Life-long Learning Perception using Cloud Database Technology

Tim Niemueller, Stefan Schiffer, and Gerhard Lakemeyer
Knowledge-based Systems Group, RWTH Aachen University

Safoura Rezapour-Lakani
Intelligent and Interactive Systems, University of Innsbruck

RWTH AACHEN UNIVERSITY

Motivation

Identify specific objects of interest in sensor range.

- Describe objects by attributes instead of classes
- Learn objects over time
- Integrate new perception approaches over time
- Accommodate various sensor modalities

Motivation

Identify specific objects of interest in sensor range.

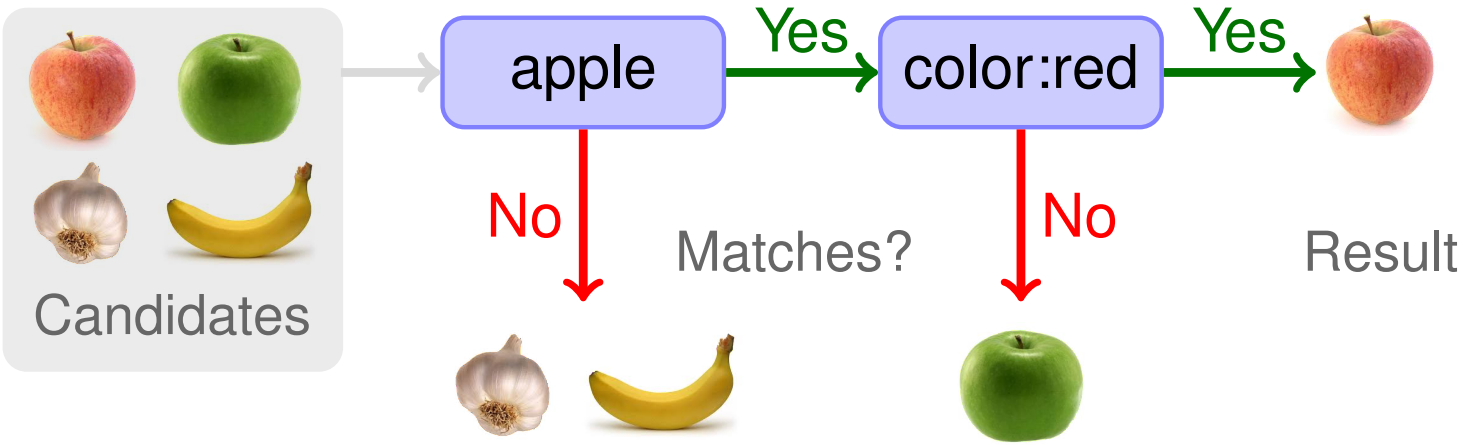
- Describe objects by attributes instead of classes
- Learn objects over time
- Integrate new perception approaches over time
- Accommodate various sensor modalities

Distributed Robot Perception Database

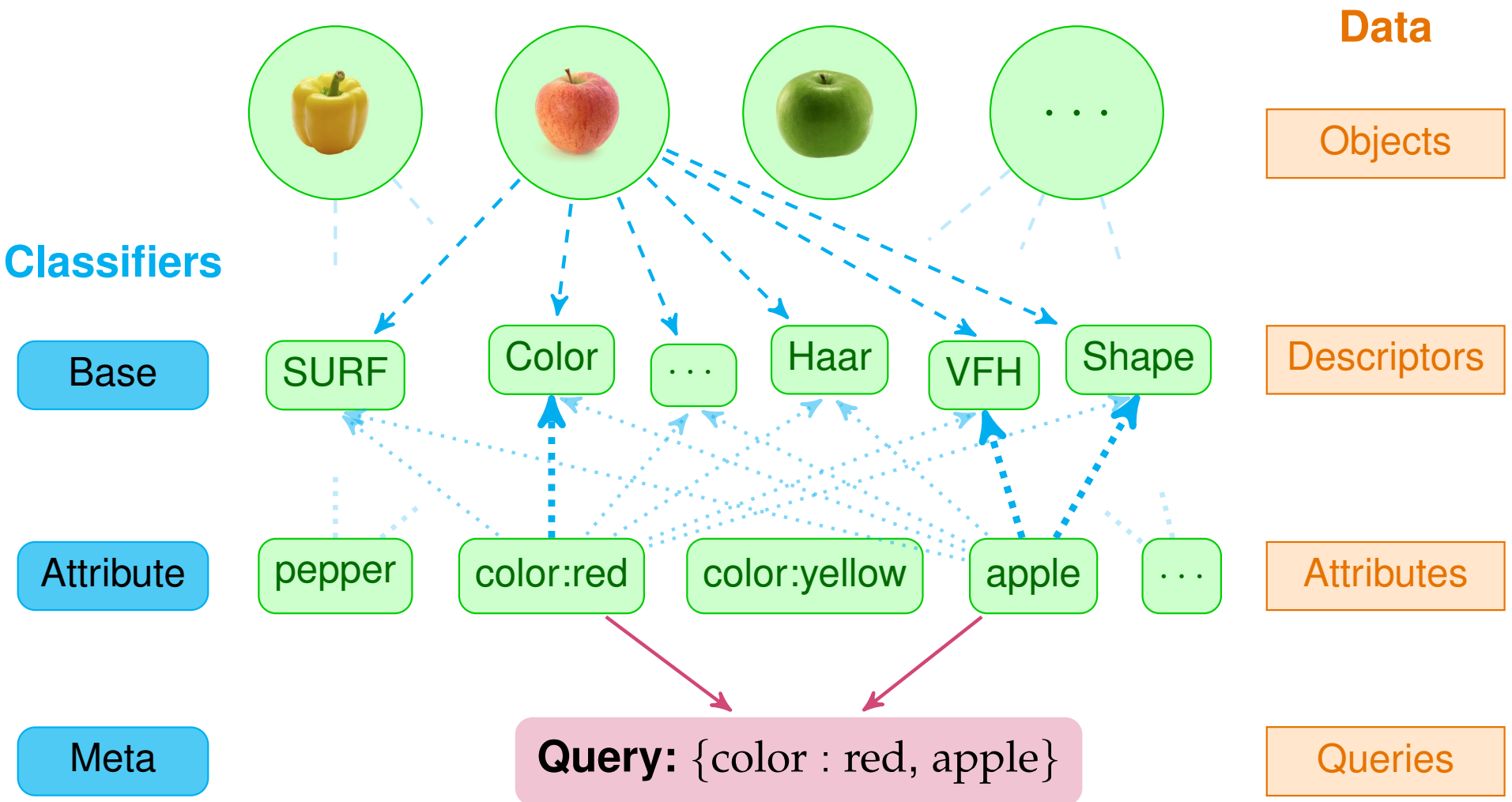
Extend perception system and object database over time and share it among robots.

Perception Classifier Cascades

Find a red apple.



Architecture



Perception Database Requirements

Flexible Data Structures

- varying/evolving data structures

Data Management

- unified storage architecture
- replication, backup and restore

Flexible and Efficient Retrieval

- query for specific data
- low-overhead retrieval of diverse and large data

Perception Database Requirements

Flexible Data Structures

- varying/evolving data structures

Data Management

- unified storage architecture
- replication, backup and restore

Flexible and Efficient Retrieval

- query for specific data
- low-overhead retrieval of diverse and large data

MongoDB, the document-oriented, schema-less database, is particularly well-suited to fulfill these criteria.

MongoDB and its Building Blocks

Document-oriented

- Grouped key-value pairs

Schema-less

- No declaration or enforcement of particular structure by DB

Collections

- Similarly structured documents
- Indexing reference frame

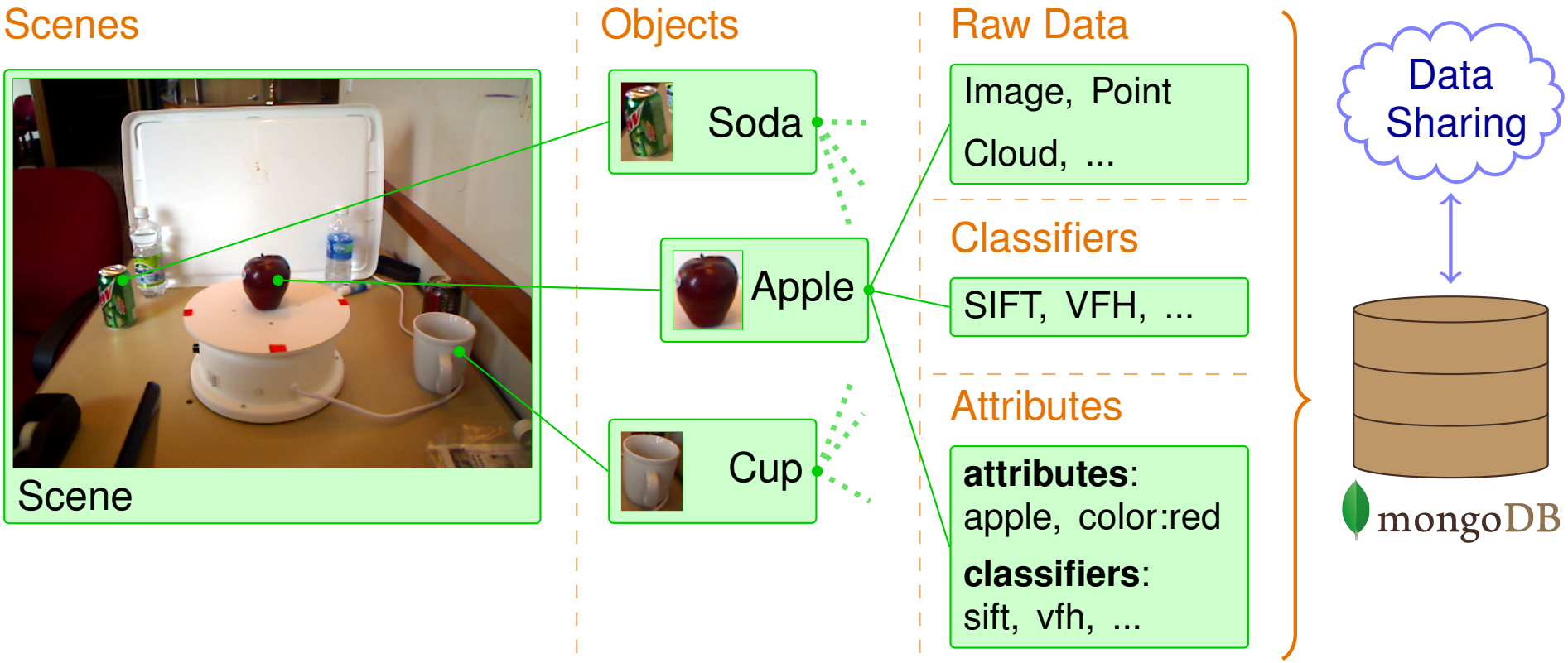
Queries

- JavaScript based query language
- Select based on document fields

```
{ // attributes/classifiers
  // for specific object
  "_id" : ObjectId("50e..."),
  "data_id" : "apple_1_1_10_c"
  "scene_id" : "apple_1_1_10"
  "attributes" : {
    "apple" : true,
    "color" : "red"
  }
  "classifiers" :
    ["SIFT", "SURF", "Gabor",
     "Haar", "Color", "VFH" ...]
}

{ // classifier info excerpt
  // for attribute doc
  "_id" : ObjectId("52..."),
  "data_id" : "apple_1_1_10_c"
  "VFH" : {
    "model_file" :
      "apple_1_1_10_c_vfh.txt"
    "extract_time" : 20
  },
  // [...]
}
```

MongoDB in our Perception System



Query Example

$$Q = \{\text{color} : \text{red}, \text{cup}\}$$

```
{
  attributes: {
    "apple": true,
    "color": "red"
  }
}
```

Query Example

apple

color:red

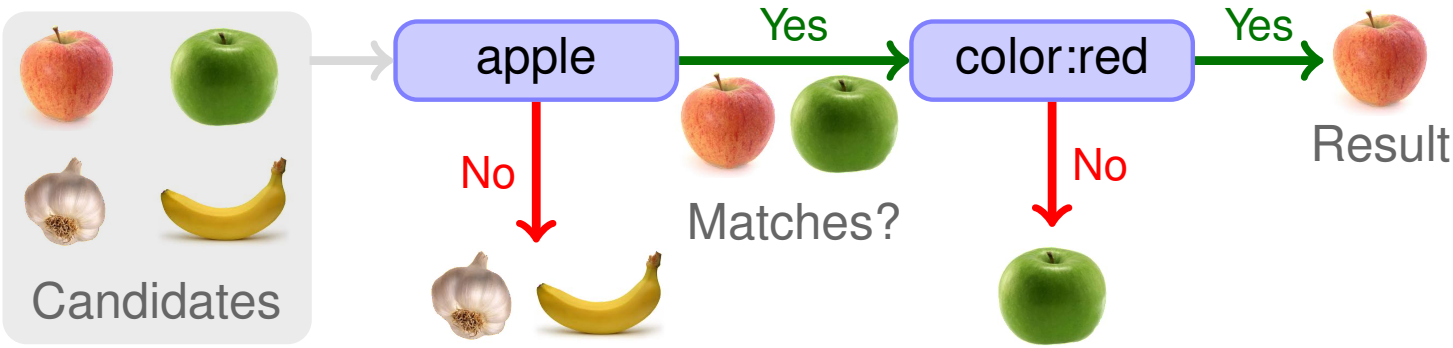
$$C_q^D = D.\text{classifiers}, \quad \text{where } q \in D.\text{attributes}$$

$$C_q = \bigcap_{C_q^D \neq \emptyset} C_q^D$$

```
docs = db.attributes.aggregate(
  {$match: { "attributes.color": "red"}},
  {$project: {classifiers: 1}},
  {$group: {_id: "$classifiers"}})
}

set_intersect(docs, "classifiers");
```

Query Example



$$O_q = C_q(\text{input})$$

$$O = \bigcap_{q \in Q} O_q$$

- Apply classifiers
- Filter through cascade

Why a Cloud Database?

Flexible Data Structures

- Easily accommodate various data types
- Quickly grow w/o tedious specification

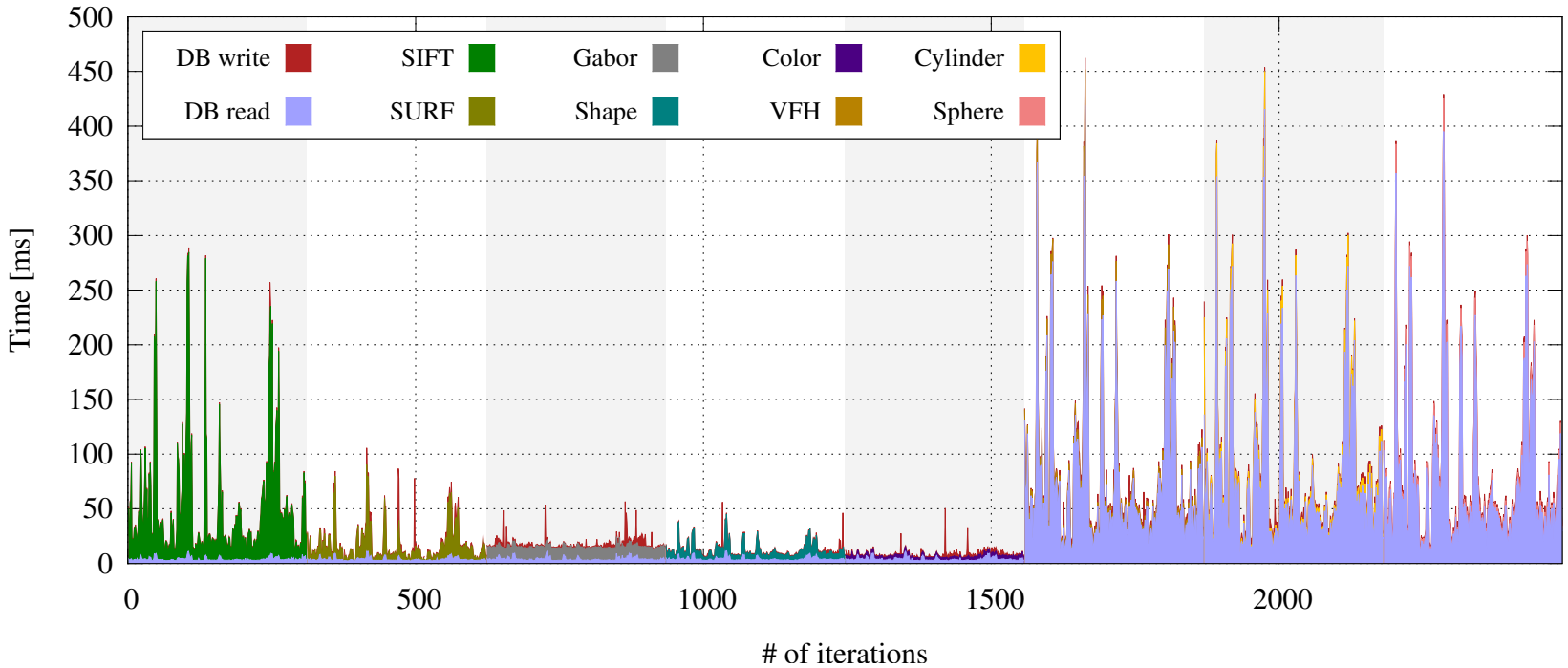
Query Capabilities

- Formulate queries deep into data structures
- Major benefit over traditional file system storage

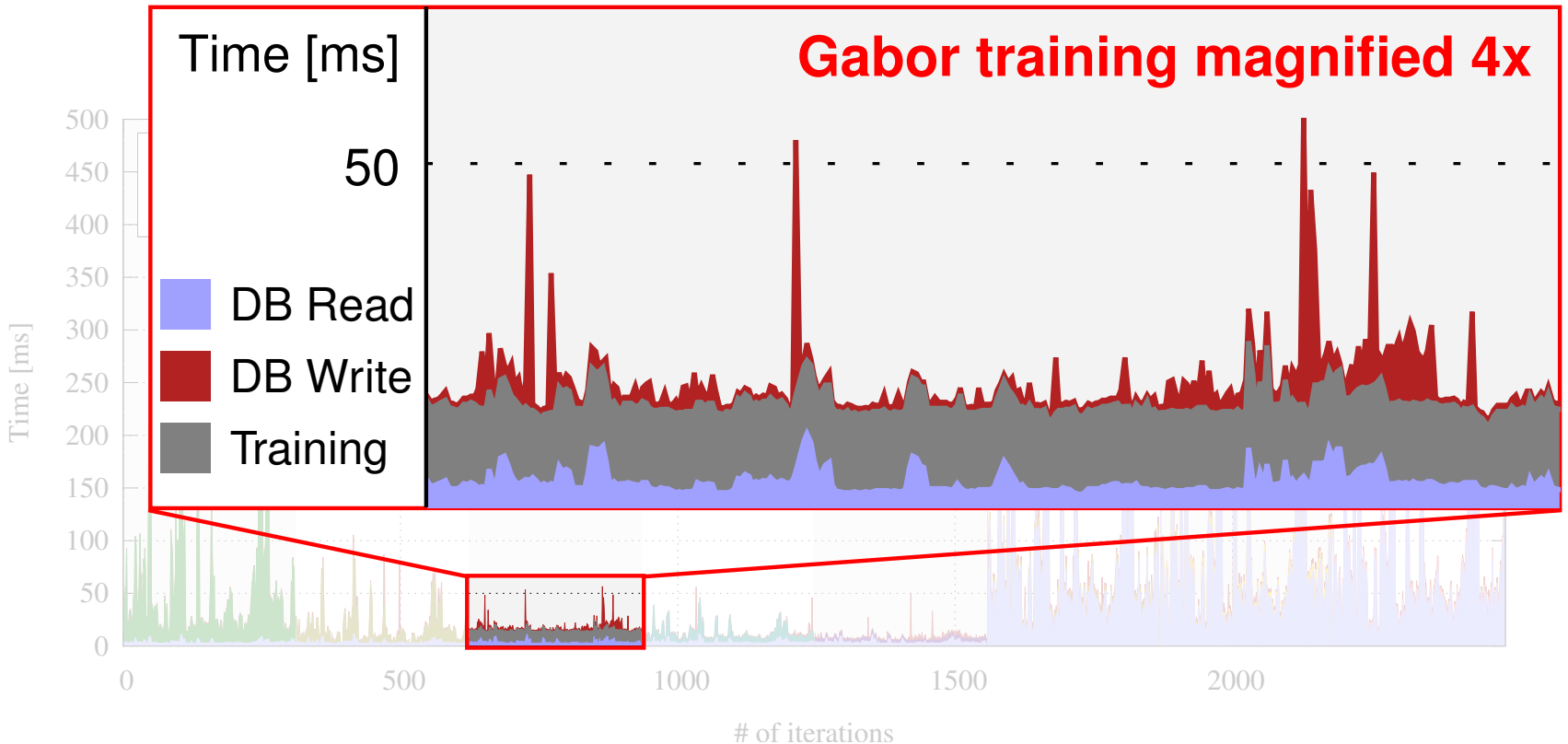
Distributed Data

- Replicate for off-line training
- Quick boot-strapping for new robots/methods
- Sharding for multi-host robots

Full Retraining



Full Retraining



Conclusion and Questions

Cloud database for perception which is extensible in terms of known objects and perception methods.

- Attribute-based perception
- Increasing number of objects
- Evolve perception methods
- Flexible storage w/ MongoDB
- Capable query features
- Share data among robots

`www.fawkesrobotics.org`