Universität Rostock

Traditio et Innovatio

LiMa: Sequential Lifted Marginal Filtering on Multiset State Descriptions

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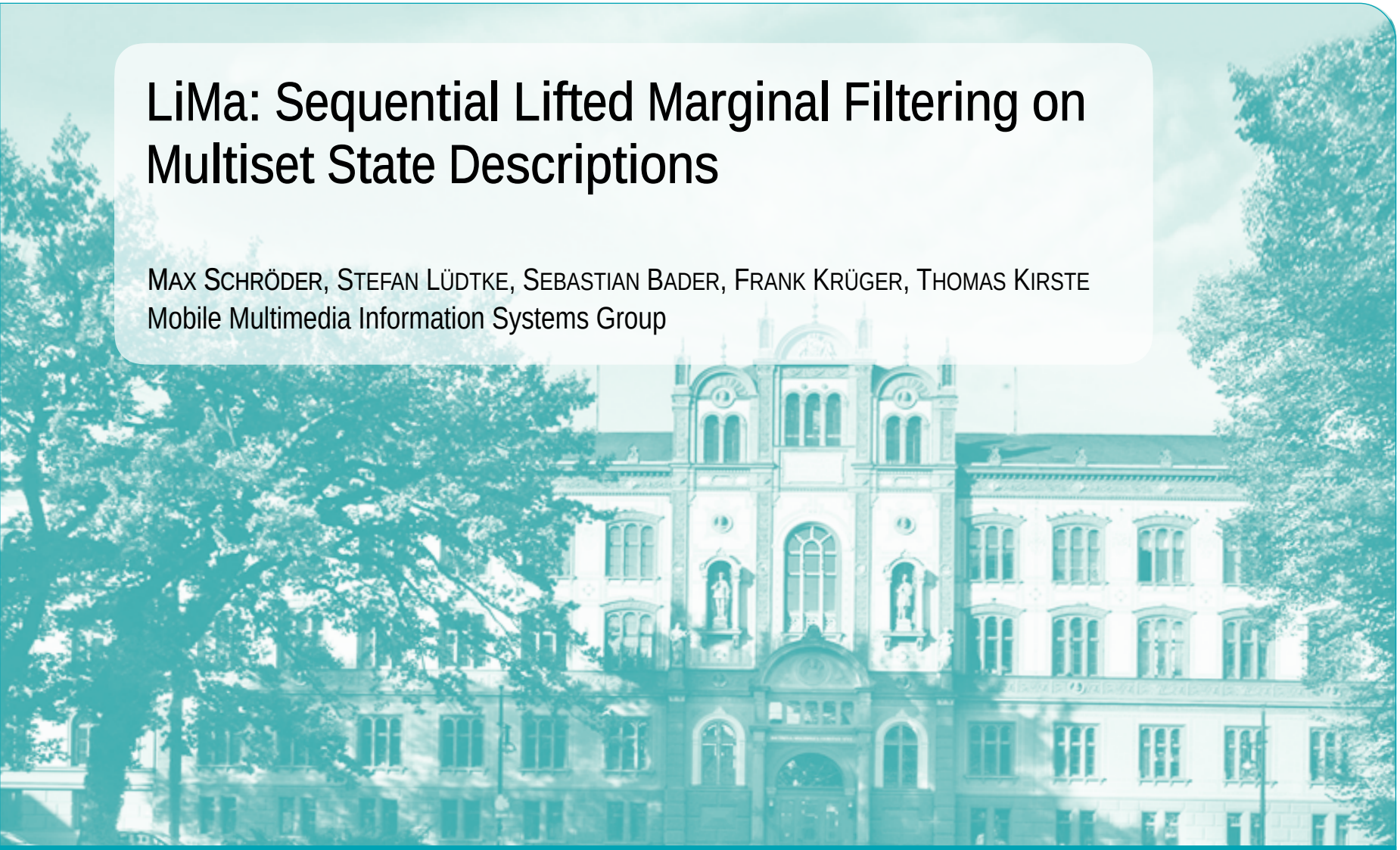


The problem we are concerned with…

- is **activity recognition** from **noisy** and **ambiguous sensor data**
- in **dynamic systems** with a high number of **symmetrical situations** with respect to the observation data
- but sometimes the need to **identify** a particular of the symmetric situations.

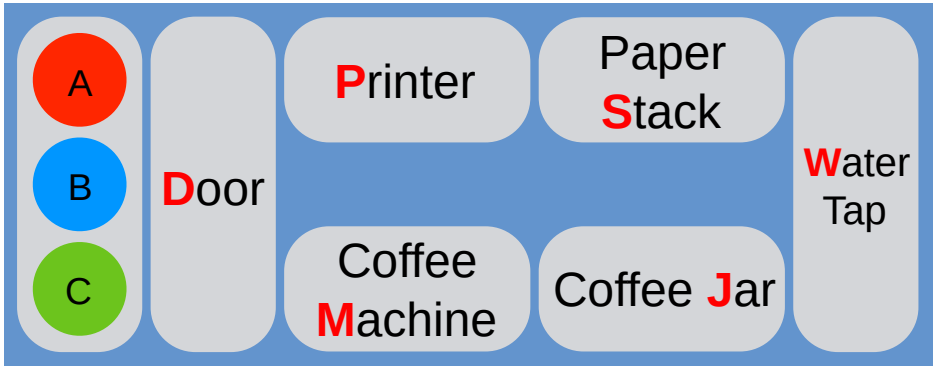
LiMa aims towards a solution of this problem by…

- sequentially estimating a **probability distribution over states** in a Bayesian Filtering context
- an **abstract state representation** encoding these symmetries with the possibility to **break them** at any point during the inference.

Applications

Alice, Bob & Charlie

Outside



- Alice, Bob & Charlie can **move** between all locations after entering through the door
- They can **print a document** if paper is provided and **get a coffee** if ground coffee and water is provided as well as **replenish** any of these resources
- Their **goal** is to get a coffee and print a document
- **Observations** indicate the presence of at least one of them at a location

D	P	M	S	W	J
.	.	.	.	.	.
1	.	.	.	.	.
.	1	.	.	.	.
.	1	.	.	.	.
.	.	.	1	.	.
.	.	.	1	.	.
.	1	.	.	.	.
1	1	.	.	.	.
.	1	.	.	1	.
.	1	.	.	1	.
.	1	.	.	1	.
.	.	.	.	1	1
.	.	.	.	1	1
.	.	.	.	1	1
.	.	.	.	1	1
.	.	.	.	1	1
.	.	1	.	.	1
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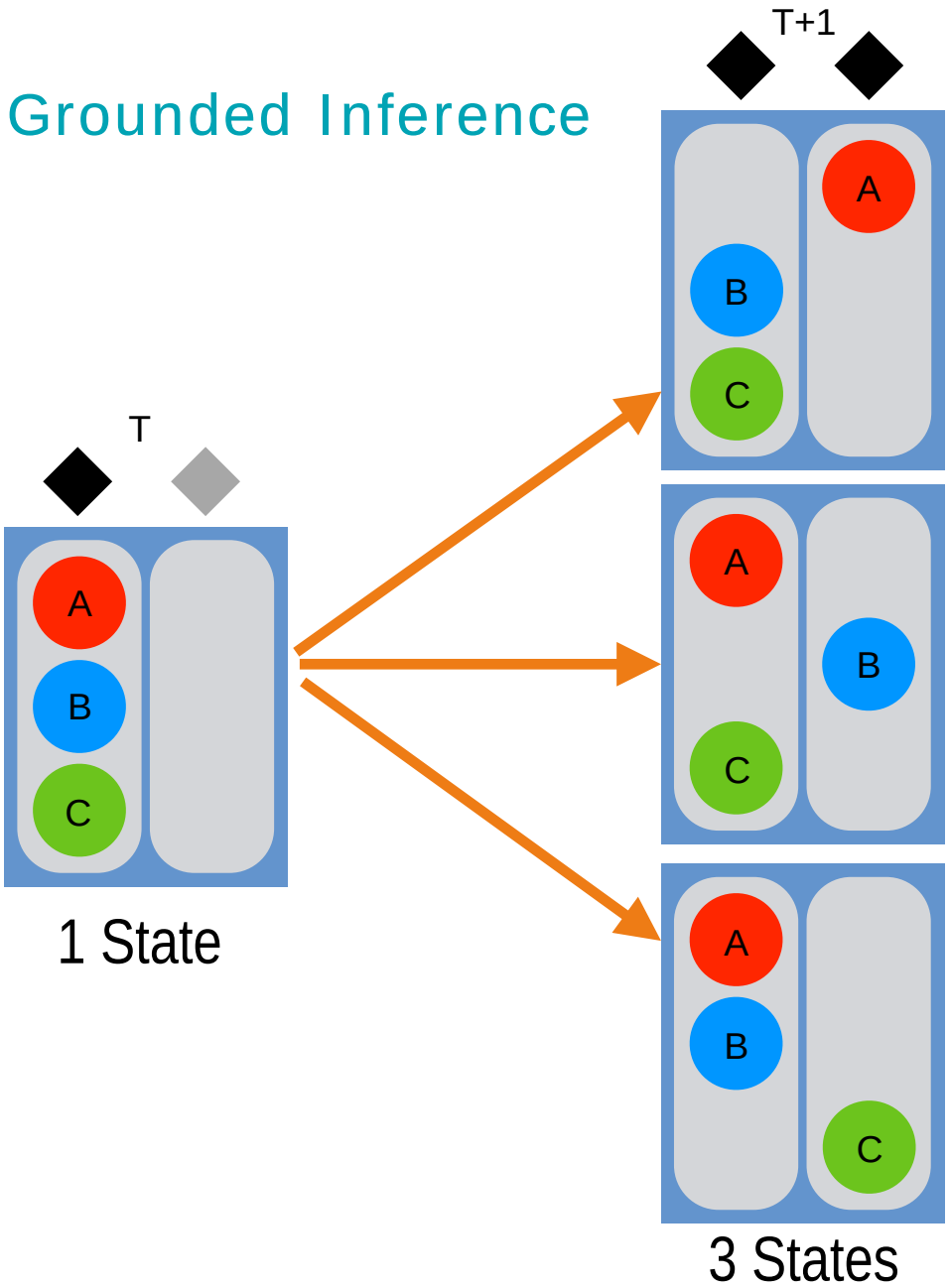
Grounded Inference

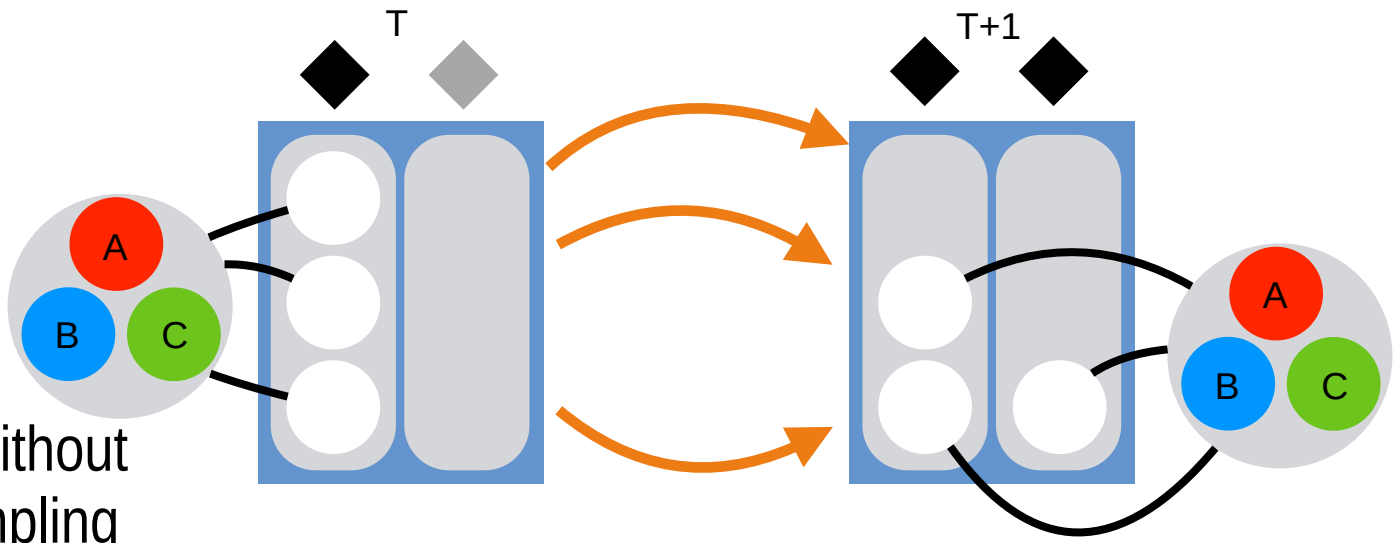


For increasing number of entities, this leads to a **combinatorial explosion** in the number of hypotheses that need to be considered (i.e. the number of states)

No. Agents	No. Locations	No. States
1	14	14
2	14	196
3	14	2,744
4	14	38,416
5	14	537,824
6	14	7,529,536
7	14	105,413,504

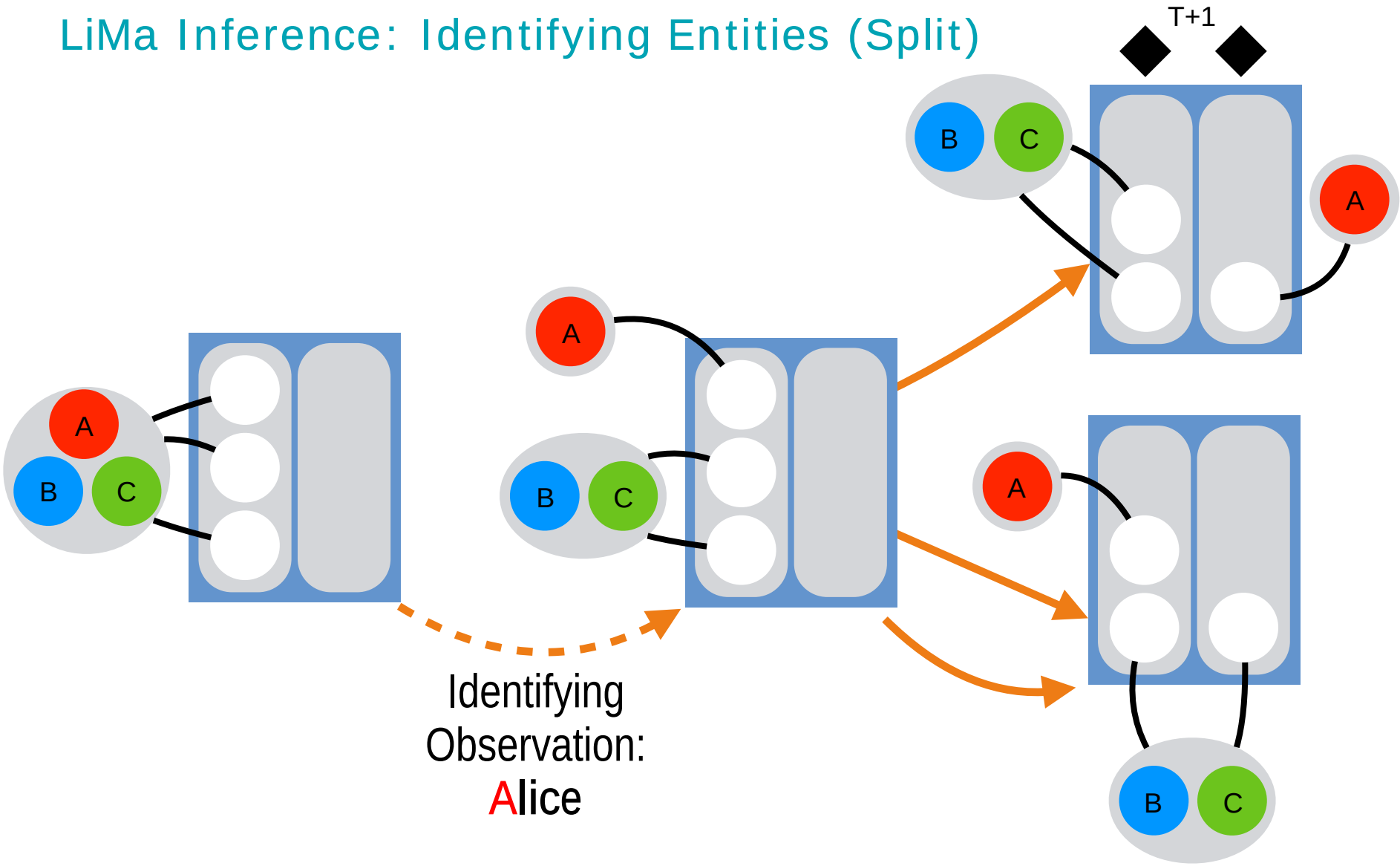
LiMa Inference: Abstract State Description

- Abstract from **particular states** that represent instances of the same **group of undistinguishable situations** in order to represent and consider them during inference **together**
- Abstraction is done by separating the **structure of the state** from the **particular values** that may be inserted into that structure

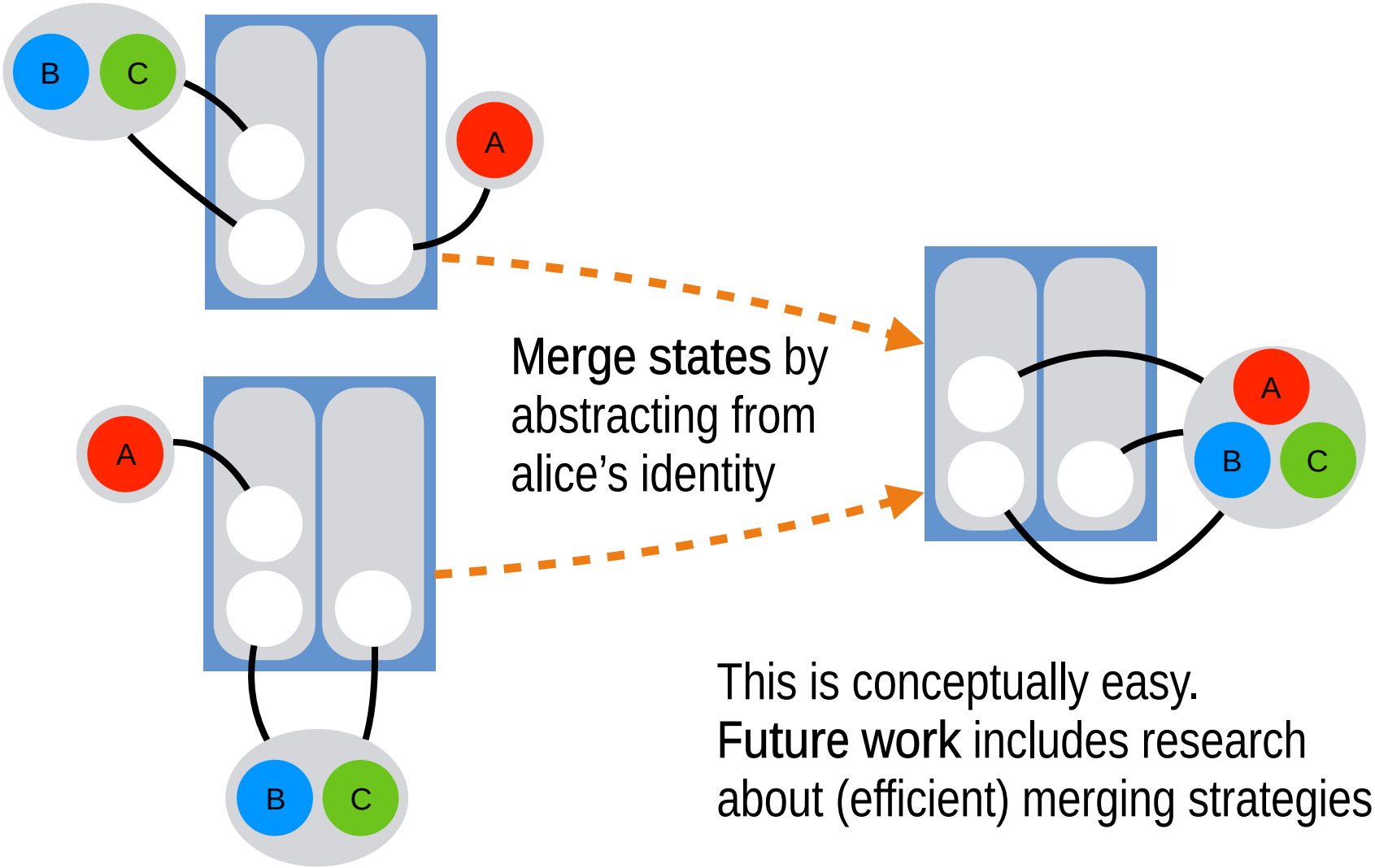


Urn without resampling

LiMa Inference: Identifying Entities (Split)



LiMa Inference: Merging States



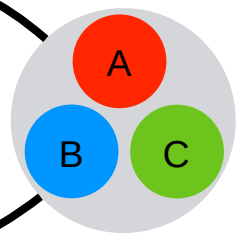
This is conceptually easy.
Future work includes research about (efficient) merging strategies.

LiMa Inference: Underlying Techniques

- A **lifted state** is represented by:
  1. A **multi-set** of the **structure of the entities** (property-label maps)
  2. A **context** defining the actual **values** (label-distribution maps)

{2⟨Location: *Outside*, Holds: *Nil*, Name:●⟩,

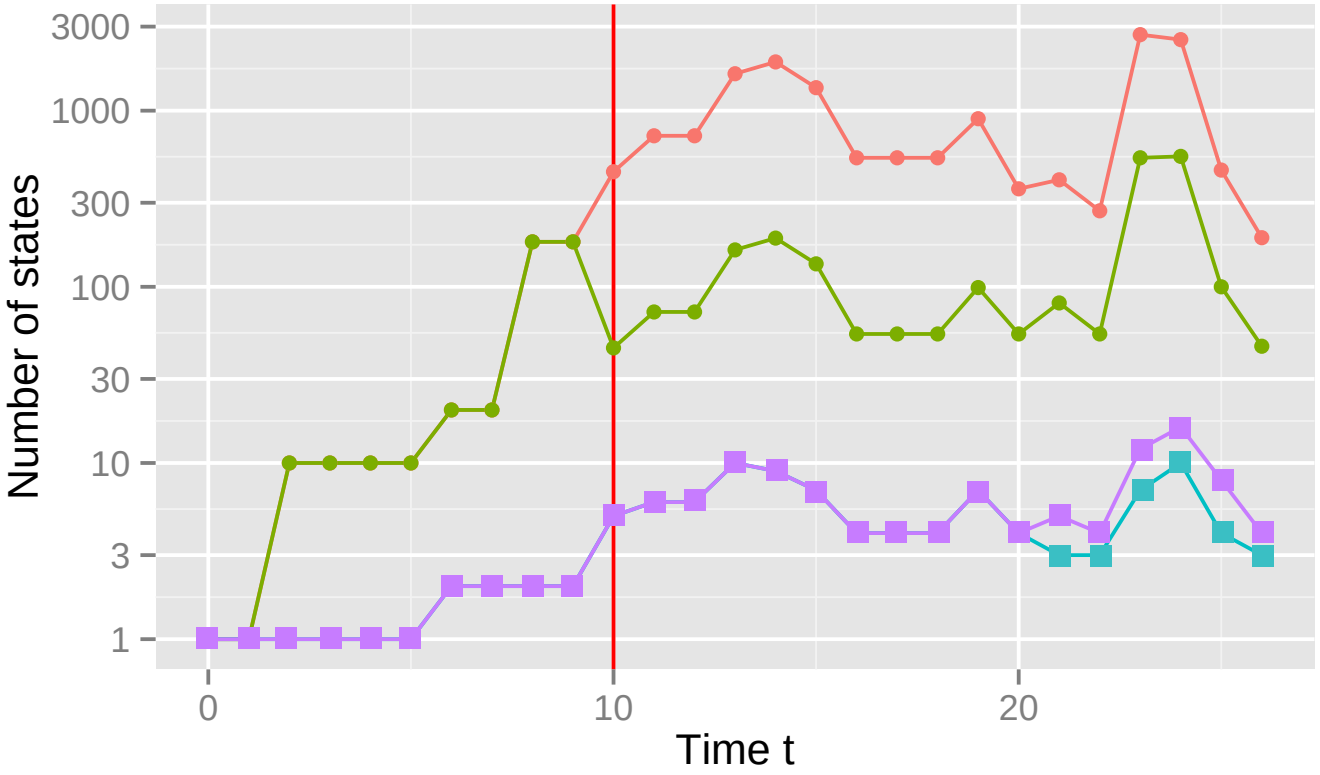
1⟨Location: *Door*, Holds: *Nil*, Name:●⟩}



- **Uncertainty** about the group of situations is represented by a **probability distribution** over lifted states
- **Precondition/effect-rules** describe the model dynamics and are synthesized to **Compound Actions** modeling parallel execution of actions
- This encodes a probabilistic **Multi-set Rewriting System** with maximally parallel Compound Actions
- Compound Actions are applied to every lifted state to **predict** the next belief state, followed by an **update** corresponding to the observation model

Evaluation Results: Alice, Bob & Charlie

```
D  .1....1.................1.1.
P  ..11..111A1..............
M  ..........................111111111..
S  ....11....................
W  ........111111111.........
J  ..........111111.........
```



Run	Model	Observations
	Ground	Anonymous
	Ground	Identifying
	LiMa	Anonymous
	LiMa	Identifying

Summary

- We presented the **Lifted Marginal Filtering** algorithm that sequentially estimates a probability distribution over situations in the **Bayesian Filtering** framework.
- The inference is performed in an abstract manner by grouping situations that are **undistinguishable** with respect to the observation data.
- The state representation consists of (1) a multi-sets of entities (*structure of the situation*) and, (2) the context (*particular situation information*) and thus encodes a **Multi-set Rewriting System** with maximally parallel **Compound Actions**.
- This lifted state representation can be **adapted dynamically** to encode further evidence about particular situations (*split*) or abstract from currently uncertain properties (*merge* – future work).