
  ➡ Feasible

- Requires **consistency model**

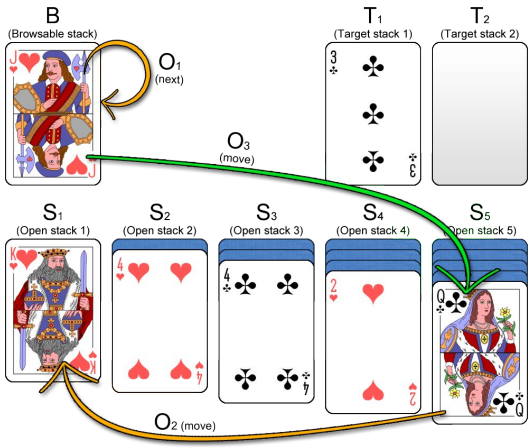




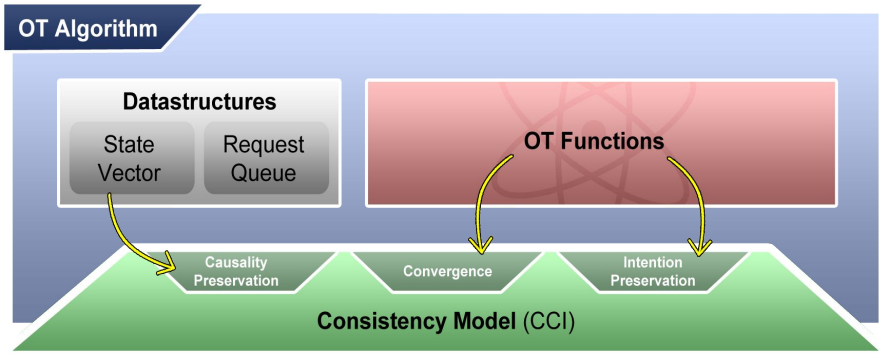
- Realized by **OT Algorithm**

Conclusion

- **OT in games** (Example: Simplified Solitaire)
  ➡ Feasible



- Requires **consistency model**



- Realized by **OT Algorithm**

- New definition of:

  Collaborative games

Turn-Based	Single-Object	Multi-Object
No	0 Pokemon, FPS, Action and Racing Games, ...	+ Solitaire, Puzzles, Strategy and Tycoon Games, ...
Yes	- Chess, Monopoly, Worms, ...	0 Scrabble, Rummy, ...

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