Meta-set calculus as mathematical basis for creating abstract, structured data store querying technology

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Abstraction of object set: Meta-set

- Metaset consists of:

  <type constraints>
  - Defines types in object databases
  - Defines tables in relational databases
  - Defines basic structures in other databases

  [property-value constraints] are combinations of metadata and value (data);
  - In relational context it can be interpreted as property-value constraint;
  - In key-value stores it can be interpreted as key-value pair;

  {object set constraints} which defines relationships between 2 sets
- Example:

```
<Person>[FirstName="Mikus", LastName= ="Vanags"]
```

- Meta-set can be interpreted as query to data store. Equivalent query to relational database:

```
SELECT * FROM PERSONS
WHERE FirstName="Mikus" AND LastName="Vanags"
```

Mostly people use many abstractions, but do not interpret them as abstractions

$$\sin x = \mathrm{x} - \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} + \cdots + \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{(2n+1)!}$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} + \frac{x^6}{6!} + \cdots + \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n}}{(2n)!}$$

Trigonometric functions are abstractions of infinite Tailor series. Without these abstractions many things would not be possible!

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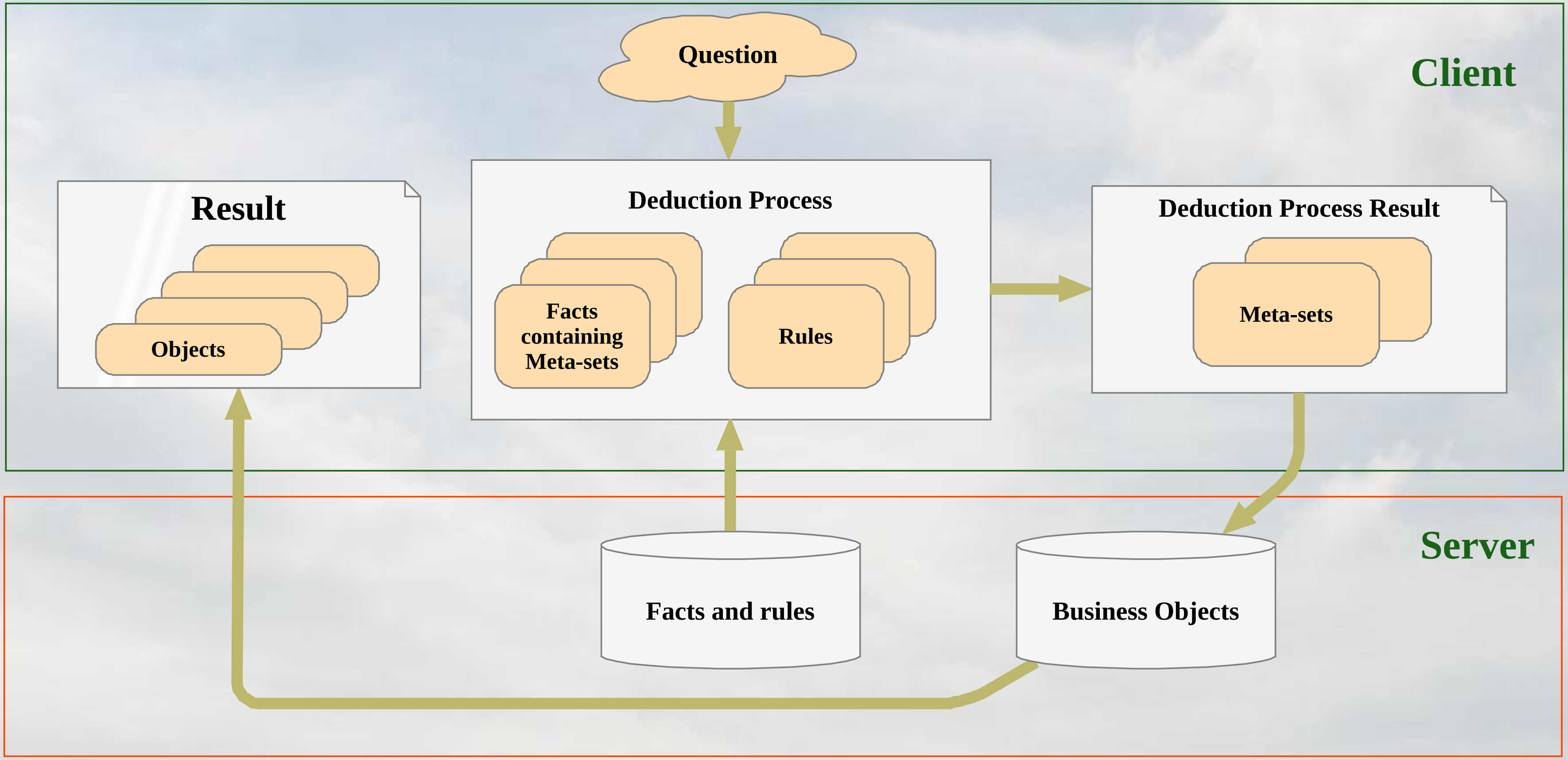
Why meta-sets are so important?

- **Meta-set describes set of unknown number of objects** (theoretically it could be even infinity).
- Second order predicate logic engine could work without meta-sets, but it still could ended with loading in memory all database content during deduction process.

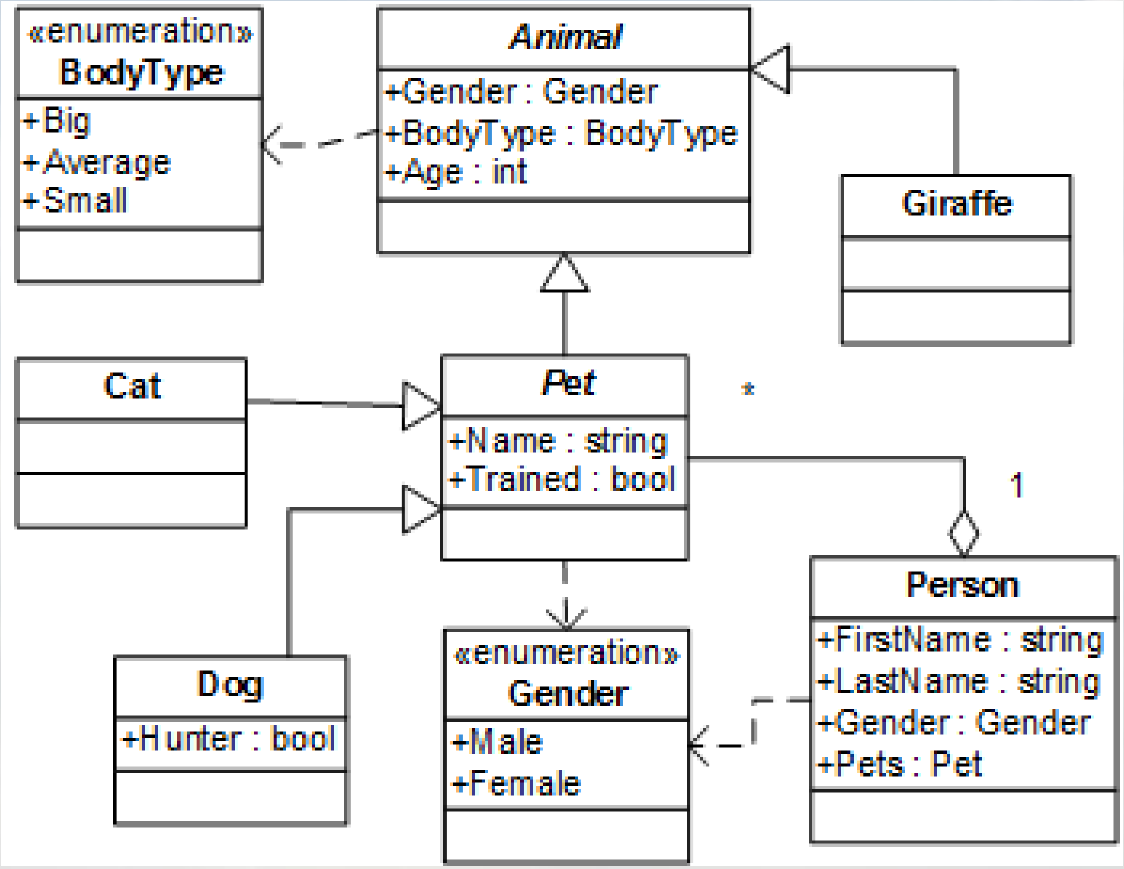
Querying process in Decentralized Deduction Engine



Meta-set calculi similarity to constraint logic programming

- In addition to constraint logic programming **Meta-set calculi**:
  - **Contain type information**
  - **Support object set abstractions**
  - **work with many constraint stores**
- Both CLP and MSC **requires modifications in logic programming engine**.

Physical model used in all examples



Meta-set matching and unification with meta-sets

- Meta-set matching differs from object matching, because meta-sets are like small parts of larger query that is being built and not all differences in meta-sets are considered as failures in matching. For example:

1) something(<Dog>) **matches** with something(<Dog>)
2) something(<Dog>) **matches** with something(<Pet>)
3) something(<Dog>) **matches** with something(<Animal>)
4) something(<Dog>) **does not match** with something(<Cat>)
5) something(<Dog>) **does not match** with something(<Person>)
6) something(<Dog>) **matches** with something(x).

- In unification, when meta-set type constraints matches and if variable was used in matching , the meta-set, to which the variable references, will contain updated list with the most specific type constraints from both meta-sets, merged lists of both meta-set property-value constraints and set-constraints

Difference between TermNode syntax and TermExpression syntax

- **TermNode** syntax is not type safe, but expressions are processed at compile time.
- **TermExpression** syntax is more type safe (still not fully type safe), but TermExpressions are evaluated at runtime.
- We wanted to design **general purpose language extensions** to support meta-sets (and get performance + full type safety), but discovered, that large software vendors can just ignore us, we needed orthogonal (independent solution)...

Proposed Solution

- **Abstract data querying language:**

  “Get” or more googlable form “GetLang”

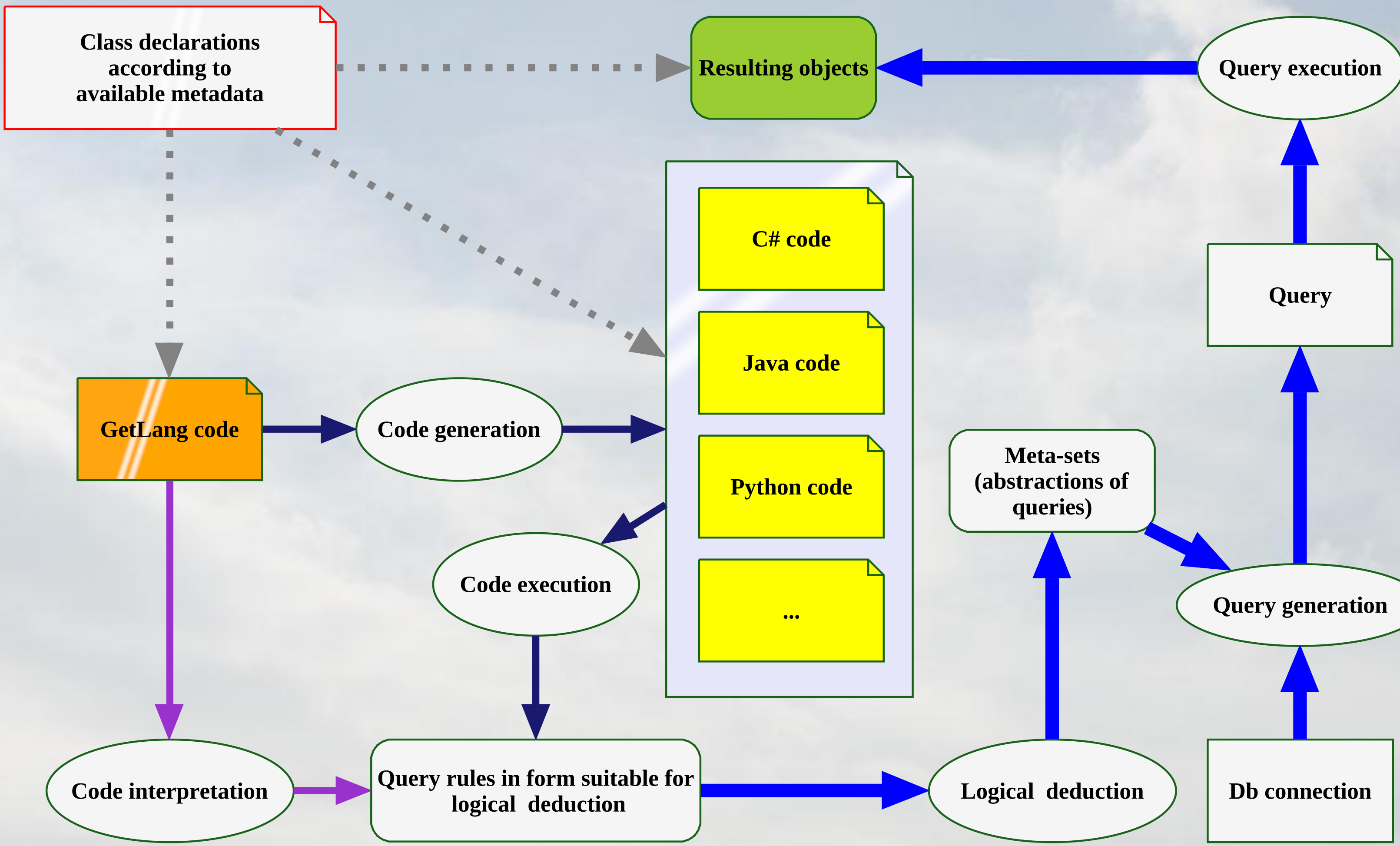
- **which is based on our invented calculus:**

  “Meta-set calculus” – extension of second order predicate calculus

- **and our calculus implementation is named:**

  “Decentralized Deduction Engine” or simply DDE

GetLang use cases



GetLang example for 4 queries reusing common query parts

```
using DataStructures;

metaset Invoice a;
metaset TransportationInvoice b;
metaset AcceptanceInvoice c;
metaset b,c d;
metaset a,d e;

parameter Warehouse Warehouse;
parameter DateTime DateFrom;
parameter DateTime DateTo;

inPeriod(e) : e.DealDate >= DateFrom, e.DealDate < DateTo;
atWarehouse(a) : a.Warehouse = Warehouse;
fromWarehouse(d) : d.WarehouseFrom = Warehouse;
toWarehouse(d) : d.WarehouseTo = Warehouse;
order(d) : OrderAscending(d.DealDate, d.DealNumber);

buyingAtWarehouseInPeriod(a) : atWarehouse(a), inPeriod(a), order(a);
transportationFromWarehouseInPeriod(b) : fromWarehouse(b), inPeriod(b);
toWarehouseInPeriod(d) : toWarehouse(d), inPeriod(d);


BuyingAtWarehouseInPeriod = buyingAtWarehouseInPeriod(a)?
TransportationFromWarehouseInPeriod = transportationFromWarehouseInPeriod(b)?
TransportationToWarehouseInPeriod = toWarehouseInPeriod(b)?
AcceptedAtWarehouseInPeriod = toWarehouseInPeriod(c)?
```

From this code will be possible to generate code in general purpose programming languages like C#, Java and others...

Comparison of db4o querying technologies

(integrated in general purpose programming languages)

```
// soda query definition execution example
var query = _db.Query();
query.Constrain(typeof(Invoice));
query.Descend("_warehouse").Constrain(_warehouse);
query.Descend("_dealDate").Constrain(dateFrom).Greater().Equal();
query.Descend("_dealDate").Constrain(dateTo).Smaller();
query.Descend("_dealDate").OrderAscending();
query.Descend("_dealNumber").OrderAscending();
var results query.Execute().OfType<Invoice>();
```

SODA queries:

- performs excellent,
- are not type safe,
- can't reuse existing query parts,
- are difficult to serialize

```
// linq query definition and execution example
var results = (from Invoice invoice in _db
               where
                    invoice.Warehouse == _warehouse &&
                    invoice.DealDate >= dateFrom &&
                    invoice.DealDate < dateTo
               orderby invoice.DealDate, invoice.DealNumber
               select invoice).ToList();
```

LINQ queries:

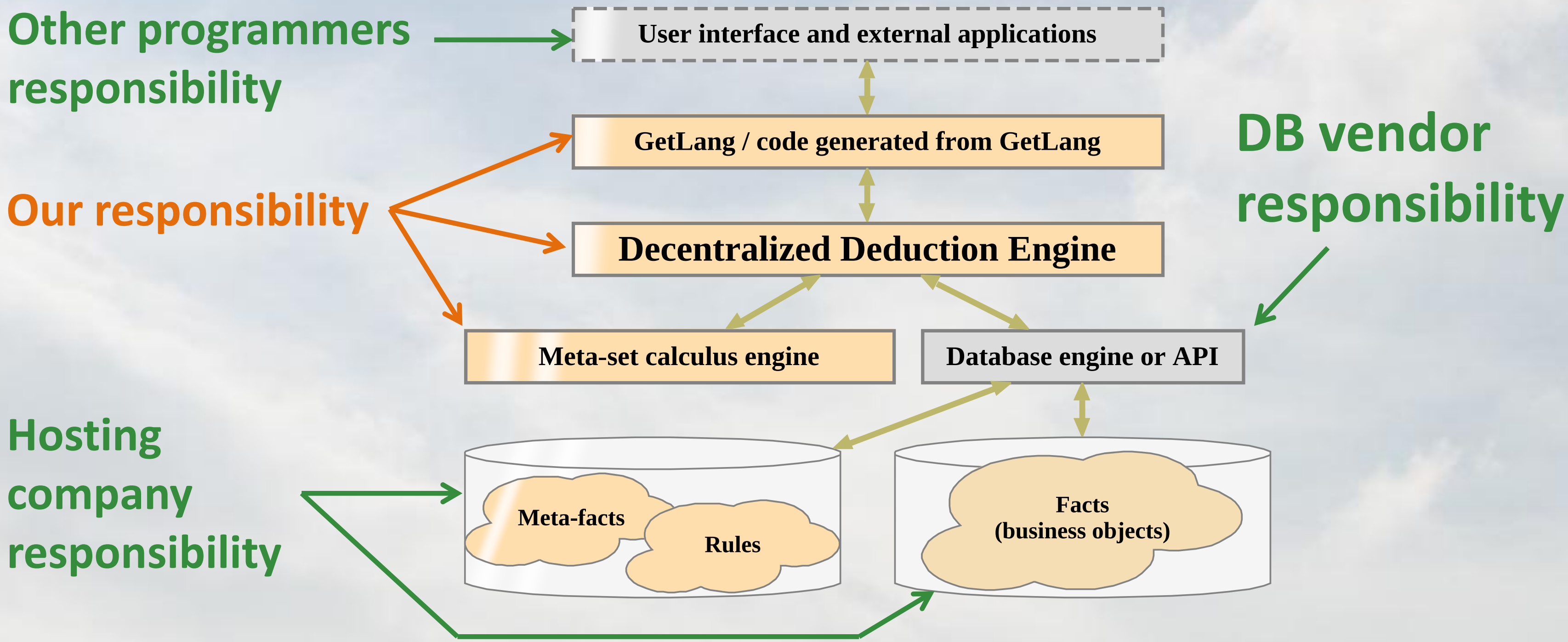
- not always performs excellent,
- are strongly typed,
- can't reuse existing query parts,
- are difficult to serialize

```
// dde query execution example
// _dde is instance of QueryingLogic class generated from GetLang code
var results _dde.BuyingAtWarehouseInPeriod(_warehouse, dateFrom, dateTo);
```

DDE queries:

- performs as fast as SODA,
- reuses existing query parts,
- are strongly typed,
- can be easily serialized,
- and used in distributed systems

Layered structure of DDE and our responsibilities



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