Architectures: Design Patterns for Component-Based Systems

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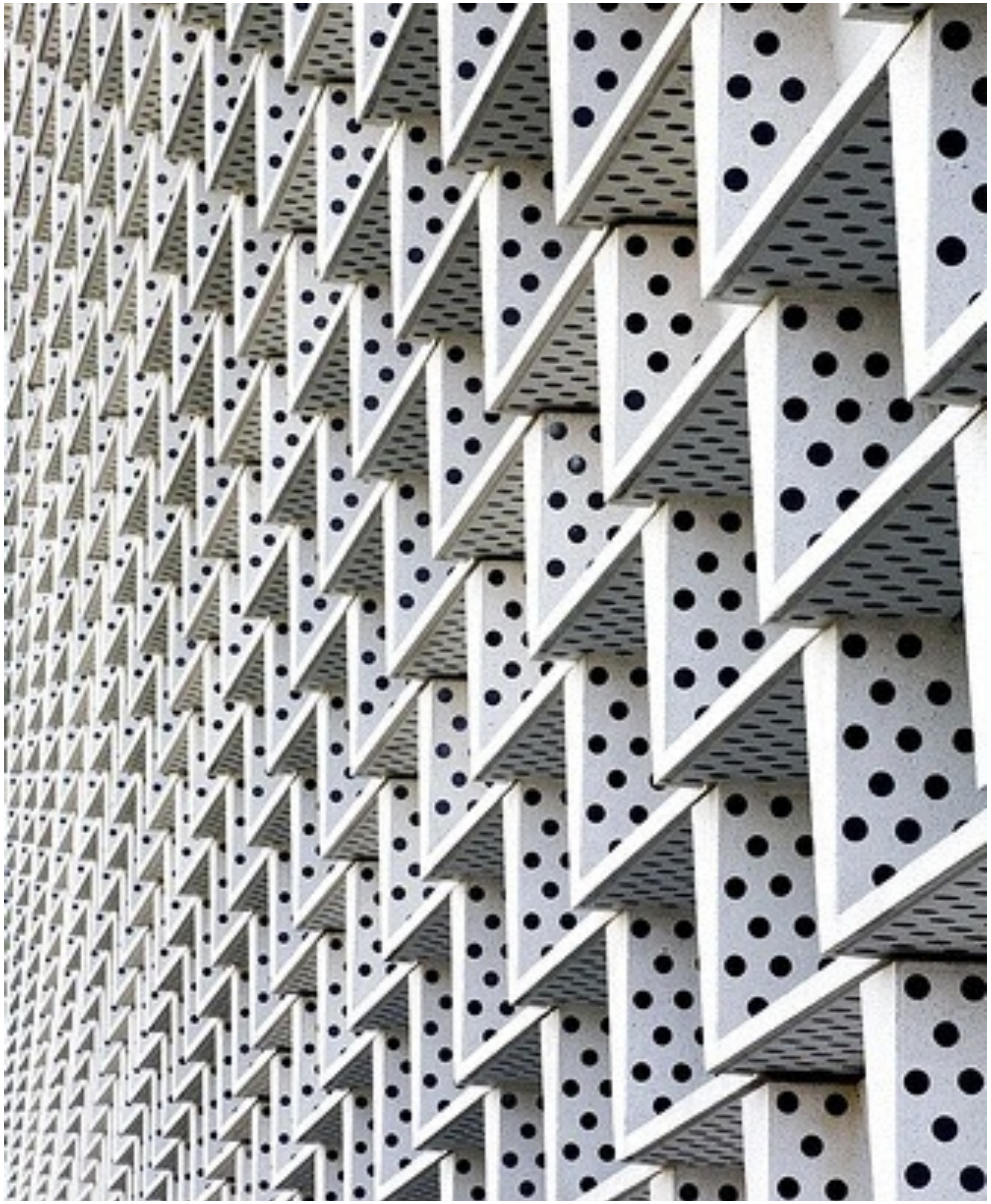
Reusable design patterns

- Systems are not built from scratch
- Maximal re-use of building blocks
  (off-the-shelf components)
- Maximal re-use of solutions (libraries, design patterns, etc.)
- Express coordination constraints in declarative manner



Applications

- Concurrency:
  (a)synchronous, time-triggered, token-ring,
  mutual exclusion

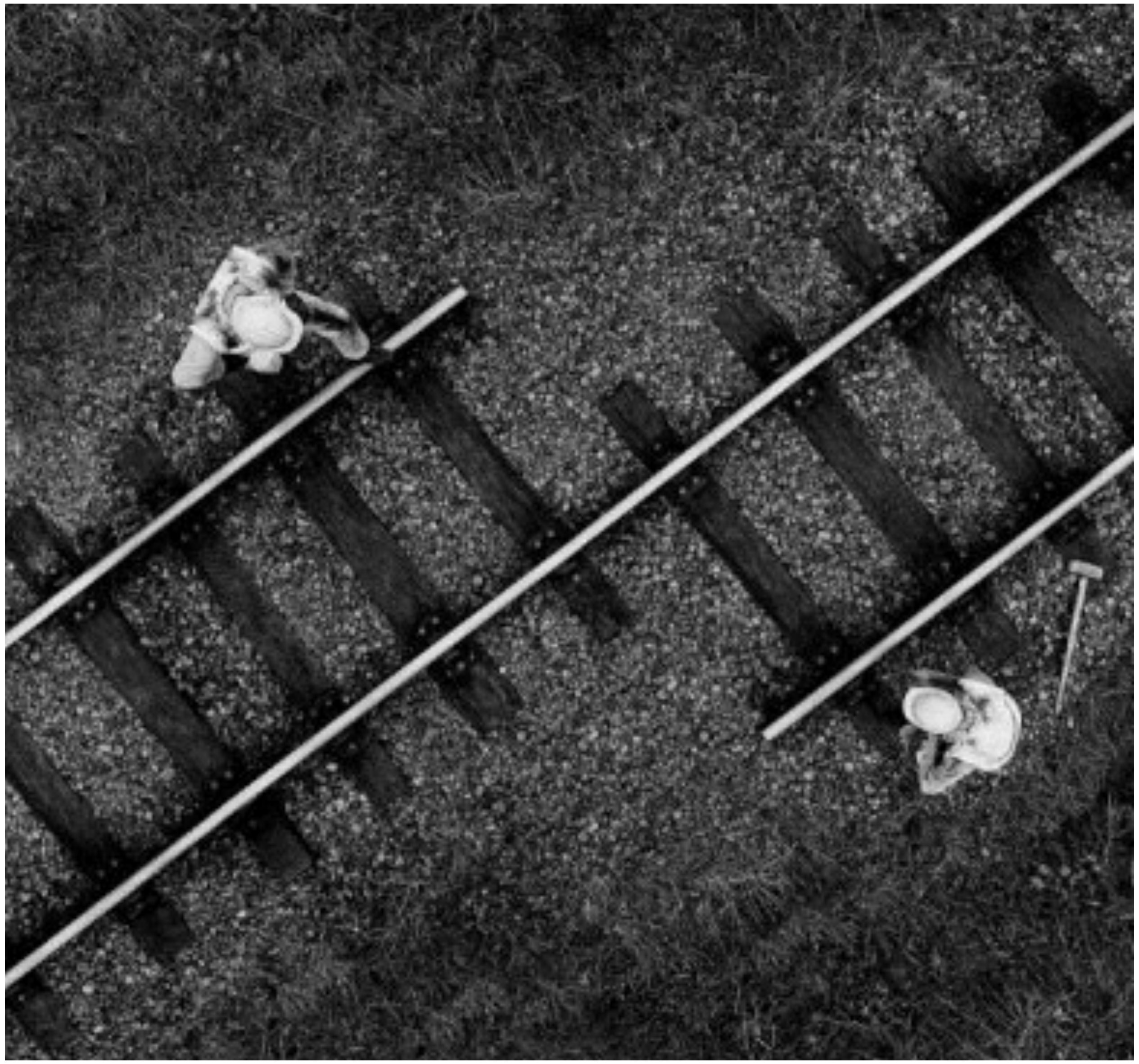
- Protocols:
  communication protocols, data access control,
  encryption, authentication

- Robustness:
  fault detection & recovery, resource management

- etc.

Theory of architectures

- How to model?
- How to specify?
- How to combine?
- How to implement efficiently?

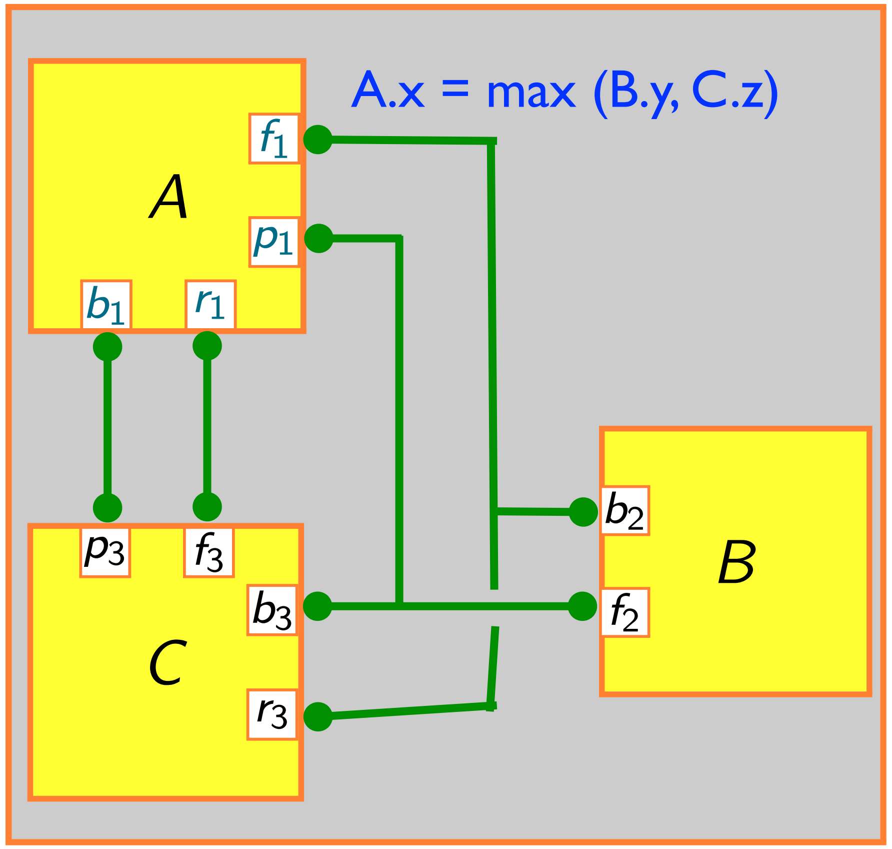


Architectures enforce characteristic properties. The crucial question is whether these are preserved by composition?

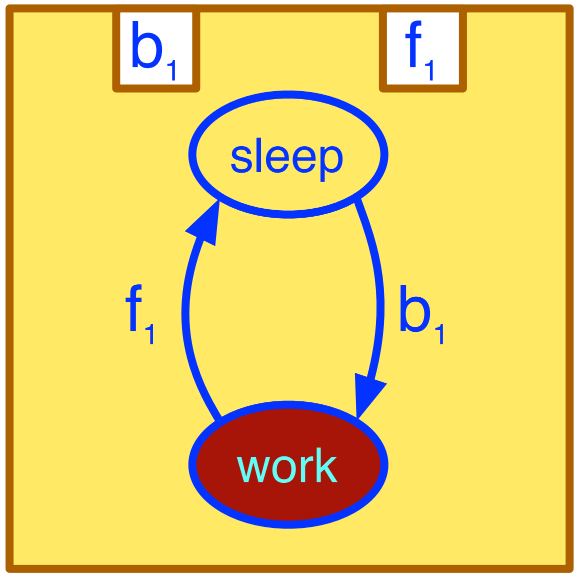
How to model?

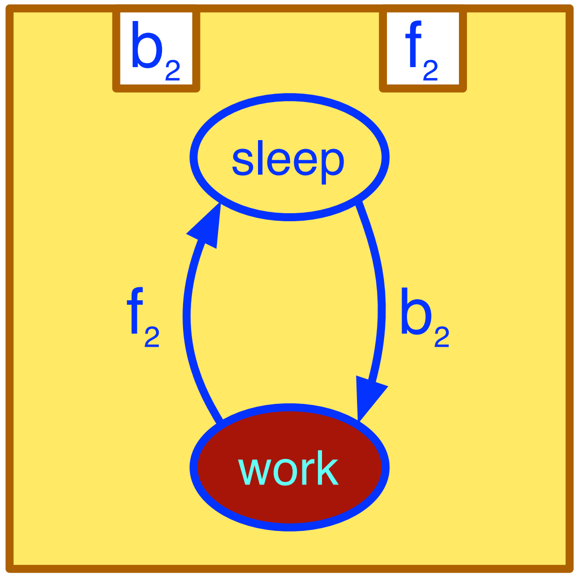
Component-based design

- Three layers
    - Component behaviour
    - Coordination
    - Data transfer



Example in BIP





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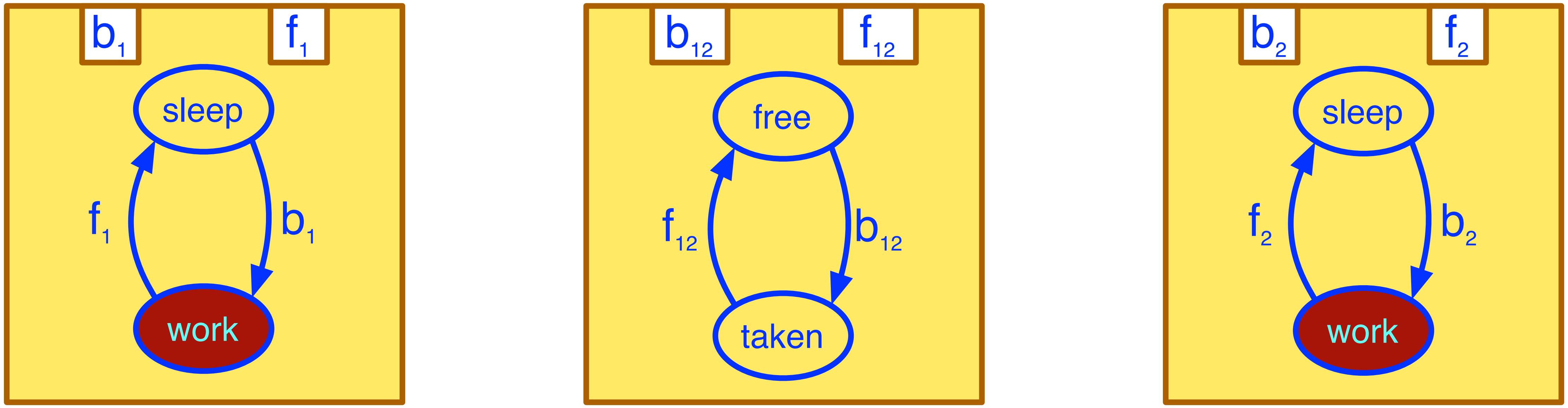

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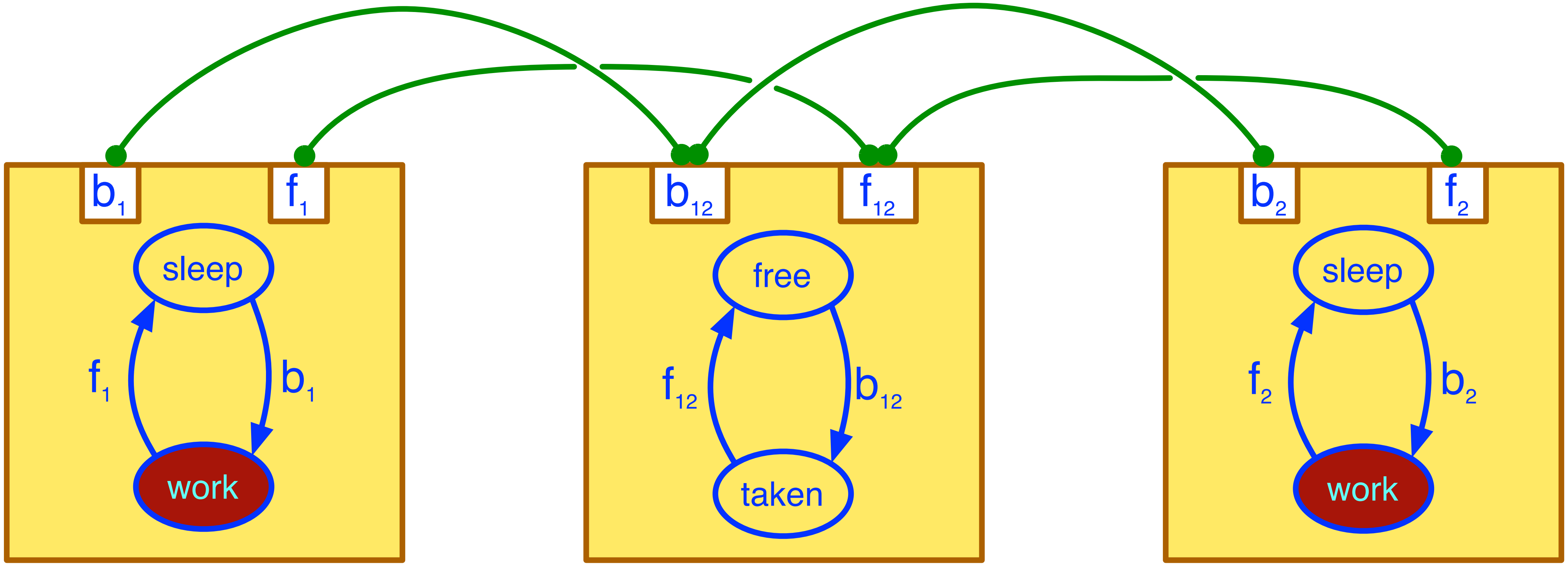

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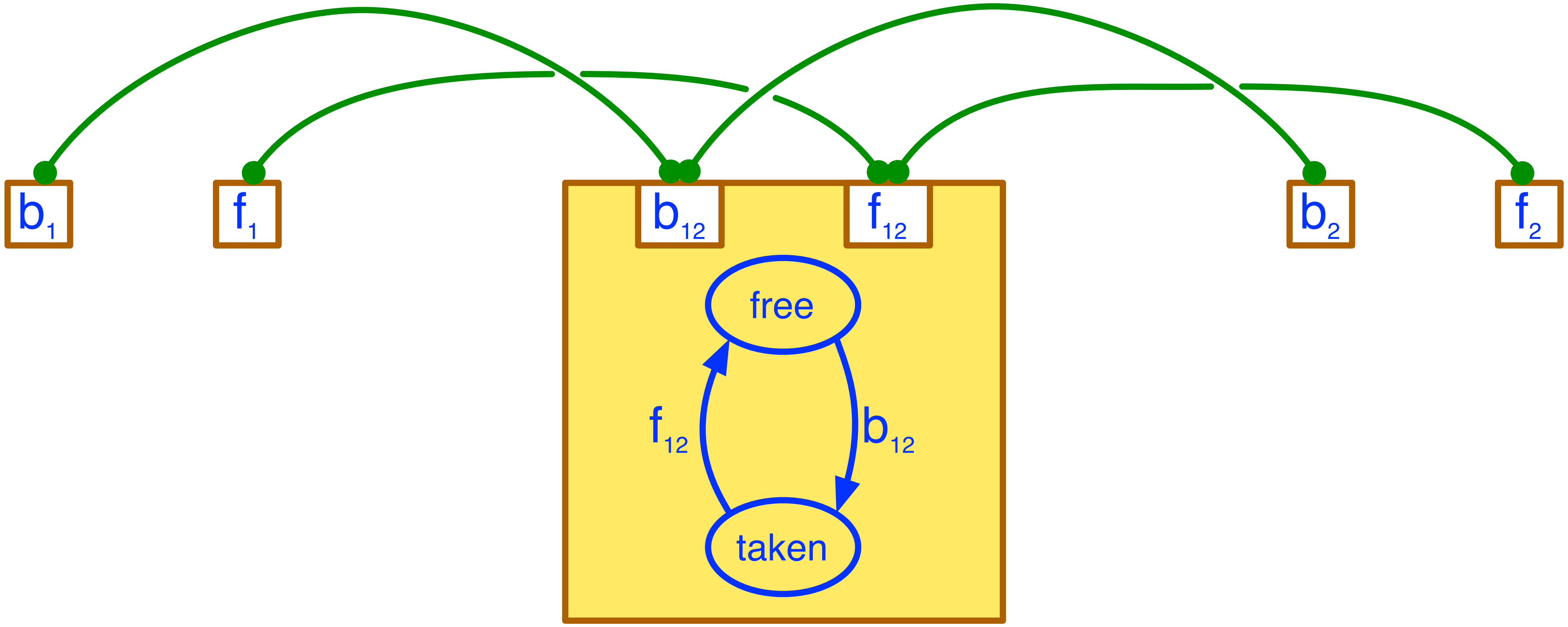

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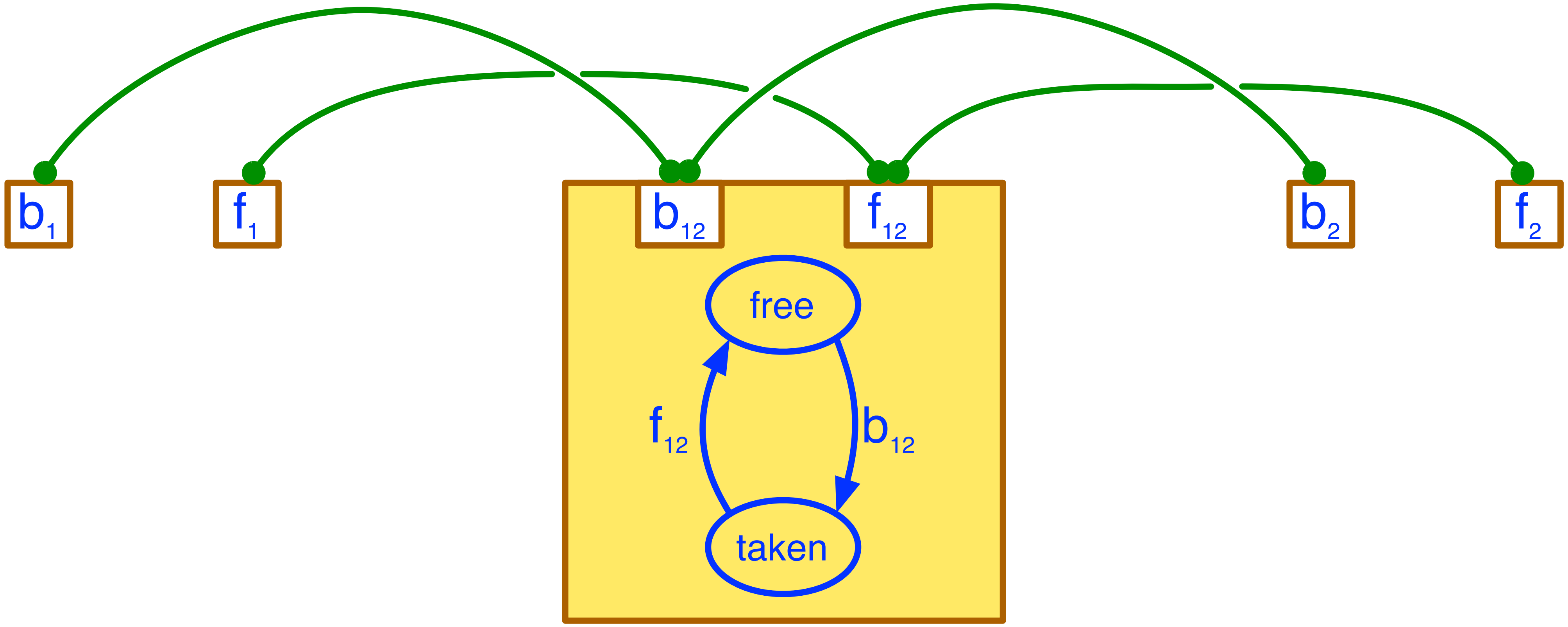


$$\gamma_{12} = \{\emptyset,\ b_1 b_{12},\ b_2 b_{12},\ f_1 f_{12},\ f_2 f_{12}\}$$

Architectures in BIP

$$A = (\mathcal{C}, P_A, \gamma)$$

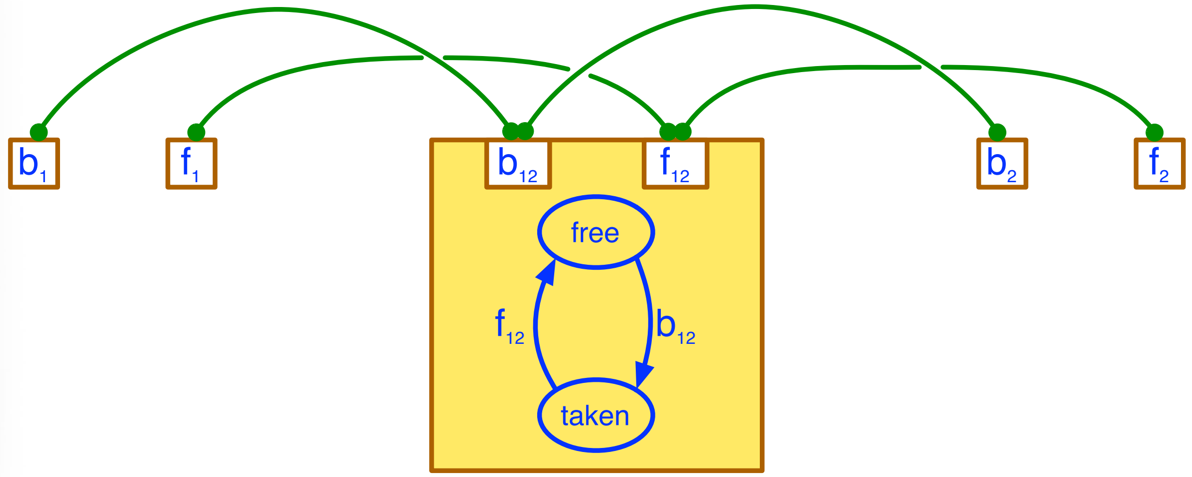
Set of coordinating behaviours

Interface (ports)

Interaction model

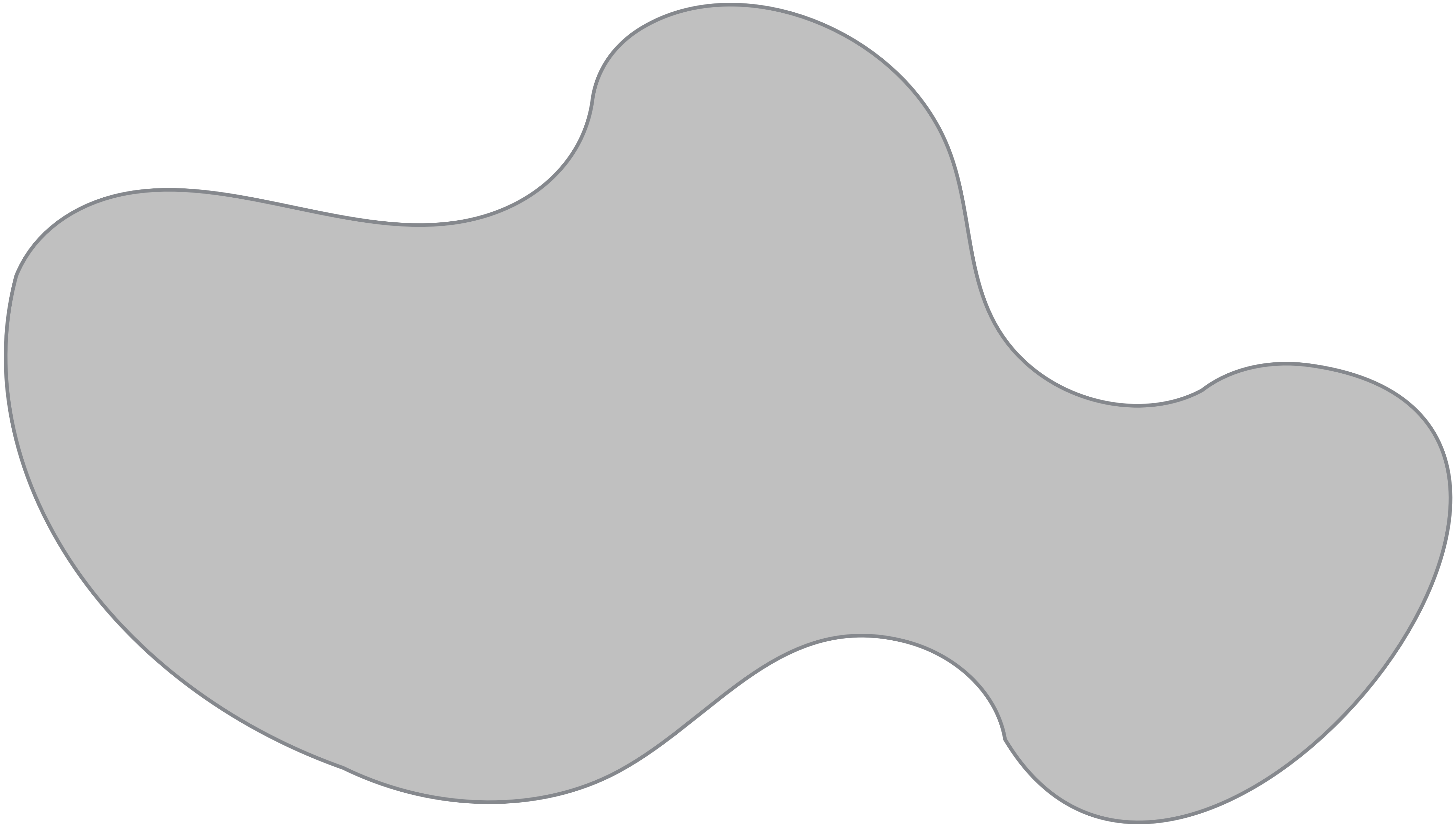
The interface includes all ports of the coordinator components

$$\bigcup_{C \in \mathcal{C}} P_C \subseteq P_A$$



How to combine?

Constraints intuition



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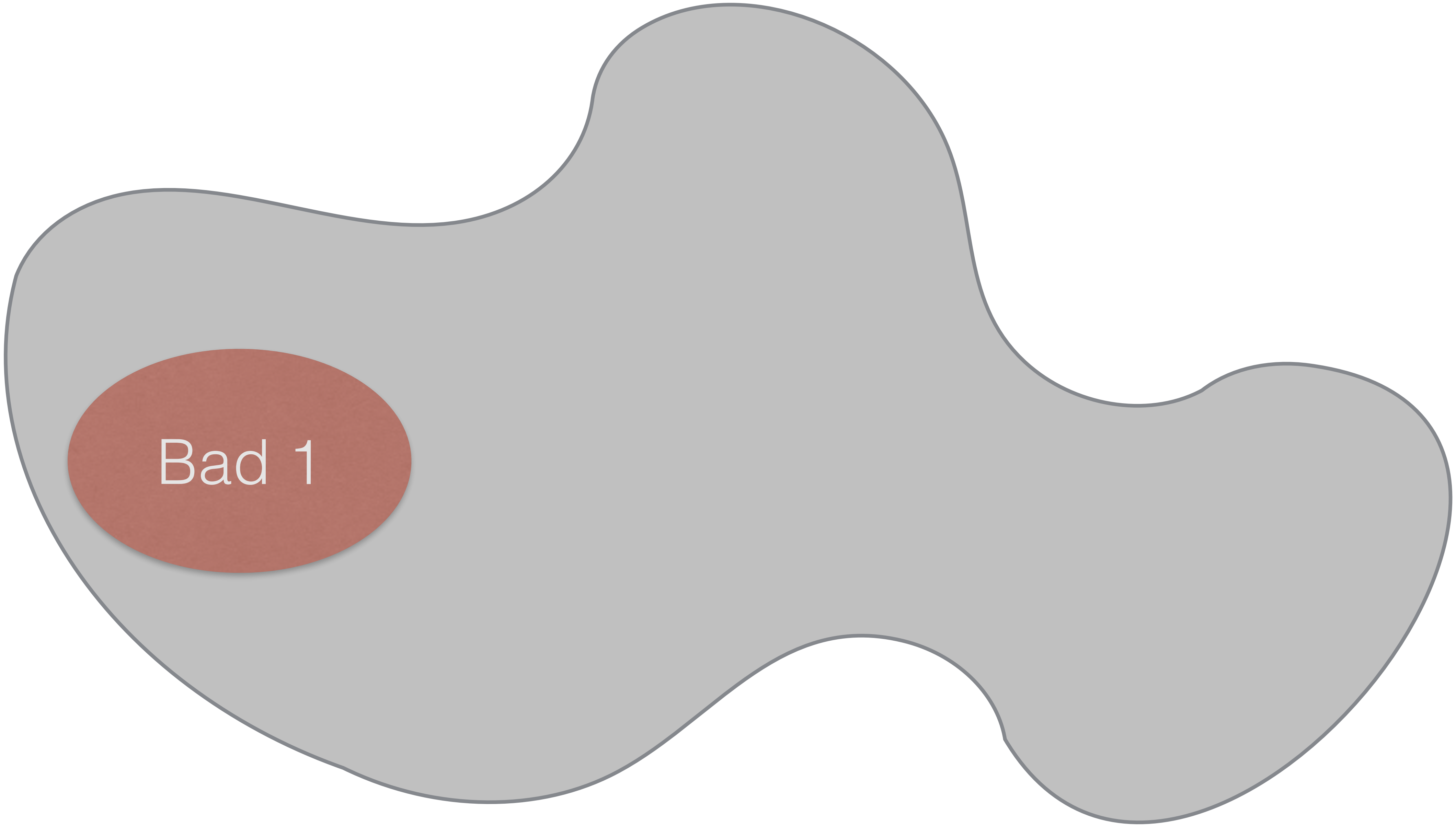

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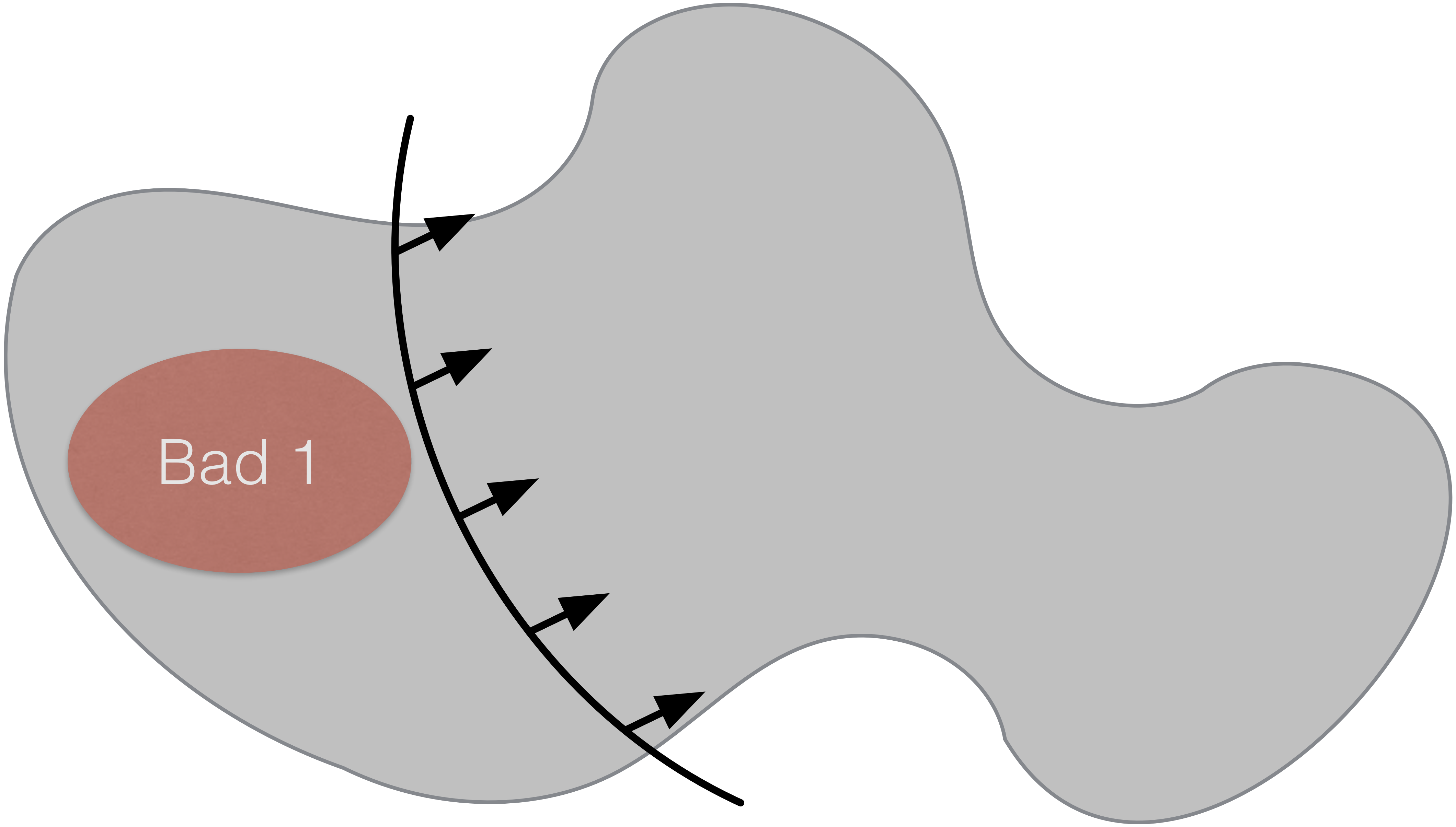

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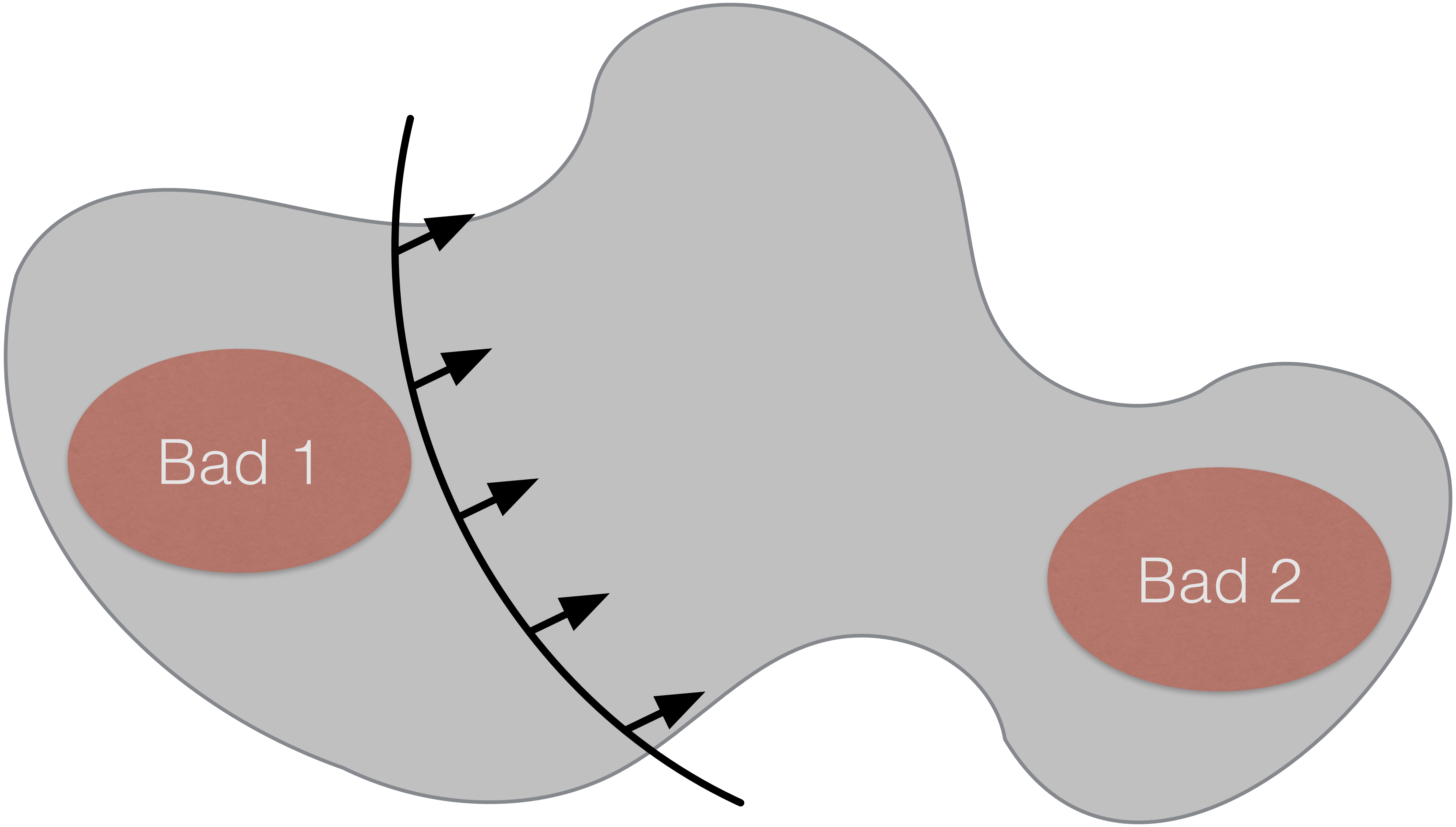

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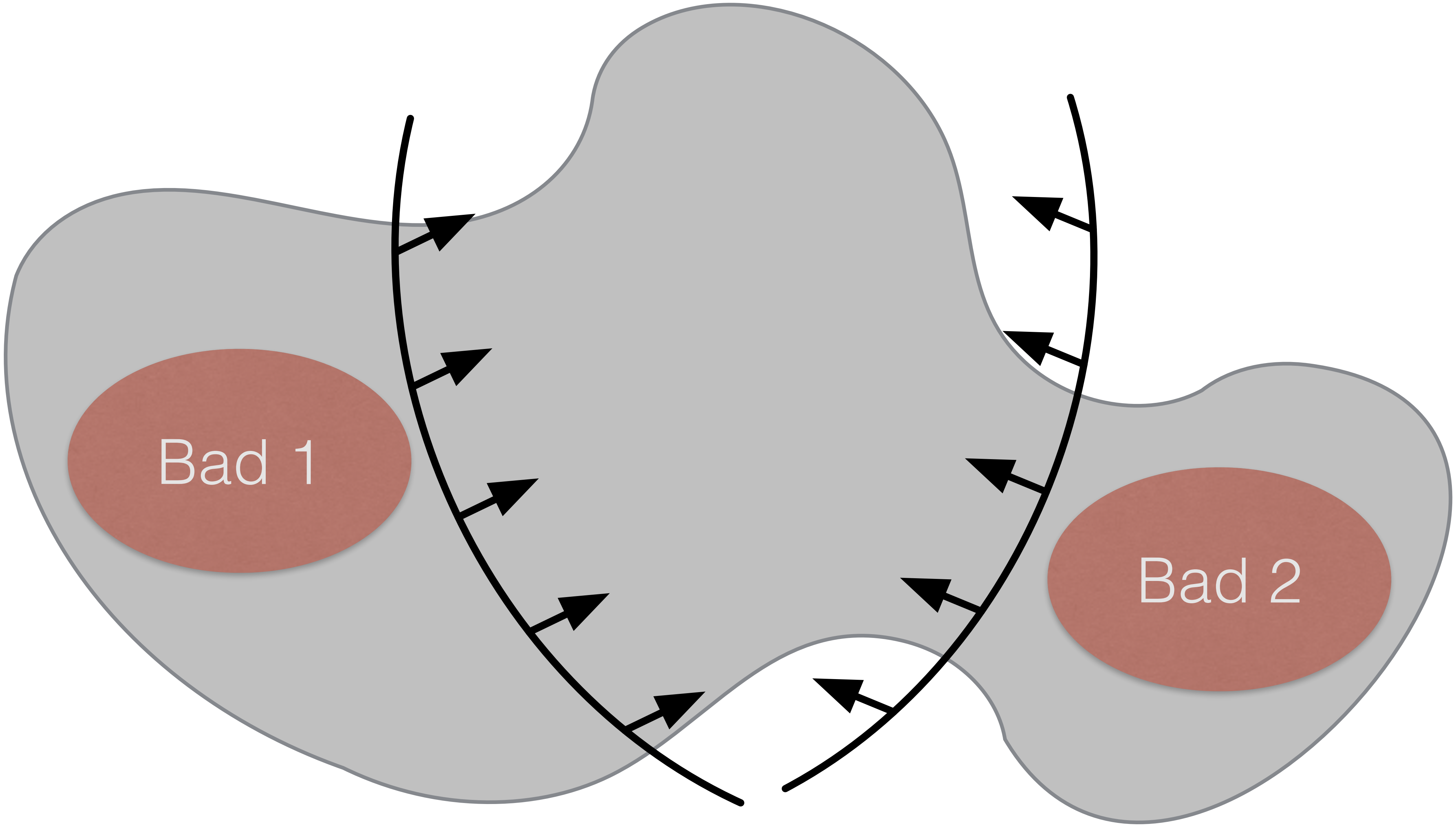

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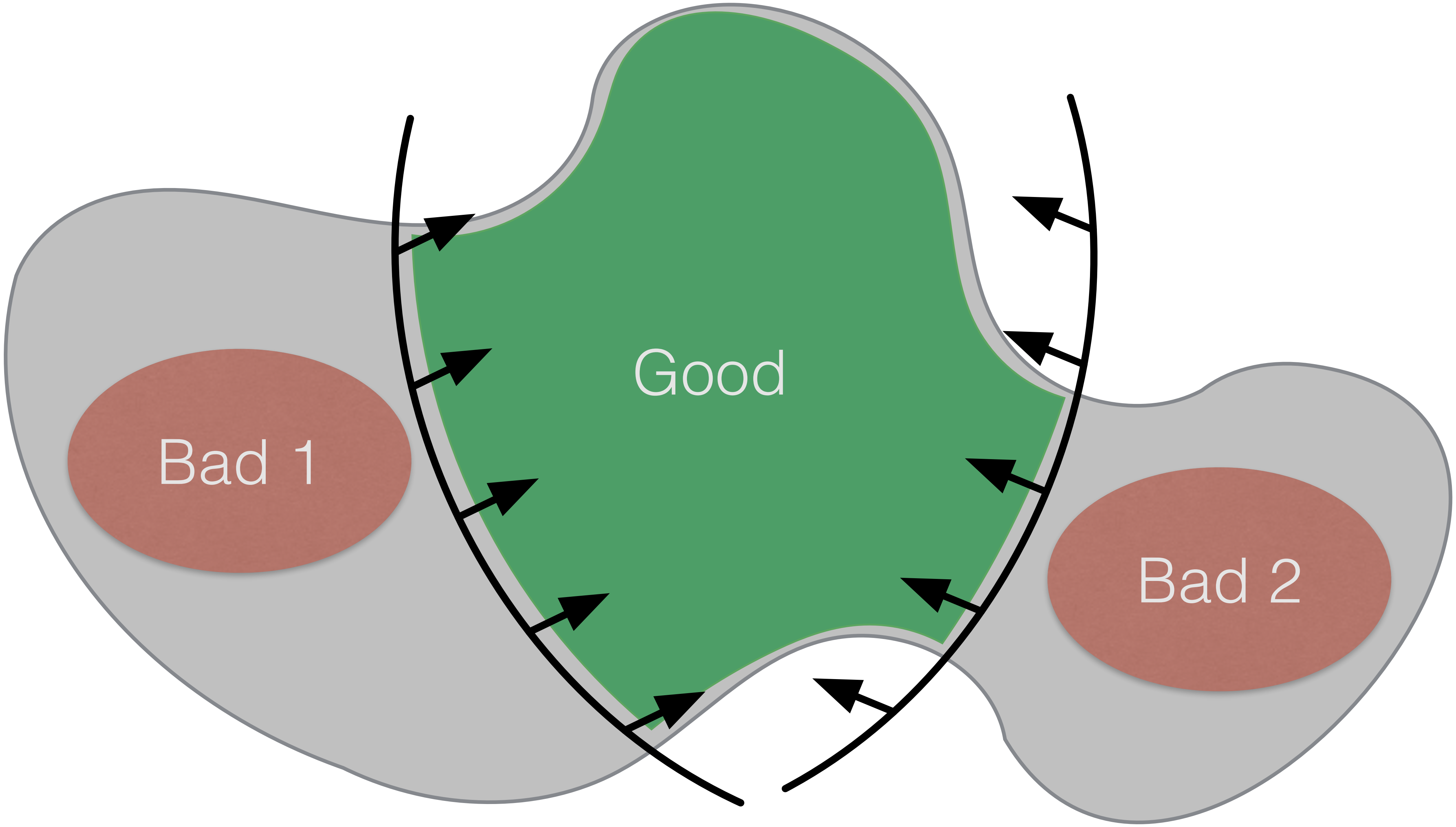
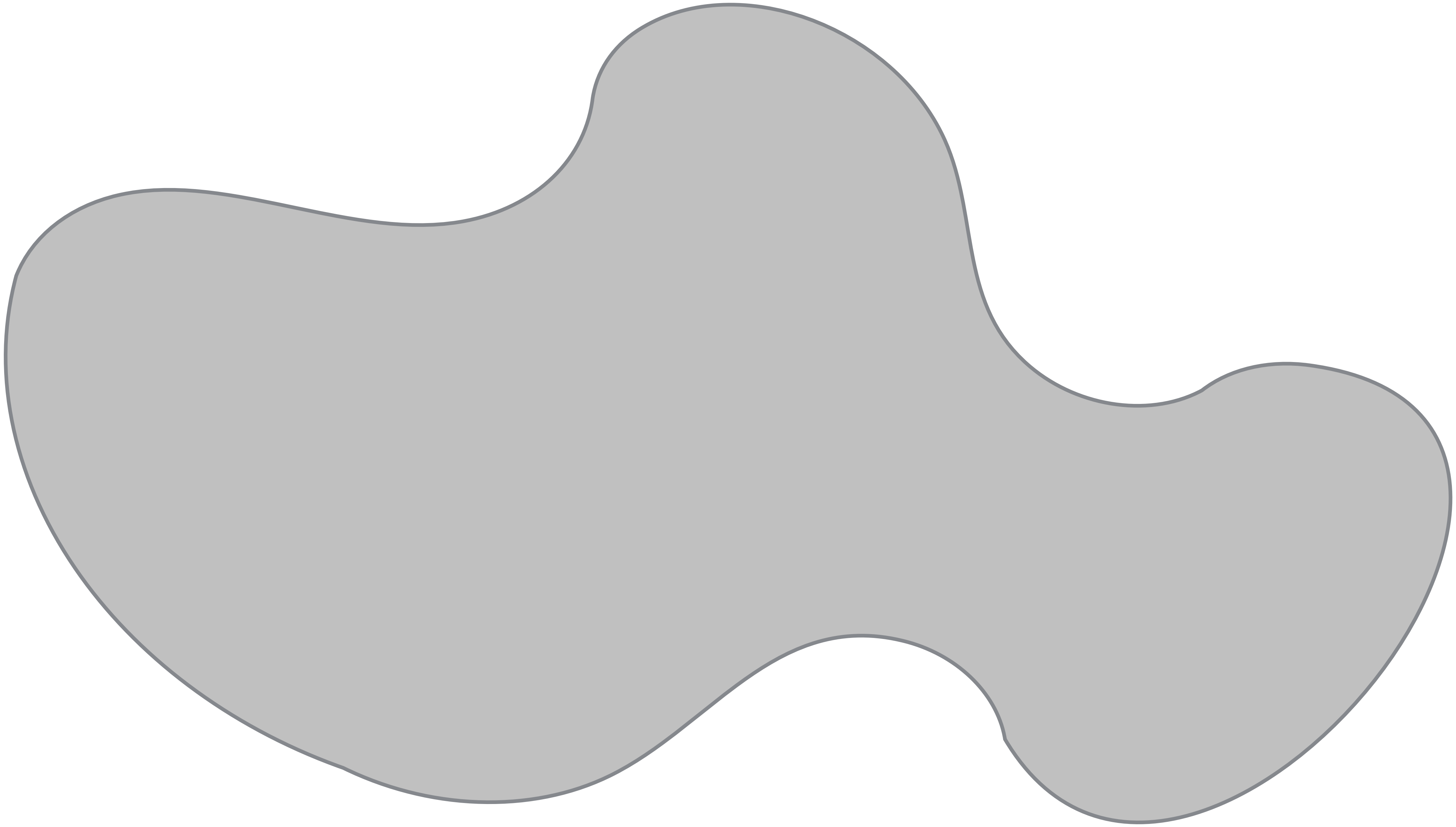


Limits of white magic



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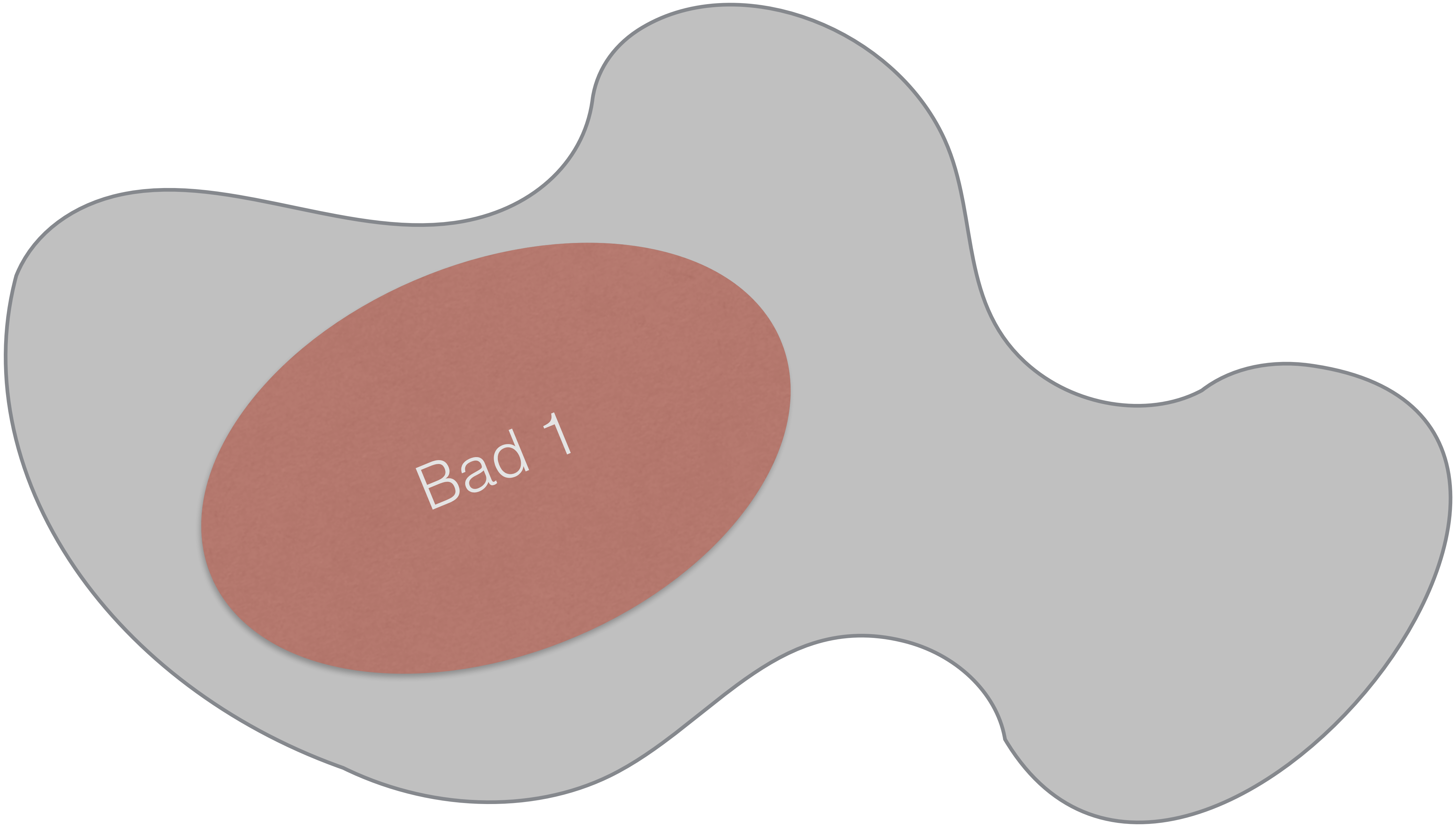

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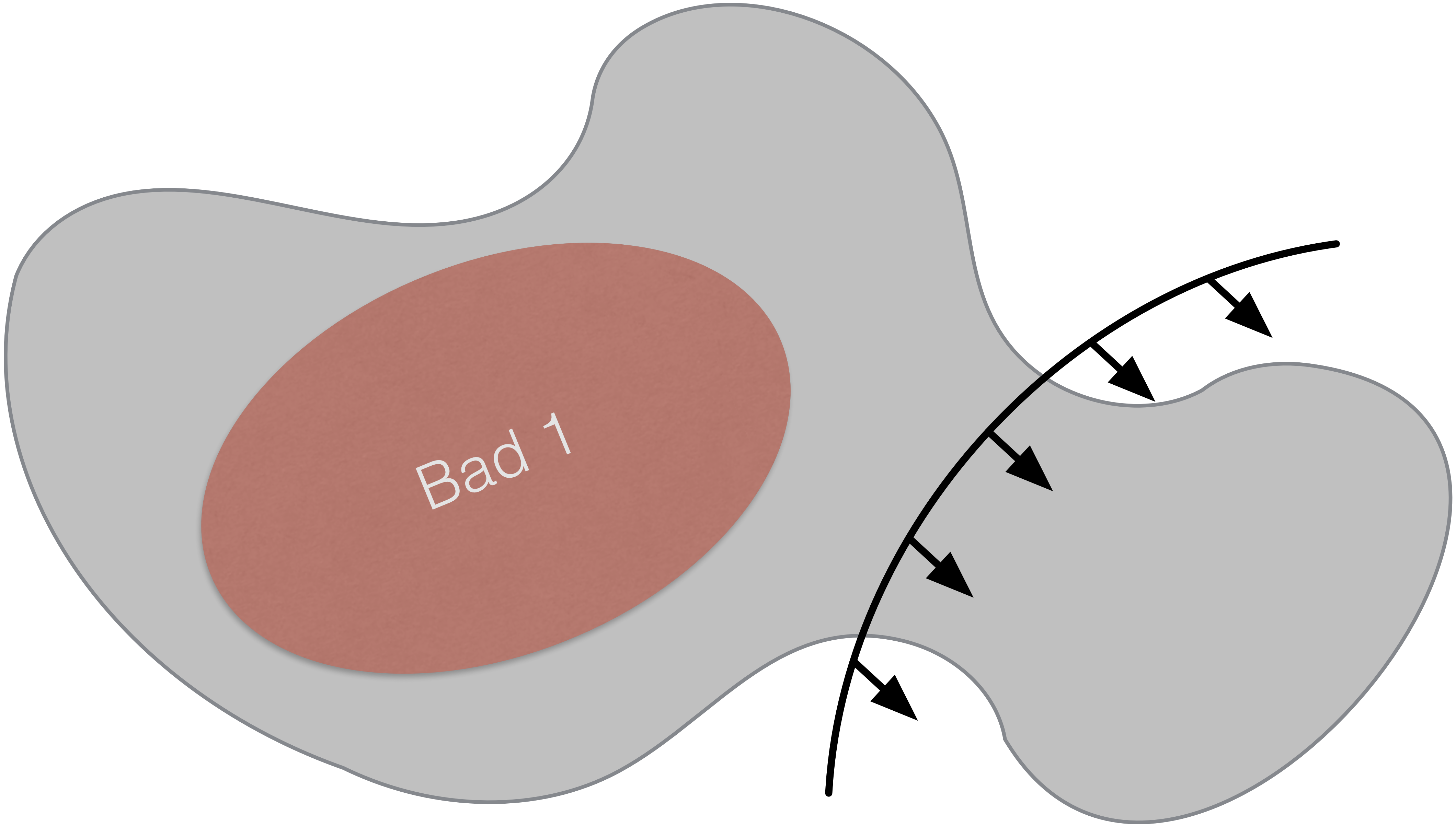

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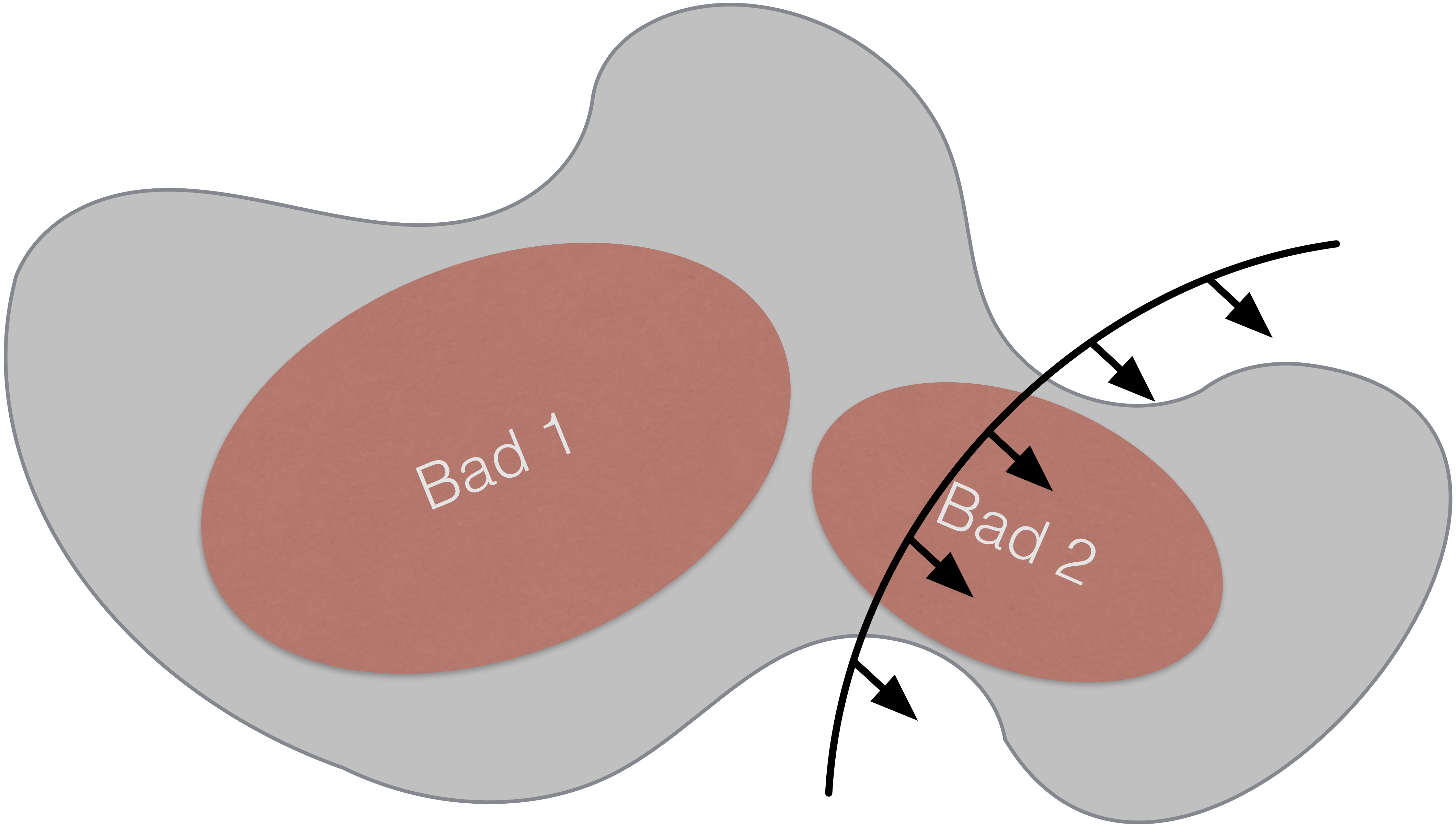

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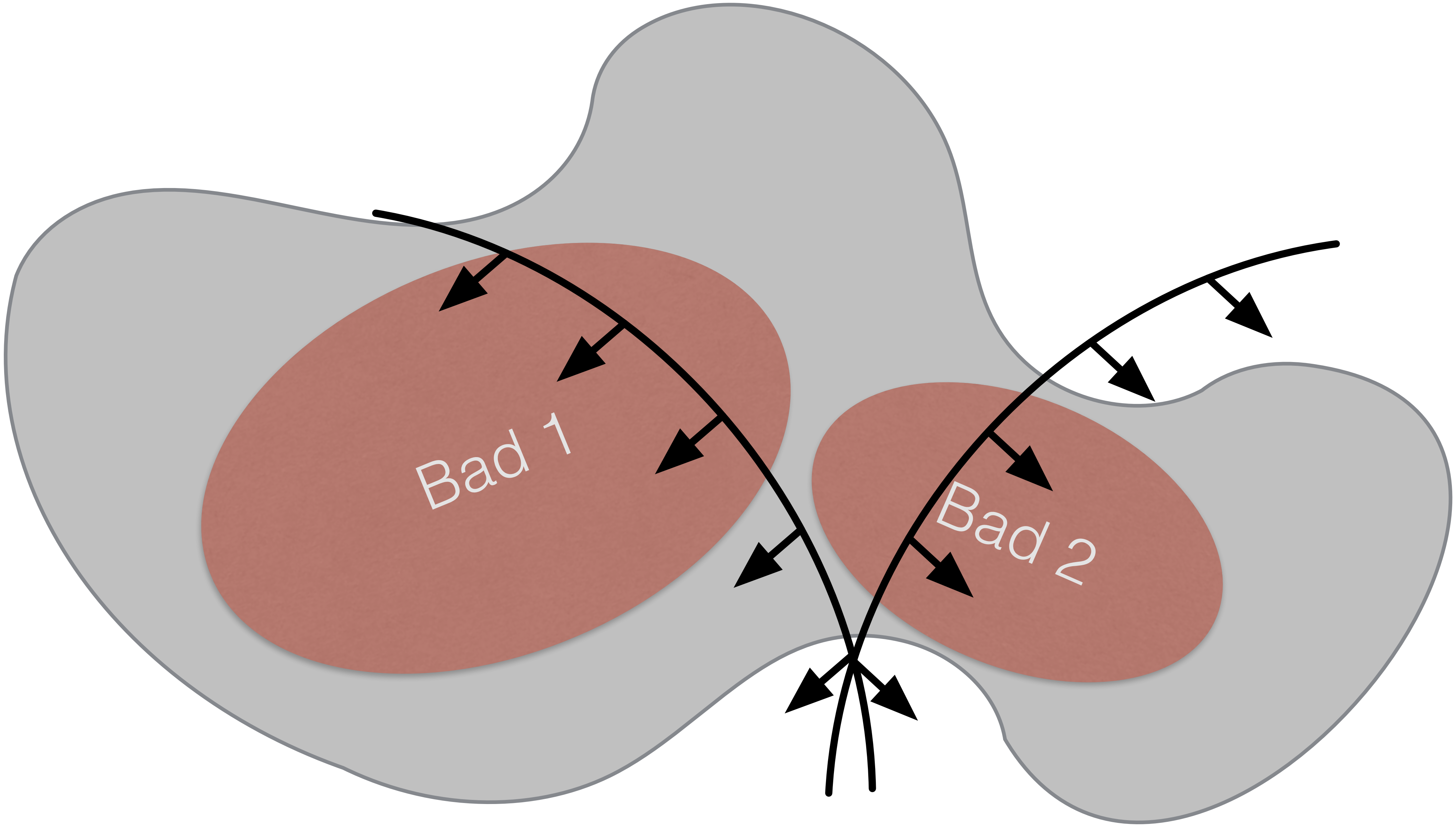

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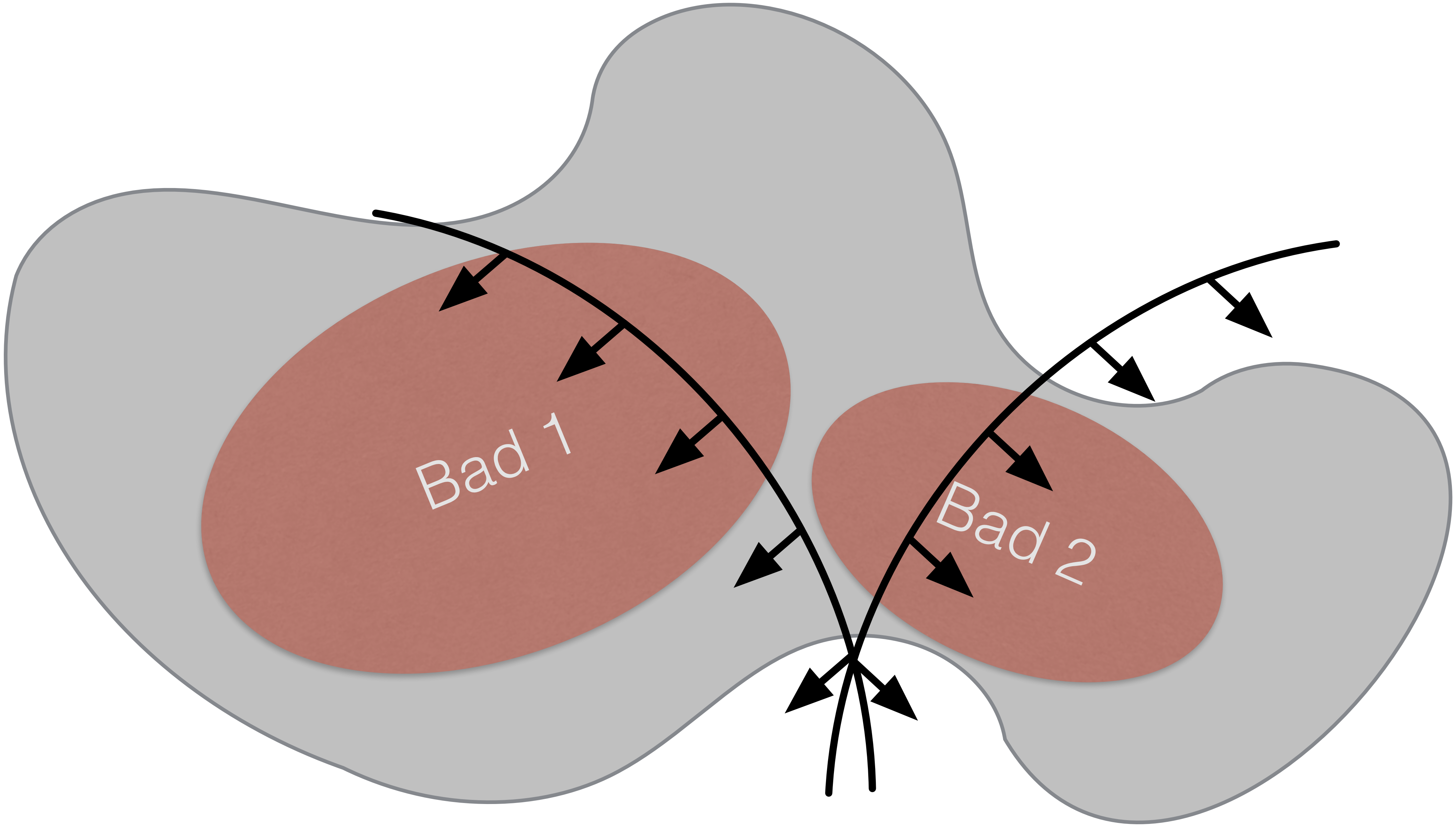
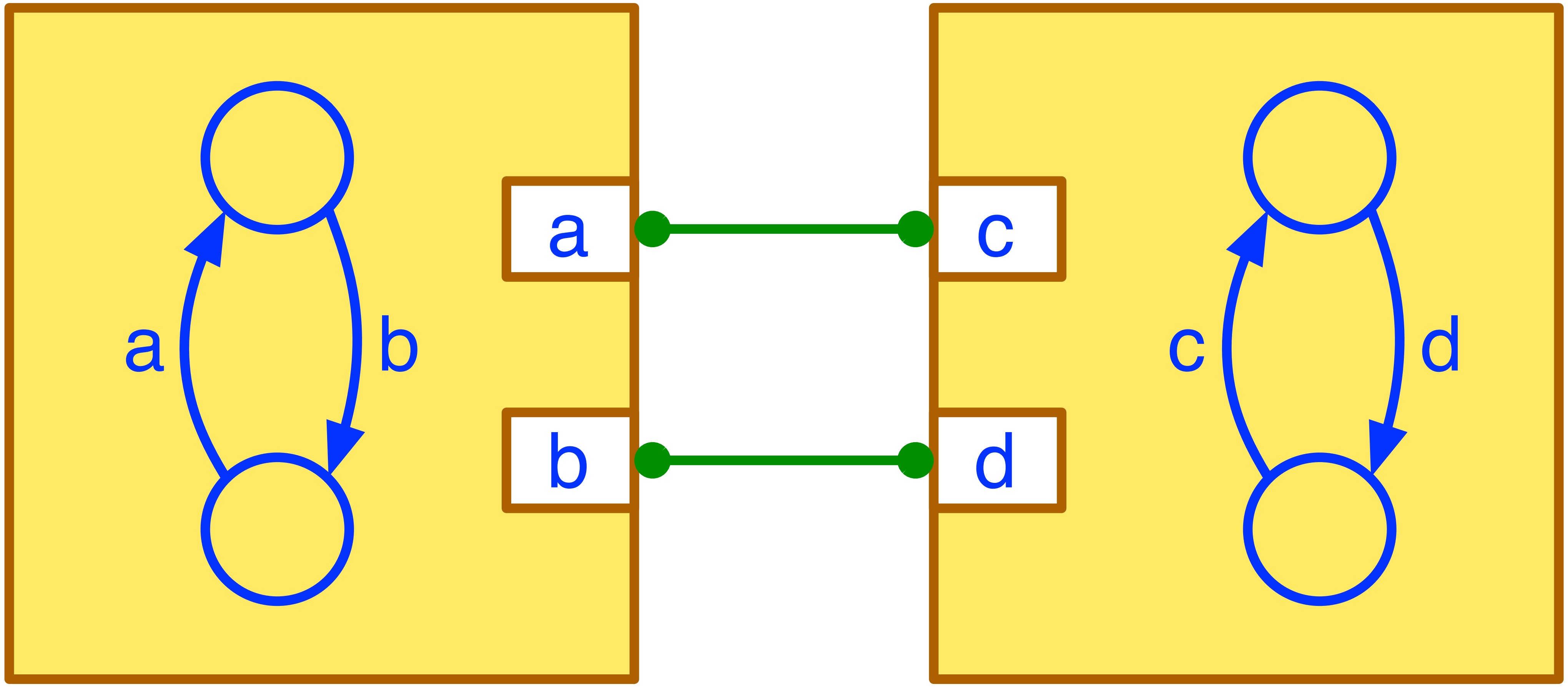


How to implement efficiently?



Architecture-based

External: component behaviour is not modified

Task 1:

```
while (true) {
   free(S1);
   take(S2);
   do-a;
   free(S1);
   take(S2);
   do-b;
}
```

Task 2:

```
while (true) {
   take(S1);
   free(S2);
   do-c;
   take(S1);
   free(S2);
   do-d;
}
```

Architecture-agnostic

Internal: the coordination primitives mix-up with the functional behaviour of the components

Two sides of the same design

- Architecture-based
  - External
  - Declarative
  - Highly abstract
  - Relies on an execution engine
  - Easy to understand, analyse and manipulate

- Architecture-agnostic
  - Internal
  - Imperative
  - Detailed
  - Relies on low-level primitives
  - Efficient

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Internalisation

Conclusion

- Architectures solve coordination problems by enforcing characteristic properties.

- First steps toward the study of a rigorous concept of architecture and its effective use for achieving correctness by construction in a system design flow.
  - A notion of architecture in BIP
  - Safety-preserving architecture composition operator
    - [SEFM 2014] *A General Framework for Architecture Composability*
  - Architecture internalisation using Top/Bottom component model
    - [CBSE 2014] *Architecture internalisation in BIP*

Future work

- Modelling
    - Study and classification of real-life architectures in various domains (Embedded systems, web services, enterprise integration, etc.)
    - Versatility of the model
    - Dynamic architectures
- Specification
    - Development of a simple powerful language for specifying architectures and their characteristic properties
- Efficiency & distribution
    - Optimisation of internalised architectures
    - Implementation based on message-passing mechanisms (e.g. AKKA)

Thank you for your attention