

FunSQL

A library for compositional construction
of SQL queries

<https://github.com/MechanicalRabbit/FunSQL.jl>

Clark C. Evans,
Kyrylo Simonov

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FunSQL? Who Needs It?

Query Algebra

Correlated Queries

Aggregate & Window Functions

Conclusion

Find all patients born in or after 1970.



```
SELECT p.person_id  
FROM person p  
WHERE p.year_of_birth >= 1970
```



```
function find_patients(conn)  
  sql = ""  
  SELECT p.person_id  
  FROM person p  
  WHERE p.year_of_birth >= 1970  
  ""  
  DBInterface.execute(conn, sql)  
end
```

Find all patients born between *and*

```
function find_patients(conn; start_year = nothing, end_year = nothing)
  sql = ""
  SELECT p.person_id
  FROM person p
  ""
  predicates = String[]
  if start_year != nothing
    push!(predicates, "p.year_of_birth >= $start_year")
  end
  if end_year != nothing
    push!(predicates, "p.year_of_birth <= $end_year")
  end
  if !isempty(predicates)
    sql *= "\nWHERE " * join(predicates, " AND ")
  end
  DBInterface.execute(conn, sql)
end
```



```
function find_patients(conn; start_year = nothing,  
                        end_year = nothing,  
                        state = nothing,  
                        condition_concepts = [],  
                        latest_visit_threshold = nothing)
```

```
    sql = ???
```

```
    DBInterface.execute(conn, sql)
```

```
end
```

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A fragment of OMOP CDM
<https://github.com/OHDSI/CommonDataModel>

```
using FunSQL: SQLTable
```

```
const person =  
    SQLTable(name = :person,  
              columns = [:person_id, :year_of_birth, :location_id])
```

```
const location =  
    SQLTable(name = :location,  
              columns = [:location_id, :city, :state, :zip])
```

```
const visit_occurrence =  
    SQLTable(name = :visit_occurrence,  
              columns = [:visit_occurrence_id, :person_id, :visit_concept_id,  
                        :visit_start_date, :visit_end_date])
```

```
const condition_occurrence =  
    SQLTable(name = :condition_occurrence,  
              columns = [:condition_occurrence_id, :person_id, :condition_concept_id,  
                        :condition_start_date, :condition_end_date])
```



Find all patients born in or after 1970.

FROM person p



FROM person p
WHERE p.year_of_birth >= 1970



SELECT p.person_id
FROM person p
WHERE p.year_of_birth >= 1970

using FunSQL: From, Get, Select, Where, render

q = From(person)



q = From(person) |>
 Where(Get.year_of_birth .>= 1970)



q = From(person) |>
 Where(Get.year_of_birth .>= 1970) |>
 Select(Get.person_id)

sql = render(q, dialect = :postgresql)

```

q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1970)
q   = q2 |> Select(q2.person_id)

```



```

q = From(person) |>
  Where(Get.year_of_birth .>= 1970) |>
  Select(Get.person_id)

```



```

BornInOrAfter(Y) = Get.year_of_birth .>= Y

```

```

q = From(person) |>
  Where(BornInOrAfter(1970)) |>
  Select(Get.person_id)

```

bound references

unbound references

person	
PK	person_id
	year_of_birth
FK	location_id

```
SELECT p.person_id  
FROM person p  
WHERE p.year_of_birth >= 1970
```

```
WHERE p.year_of_birth >= 1970 AND  
      p.year_of_birth <= 2000
```

```
WHERE p.year_of_birth  
      BETWEEN 1970 AND 2000
```

```
SELECT AVG(p.year_of_birth)  
FROM person p
```

using FunSQL: Agg, Fun

"Fun" notation

Fun.">="(Get.year_of_birth, 1970)

or

Get.year_of_birth .>= 1970

broadcasting

Fun.and(Get.year_of_birth .>= 1970,
 Get.year_of_birth .<= 2000)

Fun.between(Get.year_of_birth, 1970, 2000)

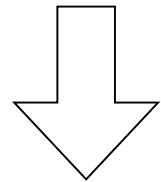
Agg.avg(Get.year_of_birth)

Show patients with their state of residence.

FROM person p



FROM person p
JOIN location l
 ON (p.location_id = l.location_id)



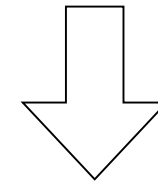
SELECT p.person_id, l.state
FROM person p
JOIN location l
 ON (p.location_id = l.location_id)

using FunSQL: Join

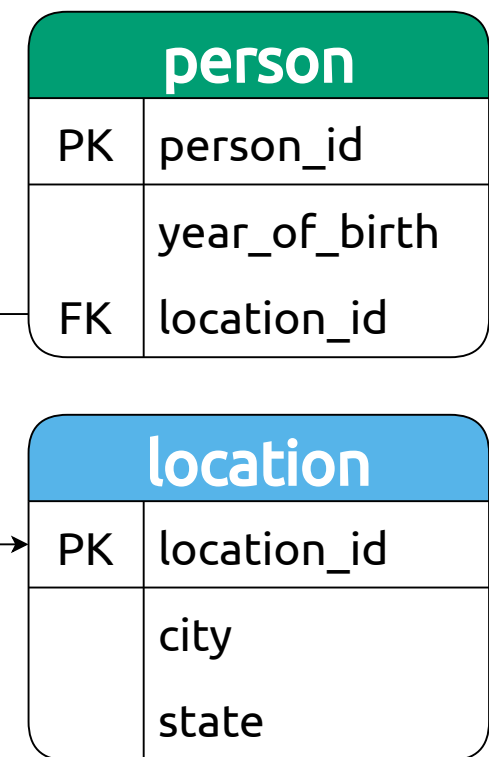
q = From(person)



q = From(person) |>
 Join(:location => location,
 Get.location_id .==
 Get.location.location_id)



q = From(person) |>
 Join(:location => location,
 Get.location_id .==
 Get.location.location_id) |>
 Select(Get.person_id, Get.location.state)



```

qp = From(person)
ql = From(location)
q  = qp |> Join(ql, qp.location_id .== ql.location_id)

```



Get

- person_id
- year_of_birth
- location_id*
- city
- state

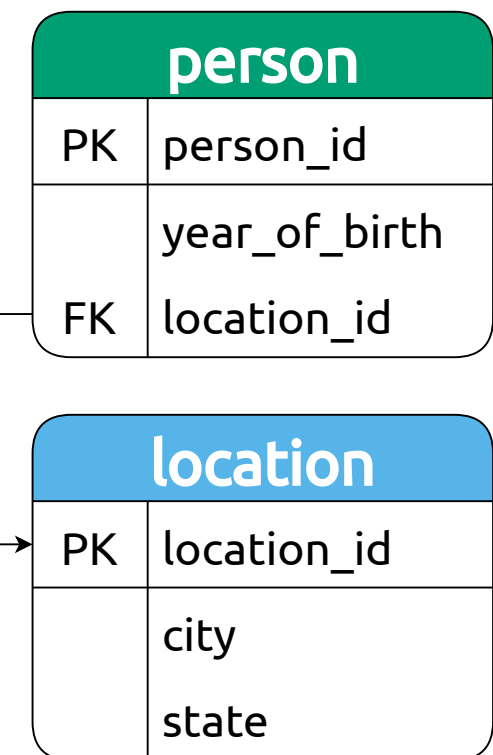
```

q = From(person) |>
  Join(:location => From(location),
       Get.location_id .== Get.location.location_id)

```

Get

- person_id
- year_of_birth
- location_id
- location**
 - location_id
 - city
 - state

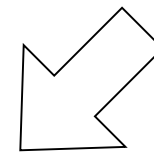
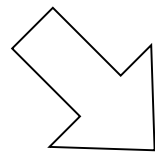


Find patients

- *born in or after 1970*
- *living in Illinois*

```
qp = From(person) |>  
  Where(Get.year_of_birth .>= 1970)
```

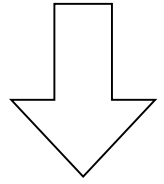
```
ql = From(location) |>  
  Where(Get.state .== "IL")
```



```
qp |> Join(ql, qp.location_id .== ql.location_id) |>  
  Select(qp.person_id)
```



FROM person p

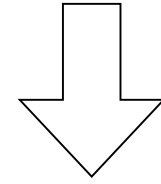


FROM person p
WHERE p.year_of_birth >= 1970



FROM person p
WHERE p.year_of_birth >= 1970
JOIN location l
 ON (p.location_id = l.location_id)

From(person)



From(person) |>
Where(Get.year_of_birth .>= 1970)



From(person) |>
Where(Get.year_of_birth .>= 1970) |>
Join(:location => From(location),
 Get.location_id .==
 Get.location.location_id)



From(*table*)

```
SELECT ???  
FROM $table
```

|>
Where(*condition*)

```
SELECT ???  
FROM ()  
WHERE $condition
```

|>
Join(, *on*)

```
SELECT ???  
FROM ()  
JOIN ()  
ON $on
```

|>
Select(*list...*)

```
SELECT $(list...)  
FROM ()
```

SELECT ???
FROM person

SELECT ???
FROM location

SELECT ???
FROM () p
WHERE p.year_of_birth >= 1970

SELECT ???
FROM () l
WHERE l.state = 'IL'

```
q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1970)
q3 = From(location)
q4 = q3 |> Where(q3.state .== "IL")
q5 = q2 |> Join(q4, q2.location_id .==
               q4.location_id)
q6 = q5 |> Select(q5.person_id)
```

SELECT ???
FROM () p
JOIN () l
ON p.location_id = l.location_id

SELECT p.person_id
FROM () p

```
SELECT person_id, year_of_birth, location_id
FROM person
```

```
SELECT location_id, state
FROM location
```

```
SELECT p.person_id, p.location_id
FROM ( ) p
WHERE p.year_of_birth >= 1970
```

```
SELECT l.location_id
FROM ( ) l
WHERE l.state = 'IL'
```

```
q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1970)
q3 = From(location)
q4 = q3 |> Where(q3.state .== "IL")
q5 = q2 |> Join(q4, q2.location_id .==
                  q4.location_id)
q6 = q5 |> Select(q5.person_id)
```

```
SELECT p.person_id
FROM ( ) p
JOIN ( ) l
      ON p.location_id = l.location_id
```

```
SELECT p.person_id
FROM ( ) p
```

```
SELECT person_id, year_of_birth, location_id
FROM person
```

```
SELECT location_id, state
FROM location
```

```
SELECT p.person_id, p.location_id
FROM person p
WHERE p.year_of_birth >= 1970
```

```
SELECT l.location_id
FROM location l
WHERE l.state = 'IL'
```

```
q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1970)
q3 = From(location)
q4 = q3 |> Where(q3.state .== "IL")
q5 = q2 |> Join(q4, q2.location_id .==
               q4.location_id)
q6 = q5 |> Select(q5.person_id)
```

```
SELECT p.person_id
FROM ( ) p
JOIN ( ) l
ON p.location_id = l.location_id
```

```
SELECT p.person_id
FROM ( ) p
```

Find patients

- *born in or after 1970*
- *living in Illinois*

```
q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1970)
q3 = From(location)
q4 = q3 |> Where(q3.state .== "IL")
q5 = q2 |> Join(q4, q2.location_id .==
               q4.location_id)
q6 = q5 |> Select(q5.person_id)
```

```
using FunSQL: AS, FROM, JOIN, OP, SELECT, WHERE

FROM(
  FROM(:person |> AS(:p)) |>
  WHERE(OP(">=", (:p, :year_of_birth), 1970)) |>
  SELECT((:p, :person_id),
          (:p, :location_id)) |>
  AS(:p)) |>
JOIN(
  FROM(:location |> AS(:l)) |>
  WHERE(OP("=", (:l, :state), "IL")) |>
  SELECT((:l, :location_id)) |>
  AS(:l),
  OP("=", (:p, :location_id),
        (:l, :location_id))) |>
SELECT((:p, :person_id))
```

Find patients

- *born in or after 1970*
- *living in Illinois*

```
q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1970)
q3 = From(location)
q4 = q3 |> Where(q3.state .== "IL")
q5 = q2 |> Join(q4, q2.location_id .==
                  q4.location_id)
q6 = q5 |> Select(q5.person_id)
```

```
SELECT p.person_id
FROM (SELECT p.person_id, p.location_id
        FROM person p
        WHERE p.year_of_birth >= 1970) p
JOIN (SELECT l.location_id
        FROM location l
        WHERE l.state = 'IL') l
ON p.location_id = l.location_id
```

using FunSQL: Define

const ObservationYear = 2000

```
FromPerson() =  
  From(person) |>  
  Define(:approx_age => ObservationYear .- Get.year_of_birth)
```

```
FromAdult() =  
  FromPerson() |>  
  Where(Get.approx_age .>= 18)
```



```
julia> q = FromAdult() |> Select(Get.person_id)
```

```
julia> q = FromAdult() |> Select(Get.person_id)
let person = SQLTable(:person, ...),
    q1 = From(person),
    q2 = q1 |> Define(Fun."-"(Lit(2000), Get.year_of_birth) |>
                    As(:approx_age)),
    q3 = q2 |> Where(Fun.">=" (Get.approx_age, Lit(18))),
    q4 = q3 |> Select(Get.person_id)
    q4
end
```


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Find all patients born in or after \$YEAR.

```
sql = """
SELECT p.person_id
FROM person p
WHERE p.year_of_birth >= :YEAR
"""
```

```
params = (YEAR = 1970,)
```

```
DBInterface.execute(conn, sql, params)
```

using FunSQL: Var, pack

```
q = From(person) |>
  Where(Get.year_of_birth .>= Var.YEAR) |>
  Select(Get.person_id)
```

```
sql = render(q, dialect = :sqlite)
```

```
params = pack(sql, (YEAR = 1970,))
```

Find patients with at least one medical condition.

```
SELECT p.*  
FROM person p  
WHERE EXISTS (SELECT NULL  
              FROM condition_occurrence c  
              WHERE c.person_id = p.person_id)
```

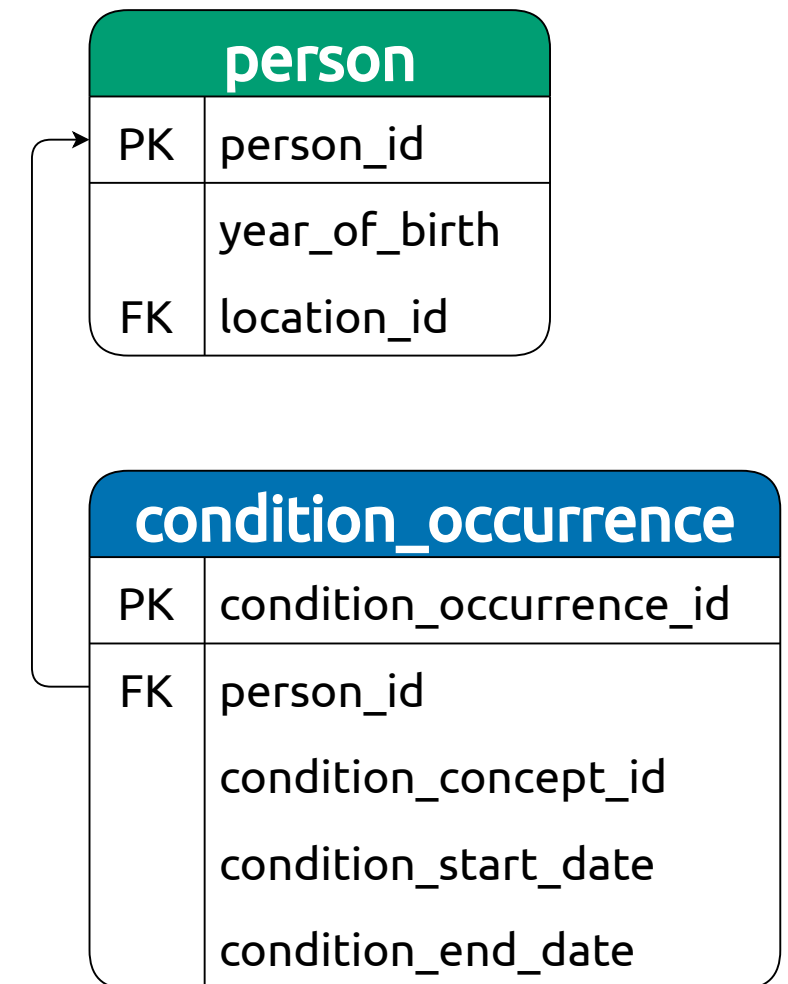


Find patients with at least one medical condition.

```
SELECT p.*  
FROM person p  
WHERE EXISTS (SELECT NULL  
              FROM condition_occurrence c  
              WHERE c.person_id = p.person_id)
```

```
qp = From(person)  
qc = From(condition_occurrence)  
qcorr = qc |> Where(qc.person_id .== qp.person_id)  
q = qp |> Where(Fun.exists(qcorr))
```

ERROR: Cannot find person_id



Find patients with at least one medical condition.

```
SELECT p.*
FROM person p
WHERE EXISTS (SELECT NULL
              FROM condition_occurrence c
              WHERE c.person_id = p.person_id)
```



CorrelatedCondition : $X \mapsto$

```
SELECT NULL
FROM condition_occurrence c
WHERE c.person_id = X
```

```
SELECT p.*
FROM person p
WHERE EXISTS CorrelatedCondition(p.person_id)
```



```
From(condition_occurrence) |>  
Where(Get.person_id .== Var.X)
```



using FunSQL: Bind

```
CorrelatedCondition(X) =  
  From(condition_occurrence) |>  
  Where(Get.person_id .== Var.X) |>  
  Bind(:X => X)
```

```
CorrelatedCondition(6)
```

```
SELECT c.*  
FROM condition_occurrence c  
WHERE c.person_id = :X
```

```
SELECT c.*  
FROM condition_occurrence c  
WHERE c.person_id = 6
```

```
CorrelatedCondition(X) =  
  From(condition_occurrence) |>  
  Where(Get.person_id .== Var.X) |>  
  Bind(:X => X)
```

```
From(person) |>  
Where(Fun.exists(  
  CorrelatedCondition(Get.person_id)))
```

```
SELECT p.*  
FROM person p  
WHERE EXISTS (SELECT NULL  
              FROM condition_occurrence c  
              WHERE c.person_id = p.person_id)
```

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Number of patients by the year of birth.

FROM person p



FROM person p
GROUP BY p.year_of_birth



SELECT p.year_of_birth, COUNT(*)
FROM person p
GROUP BY p.year_of_birth

using FunSQL: Agg, Group

From(person)



From(person) |>
Group(Get.year_of_birth)



From(person) |>
Group(Get.year_of_birth) |>
Select(Get.year_of_birth, Agg.count())

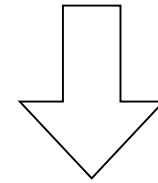
Average year of birth.

FROM person p



SELECT AVG(p.year_of_birth)
FROM person p

From(person)



From(person) |>
Group()



From(person) |>
Group() |>
Select(Agg.avg(Get.year_of_birth))

Patients who saw a doctor within the last 12 months.

FROM visit_occurrence v



FROM visit_occurrence v
GROUP BY v.person_id

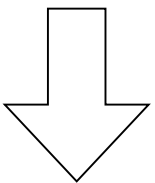


SELECT v.person_id
FROM visit_occurrence v
GROUP BY v.person_id
HAVING CURRENT_DATE -
MAX(v.visit_end_date) <= 365

From(visit_occurrence)



From(visit_occurrence) |>
Group(Get.person_id)



From(visit_occurrence) |>
Group(Get.person_id) |>
Where(Fun.current_date() .-
Agg.max(Get.visit_end_date) .<= 365)

visit_occurrence	
PK	visit_occurrence_id
FK	person_id
	visit_concept_id
	visit_start_date
	visit_end_date

Patients who saw a doctor within the last 12 months.

```
From(visit_occurrence) |>  
Group(Get.person_id) |>  
Where(Fun.current_date() .-  
      Agg.max(Get.visit_end_date) .<= 365)
```

```
SELECT person_id, visit_start_date  
FROM visit_occurrence
```

```
SELECT v.person_id,  
       MAX(v.visit_end_date) AS max  
FROM ( ) v  
GROUP BY v.person_id
```

```
SELECT g.person_id  
FROM ( ) g  
WHERE CURRENT_DATE - g.max <= 365
```

Patients who saw a doctor within the last 12 months.

```
From(visit_occurrence) |>  
Group(Get.person_id) |>  
Where(Fun.current_date() .-  
      Agg.max(Get.visit_end_date) .<= 365)
```

```
SELECT person_id, visit_end_date  
FROM visit_occurrence
```

```
SELECT v.person_id,  
FROM visit_occurrence v  
GROUP BY v.person_id  
HAVING CURRENT_DATE -  
        MAX(v.visit_end_date) <= 365
```

```
SELECT g.person_id  
FROM ( ) g  
WHERE CURRENT_DATE - g.max <= 365
```

For each visit, show the time passed since the previous visit.

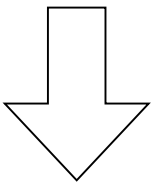
FROM visit_occurrence v



FROM visit_occurrence v
WINDOW w **AS** (
 PARTITION BY v.person_id
 ORDER BY v.visit_start_date
 ROWS BETWEEN UNBOUNDED PRECEDING AND
 1 PRECEDING)

using FunSQL: Partition

From(visit_occurrence)



From(visit_occurrence) |>
Partition(Get.person_id,
 order_by = [Get.visit_start_date],
 frame = (mode = :rows,
 start = -Inf,
 finish = -1))

visit_occurrence	
PK	visit_occurrence_id
FK	person_id
	visit_concept_id
	visit_start_date
	visit_end_date

For each visit, show the time passed since the previous visit.

visit_occurrence	
PK	visit_occurrence_id
FK	person_id
	visit_concept_id
	visit_start_date
	visit_end_date

```
SELECT v.visit_start_date,
       v.visit_start_date -
       MAX(v.visit_end_date) OVER w
FROM visit_occurrence v
WINDOW w AS (
  PARTITION BY v.person_id
  ORDER BY v.visit_start_date
  ROWS BETWEEN UNBOUNDED PRECEDING AND
            1 PRECEDING)
```

```
From(visit_occurrence) |>
Partition(Get.person_id,
          order_by = [Get.visit_start_date],
          frame = (mode = :rows,
                   start = -Inf,
                   finish = -1)) |>
Select(Get.visit_start_date,
       :gap => Get.visit_start_date .-
              Agg.max(Get.visit_end_date))
```



From(visit_occurrence)

```
From(visit_occurrence) |>
Group(Get.person_id) |>
Where(Fun.current_date() .-
      Agg.max(Get.visit_end_date) .<= 365)
```



```
From(visit_occurrence) |>
Partition(Get.person_id,
          order_by = [Get.visit_start_date],
          frame = (mode = :rows,
                   start = -Inf,
                   finish = -1)) |>
Select(Get.visit_start_date,
       :gap => Get.visit_start_date .-
              Agg.max(Get.visit_end_date))
```


From(visit_occurrence)

person_id	
1	■
1	◀
1	●
2	▱
2	□



Group(Get.person_id)

person_id	
1	■
1	◀
1	●
2	▱
2	□

Partition(Get.person_id, order_by = [Get.visit_start_date],
frame = (mode = :rows, start = -Inf, finish = -1))

person_id	
1	■
1	◀
1	●
2	▱
2	□

Merge overlapping visits.



visit_occurrence	
PK	visit_occurrence_id
FK	person_id
	visit_concept_id
	visit_start_date
	visit_end_date

Merge overlapping visits.

[visit_start_date, visit_end_date]	
	
	
	
	




[visit_start_date, visit_end_date]	new
	1
	0
	1
	0

```
From(visit_occurrence) |>
Partition(Get.person_id, order_by = [Get.visit_start_date],
          frame = (mode = :rows, start = -Inf, finish = -1)) |>
Define(:boundary => Agg.max(Get.visit_end_date)) |>
Define(:gap => Get.visit_start_date .- Get.boundary) |>
Define(:new => Fun.case(Get.gap .<= 0, 0, 1))
```

Merge overlapping visits.

[visit_start_date, visit_end_date]	new		
	1		
	0		
	1		
	0		



[visit_start_date, visit_end_date]	new	group
	1	1
	0	1
	1	2
	0	2

```
Partition(Get.person_id, order_by = [Get.visit_start_date],
  frame = (mode = :rows, start = -Inf, finish = -1)) |>
Define(:boundary => Agg.max(Get.visit_end_date)) |>
Define(:gap => Get.visit_start_date .- Get.boundary) |>
Define(:new => Fun.case(Get.gap .<= 0, 0, 1)) |>
Partition(Get.person_id, order_by = [Get.visit_start_date, .- Get.new],
  frame = :rows) |>
Define(:group => Agg.sum(Get.new))
```

Merge overlapping visits.

[visit_start_date, visit_end_date]	new	group
	1	1
	0	1
	1	2
	0	2



[start_date, end_date]	group
	1
	2

```
Get.new := Get.visit_end_date - Get.visit_start_date
Define(:new => Fun.case(Get.gap .<= 0, 0, 1)) |>
Partition(Get.person_id, order_by = [Get.visit_start_date, .- Get.new],
  frame = :rows) |>
Define(:group => Agg.sum(Get.new)) |>
Group(Get.person_id, Get.group) |>
Define(:start_date => Agg.min(Get.visit_start_date),
  :end_date => Agg.max(Get.visit_end_date)) |>
Select(Get.person_id, Get.start_date, Get.end_date)
```

Merge overlapping visits.

```
CollapseIntervals(start_date, end_date) =  
  Partition(Get.person_id, order_by = [start_date],  
    frame = (mode = :rows, start = -Inf, finish = -1)) |>  
  Define(:boundary => Agg.max(end_date)) |>  
  Define(:gap => start_date .- Get.boundary) |>  
  Define(:new => Fun.case(Get.gap .<= 0, 0, 1)) |>  
  Partition(Get.person_id, order_by = [start_date, .- Get.new],  
    frame = :rows) |>  
  Define(:group => Agg.sum(Get.new)) |>  
  Group(Get.person_id, Get.group) |>  
  Define(:start_date => Agg.min(start_date),  
    :end_date => Agg.max(end_date))  
  
q = From(visit_occurrence) |>  
  CollapseIntervals(Get.visit_start_date, Get.visit_end_date) |>  
  Select(Get.person_id, Get.start_date, Get.end_date)
```

visit_occurrence	
PK	visit_occurrence_id
FK	person_id
	visit_concept_id
	visit_start_date
	visit_end_date

FunSQL? Who Needs It?

Query Algebra

Correlated Queries

Aggregate & Window Functions

Conclusion



```
function find_patients(conn; start_year = nothing,  
                        end_year = nothing,  
                        state = nothing,  
                        condition_concepts = [],  
                        latest_visit_threshold = nothing)  
  q = FindPatients(; start_year, end_year, state,  
                    condition_concepts, latest_visit_threshold)  
  sql = render(q, dialect = :postgresql)  
  DBInterface.execute(conn, sql)  
end
```




```
FindPatients(; start_year = nothing, end_year = nothing,  
             state = nothing,  
             condition_concepts = [],  
             latest_visit_threshold = nothing) =  
  From(person) |>  
  FilterByYearOfBirth(; start_year, end_year) |>  
  FilterByState(; state) |>  
  FilterByConditions(; condition_concepts) |>  
  FilterByLatestVisit(; latest_visit_threshold) |>  
  Select(Get.person_id)
```

```
FilterByYearOfBirth(; start_year, end_year) =  
  if start_year != nothing && end_year != nothing  
    Where(Fun.between(Get.year_of_birth, start_year, end_year))  
  elseif start_year != nothing  
    Where(Get.year_of_birth .>= start_year)  
  elseif end_year != nothing  
    Where(Get.year_of_birth .<= end_year)  
  else  
    identity  
  end
```

```
FilterByState(; state) =  
  if state != nothing  
    Join(:location => From(location) |>  
      Where(Get.state .== state),  
      Get.location_id .== Get.location.location_id)  
  else  
    identity  
  end
```

```
ConditionsByPerson(person_id; condition_concepts) =  
  From(condition_occurrence) |>  
  Where(Fun.and(Fun.in(Get.condition_concept_id, condition_concepts...),  
                Get.person_id .== Var.person_id)) |>  
  Bind(:person_id => person_id)  
  
FilterByConditions(; condition_concepts) =  
  if !isempty(condition_concepts)  
    Where(Fun.exists(ConditionsByPerson(Get.person_id; condition_concepts)))  
  else  
    identity  
  end
```

```
FilterByLatestVisit(; latest_visit_threshold) =  
  if latest_visit_threshold != nothing  
    Join(:visit_group => From(visit_occurrence) |>  
      Group(Get.person_id),  
      Get.person_id .== Get.visit_group.person_id) |>  
    Define(:latest_visit_date =>  
      Agg.max(Get.visit_start_date, over = Get.visit_group)) |>  
    Where(Fun.current_date() .- Get.latest_visit_date .<= latest_visit_threshold)  
  else  
    identity  
  end
```

DONE

- Select, Where, Join, Define, Group, Partition, Append (UNION ALL), Parameterized and Correlated Queries
- Tested with SQLite, PostgreSQL, RedShift, Microsoft SQL Server

TODO (June 2021)

- ORDER BY and LIMIT, CTE and WITH clause, WITH RECURSIVE, CUBE/ROLLUP and more
- Documentation and examples
- Comprehensive support for SQL dialects
- Tracking column and expression types
- CRUD (INSERT, UPDATE, DELETE)
- DDL (CREATE TABLE) and schema introspection

Example

<https://github.com/MechanicalRabbit/OHDSICohortExpressions.jl>

Contact Us

julialang.zulipchat.com: funsql.jl