J-Logic: Logical Foundations for JSON Querying

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Logical Foundations for JSON Querying

- **Object descriptions:** sets of path–value pairs
- **Path variables**
- **Generating new keys** by packing
- Testing the **object-to-object property**
- **Containment** testing
- Open problems

- JSON-to-JSON queries,
  easy access to deeply nested objects

Describing a JSON object…

```
{ name:john,
  children: { 1:{name:anne,age:12},
              2:{name:bob,age:18},
              3:{name:chris,age:24} } }
```

…as a set of path–value pairs:

```
{ name:john,
  children.1.name:anne,
  children.1.age:12,
  children.2.name:bob,
  children.2.age:18,
  children.3.name:chris,
  children.3.age:24 }
```

“object description”

J-Logic ingredients

- Object descriptions as binary relations
- Input as well as output
- Path variables `$x` , concatenation `.`
- Atomic variables `@x`
- Atomic value constants `john` , `42`
- Logic-based language (Datalog)

[Sequence Datalog, Bonner&Mecca]

Hello World in J-Logic

```
T(hello:world).
> T={hello:world}
```

My first real J-Logic program

```
> Sales={ 1:{1999:40,2017:35},
          2:{1999:70,2001:80},
          3:{2001:90,2002:70,2017:33}}
ByYear(@y.@p:@s) :- Sales(@p.@y:@s).
> ByYear = { 1999:{1:40,2:70},
             2001:{2:80,3:90},
             2002:{3:70},
             2017:{1:35,3:33}}
```

```
> Sales={ 1:{1999:40,2017:35},
          2:{1999:70,2001:80},
          3:{2001:90,2002:70,2017:33}}
> ByYear = { 1999:{1:40,2:70},
             2001:{2:80,3:90},
             2002:{3:70},
             2017:{1:35,3:33}}
```

object descriptions!

```
ByYear(@y.@p:@s) :- Sales(@p.@y:@s).
```

```
ByYear={1999.1:40,      Sales={1.1999:40,
        2017.1:35,             1.2017:35,
        1999.2:70,             2.1999:70,
        2001.2:80,             2.2001:80,
        2001.3:90,             3.2001:90,
        2002.3:70,             3.2002:70,
        2017.3:33}             3.2017:33}
```

Deep equality in J-Logic

```
> R={ a: o1 ,
      b: o2 }
// Are o1 and o2 equal?
T(answer:no) :- R(a.$x:@v), not R(b.$x:@v).
T(answer:no) :- R(b.$x:@v), not R(a.$x:@v).
Q(answer:no) :- T(answer:no).
Q(answer:yes) :- not T(answer:no).
```

Key generation by packing

```
// input: R, a deeply nested object
// retrieve all subobjects with loc:chicago
Q(<$x>.$z:@v) :- R($x.loc:chicago),
                 R($x.$z:@v).
```

```
// input: R, a deeply nested object
// retrieve all subobjects with loc:chicago
Q(<$x>.$z:@v) :- R($x.loc:chicago),
                  R($x.$z:@v).
> S={a:1,b:2}
> T={a:3,b:4}
// cartesian product of JSON objects
Cart(<@x.@y>.s.@x:@u) :- S(@x:@u),T(@y:@v).
Cart(<@x.@y>.t.@y:@v) :- S(@x:@u),T(@y:@v).
> Cart={<a.a>:{s:{a:1},t:{a:3}},
        <a.b>:{s:{a:1},t:{b:4}},
        <b.a>:{s:{b:2},t:{a:3}},
        <b.b>:{s:{b:2},t:{b:4}}}
```

Cartesian product by packing

Proper objects

- JSON objects are unordered
- Are `{loc:raleigh,loc:chicago}` and `{loc:chicago,loc:raleigh}` the same?
- Not in JavaScript!
- Objects where keys are not keys (!) are called **improper**
- Input objects are normally proper
- We should avoid outputting improper objects
- **Object-object property:** **proper inputs** are mapped to **proper outputs**

The object-object (O2O) property

```
> R={raleigh:loc,chicago:loc}
Q(@v:@k) :- R(@k:@v). // not O2O
> Q={loc:raleigh,loc:chicago}
```

- All other example programs we have seen so far are O2O
- **Theorem:** It is decidable (in EXPTIME) whether a given **positive, recursion-free** J-Logic program is O2O
- "Unions of conjunctive queries" for J-Logic

Deciding the O2O property

- "JSON atomic equality-generating dependencies" (**jaegd**)
- D is proper if it satisfies these two jaegds:

```
D($x:@u),D($x:@v) ⟶ @u=@v
D($x:@u),D($x.$y:@v) ⟶ false
```

- Plan:

1. Reduce O2O decision to the **implication problem for jaegds**
2. Solve the jaegd implication problem

Chasing jaegds?

- Complications due to two kinds of variables
- Consider Σ:

```
R(@x:42) ⟶ false
R(<$x>:42) ⟶ false
R($x.$y:42) ⟶ false
```

- Then Σ logically implies σ:

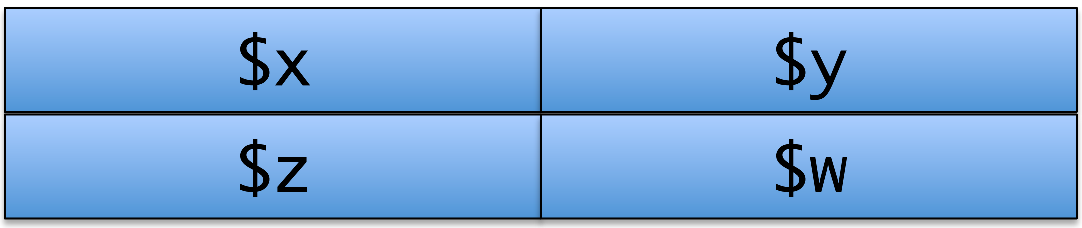
```
R($x:42) ⟶ false
```

- However, chasing σ with Σ does not fail
- Fortunately, dependencies expressing properness do not have this problem

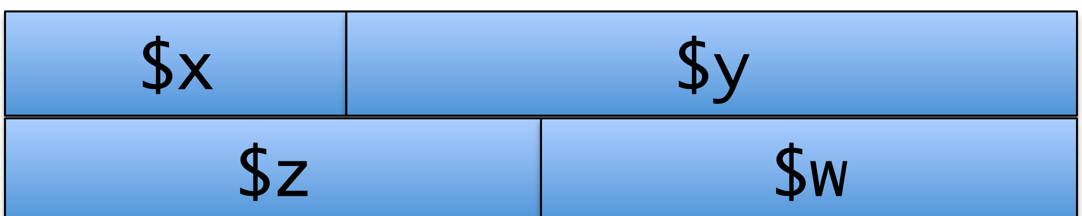
Unification in J-Logic

E.g. `$x.$y = $z.$w`

Split rule 3 ways:



`$x/$z, $y/$w`



`$x.$s/$z, $s.$w/$y`

`$z.$s/$x, $s.$y/$w`

The containment problem for J-Logic

- **Theorem:** Containment of a conjunctive J-Logic query in a union of conjunctive J-Logic queries, **over flat instances,** is decidable (Π-P-2)
- Flat instances have no packed keys
- We solve the **inclusion problem** for **pattern languages** (over an infinite alphabet) extended with atomic variables.

Conclusions

- Path variables & packing, useful for declarative JSON querying
- Further research:
  - Query processing
  - Theory of egds–tgds for J-Logic
  - Precise complexity of O2O problem, containment
  - Containment over non-flat instances?
  - Is packing necessary for recursion-free **flat-flat** queries?

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Pattern inclusion

- `$x.$y` included in `@x.$y`
- No homomorphism from right to left!
- Replace left pattern by four variants:
  - $@x_1.@y_1$
  - $@x_1.@x_2.@y_1$
  - $@x_1.@y_1.@y_2$
  - $@x_1.@x_2.@y_1.@y_2$