MEMO-F-524 Masters Thesis (MA-INFO)

Manipulation of GTFS periodic trajectories in MobilityDB

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Year

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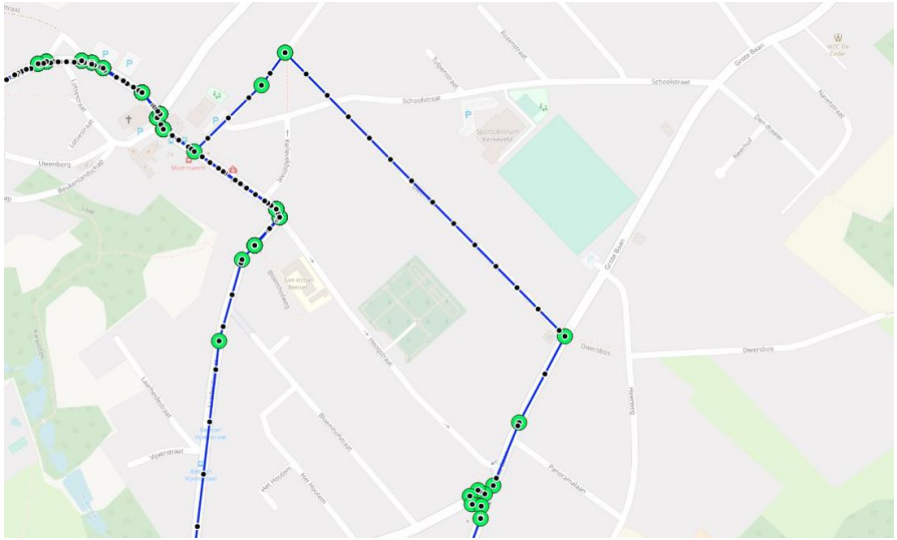
Outline

- Background
  - MobilityDB
  - GTFS
- Problem and Objectives
- Literature Overview
  - Periodic Motion
  - In Database Management Systems
  - In Data Mining
- Implementation
  - Periodic Sequences in MobilityDB
  - Operations
- Use Case: GTFS of STIB/MIVB in MobilityDB
- Conclusion and Future Work

Background

MobilityDB (1/2)

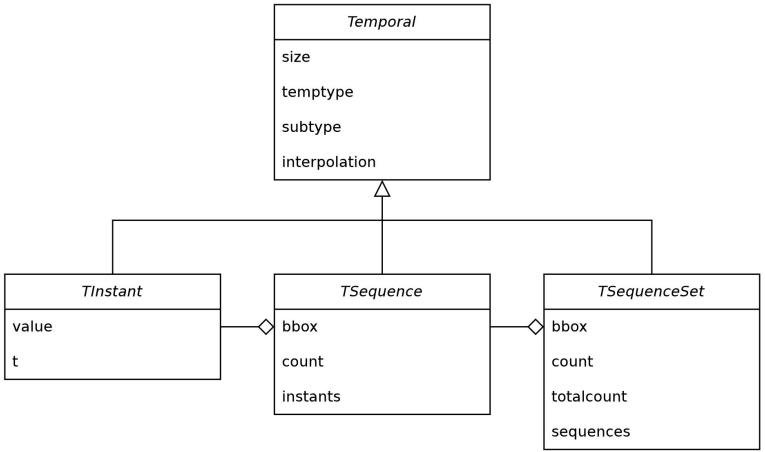
- Moving Object Database 

- PostgreSQL  + PostGIS 
- 

MobilityDB (2/2)

SELECT ttype '[v1@t1, ..., vn@tn]'

SELECT ttext '[Buyl@2024-09-04 14:00:00, ULB@2024-09-04 14:10:00]'
SELECT tgeompoint '[Point(0 0)@2024-09-04 14:00:00, Point(2 3)@2024-09-04 14:10:00]'



GTFS

- **G**eneral **T**ransit **F**eed **S**pecification
- Open Standard for Transit Information

- GTFS Schedule
  - Static Data
  - Routes & Stops
  - Schedules & Frequencies

- GTFS Realtime
  - Live Updates
  - Vehicle Locations
  - Service Alerts

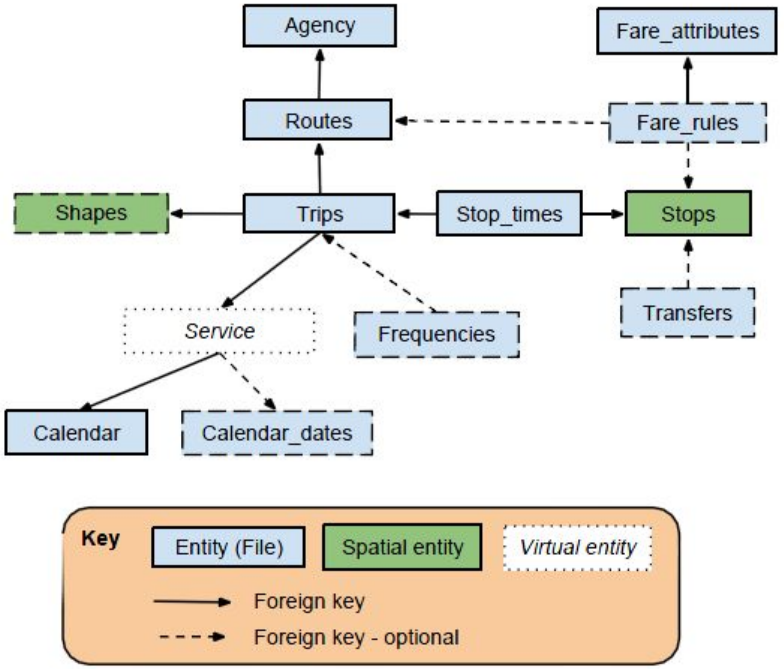


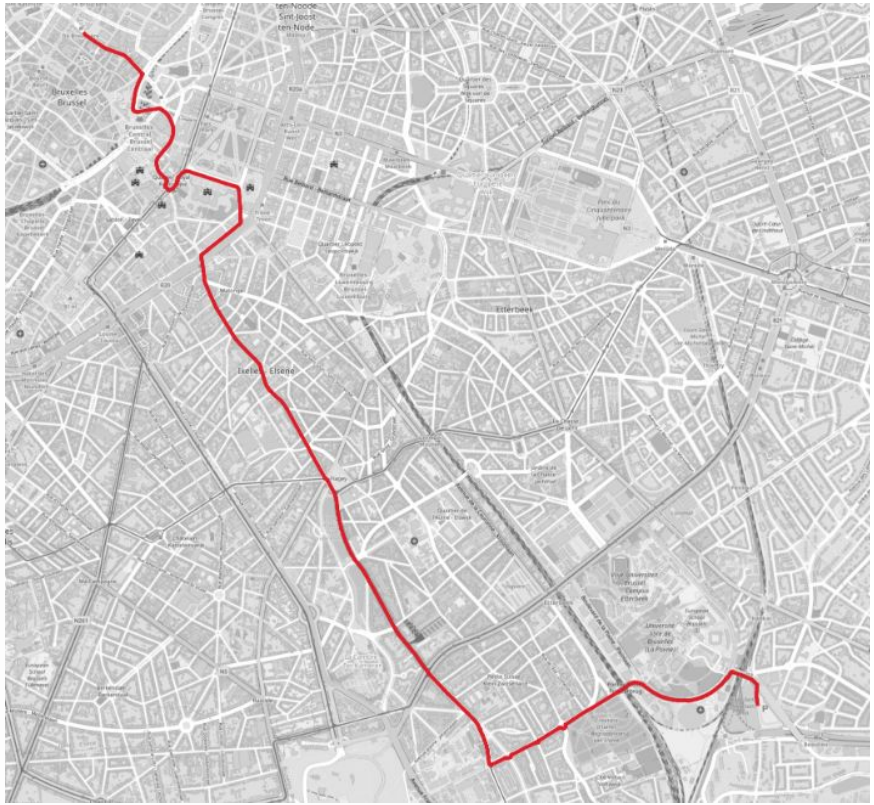
Diagram source:
http://lin-ear-th-inking.blogspot.com.au/2011/09/data-model-diagrams-for-gtfs.html

MobilityDB + GTFS

- GTFS → MobiltyDB trajectories

- service_id = 250654060
  monday = 1
  tuesday = 1
  wednesday = 1
  thursday = 1
  friday = 1
  saturday = 0
  sunday = 0
  start = 2023-03-23
  end = 2023-04-13

- Problem: **repetitions**
- Periodic Movement Data



Literature

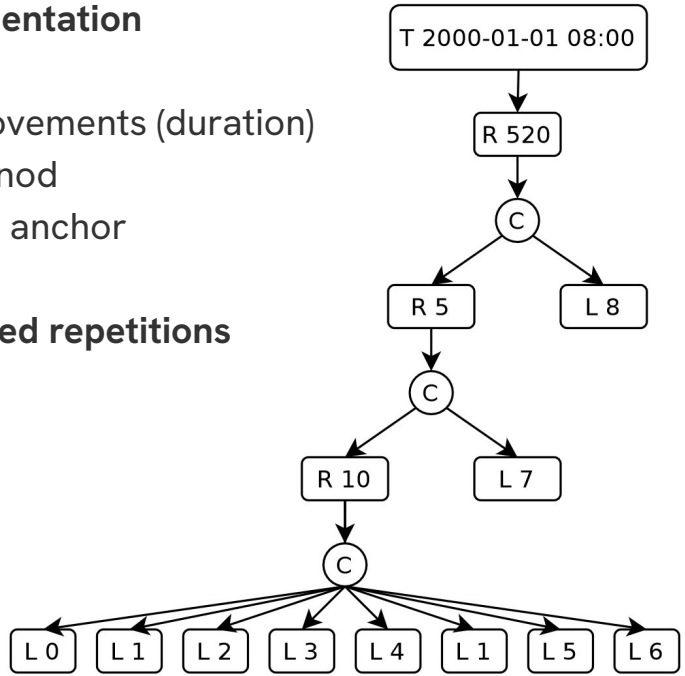
Periodic Trajectories

- **Periodic movement** = repeated in equal time intervals
- **Period** = length of a cycle

- # Periodicities
  - Strong
    - Each Monday at 08:00
  - Near
    - Once a week
  - Weak
    - Eventually in the future

Literature – In Databases (1/3)

- **Periodic tree representation**
  - **(L)** Relative movements (duration)
  - **(R)** Repetition nod
  - **(T)** Timestamp anchor
  - Supports **nested repetitions**

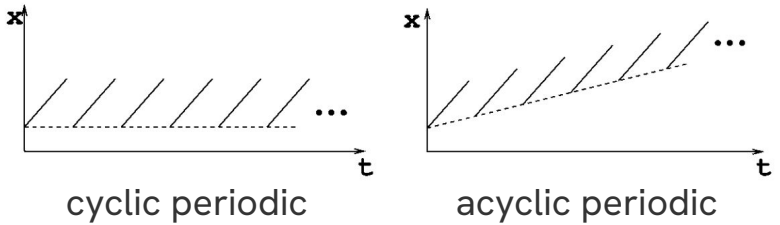


Literature – In Databases (2/3)

- **Multislices / Mixed recurrences**
  - Split in 2 parts:
    - Relative trip (spatial)
    - Repeating trip *λ* (start time rule set)
  - *λ = (yea{24}, wee{0 – 25}, day{0 – 4}, hou{7}, min{0, 25, 55})*
  - Mixed recurrence = Rule multislices \ Exceptions multislices
  - Supports **exceptions** (e.g. holidays)

Literature – In Databases (3/3)

- **Periodic Parametric Rectangles**
  - *r* = < *[5t + 9, 5t + 19], [10, 20], [0, 10]* > with *r* = < *X1, . . . , Xd, T* >
    - Speed = 5 east (positive x)
    - Initial x between 9 and 19
    - Initial y between 10 and 20
    - Between time [0, 10]
  - Periodicity with *f(t mod p)*
  - Supports **acyclic periodic movements**
    - cyclic(t) + linear(t)



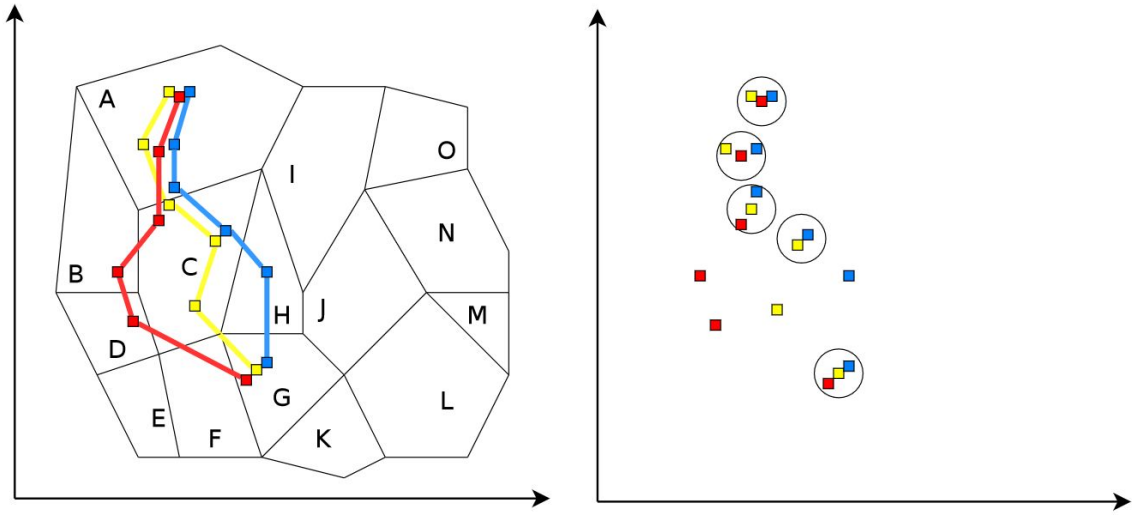
cyclic periodic acyclic periodic

Literature – In Data Mining (1/2)

- Sequence → Periodic Pattern
- Periodic Pattern Mining (PPM)
- Difficulties with GPS data:
  - Inaccuracies
  - Irregular sampling
- Detecting repetition period
  - Fourier transform
- Finding repeating patterns

Literature – In Data Mining (2/2)

- Basic idea: simplify into regions or clusters



- AACCCG AACBDG AAACHG → AA***G (3) AAC**G (2) AA*C*G (2)

Implementation

Relative Sequences

Temporal

- SELECT ttext '[A@2024-09-04 14:00:00, B@2024-09-05 14:30:00, C@2024-09-06 15:00:00]'

Relative

- SELECT ttext '[A#0, B#1 day 30 minutes, C#2 days 1 hour]'

Semi-relative

- SELECT ttext '[A#14 hours, B#1 day 14 hours 30 minutes, C#2 days 15 hours]'

Anchor

- SELECT ttext '[A#14 hours, B#1 day 14 hours 30 minutes, C#2 days 15 hours]'

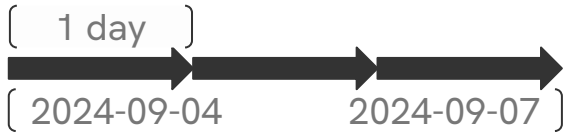
⬇ **2024-09-04**

- SELECT ttext '[A@2024-09-04 14:00:00, B@2024-09-05 14:30:00, C@2024-09-06 15:00:00]'

Periodicity

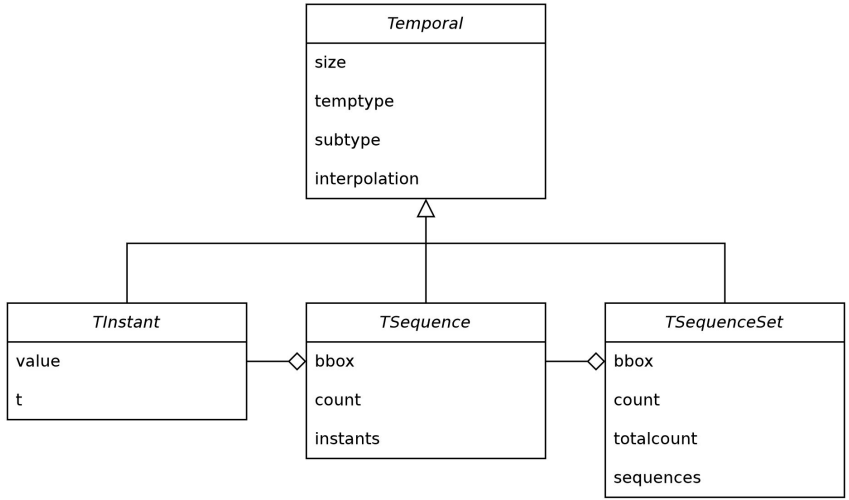
- Parameters
  - Period **:=** Interval
  - Anchor span **:=** TimestampSpan

- Others
  - Number of repetitions **:=** Integer
  - Strict pattern **:=** Boolean
  - ...



Implementation.. attempts

- How to implement periodicity?
- Inheritance?
  - Temporal = **variable-length** struct
  - Inefficient + casting problems
- New Temporal sub-type?
  - Highly increased code complexity



Implementation (1/2)

- **Temporal**
  - 2000-01-01 00:00:00 UTC
  - Flags
    - Normal = 0
    - Periodic = 1
    - ...

- **PMode** data structure
  - Additional periodic parameters

```
double tpoint_length(const Temporal *temp)
double periodic_point_length(const Temporal *temp, const PMode *pmode)
double periodic_point_length(const Temporal *temp, const Interval *period, const Span *anchor)
```

Implementation (2/2)

- **Timestamp** (Internal)
  - ’[A#2000-01-01 00:00:00, B#2000-01-01 10:00:00, ...]’
- **Interval** (Default)
  - ’[A#0 days 00:00:00, B#0 days 10:00:00, ...]’
- **Daily**
  - ’[A#00:00:00, B#10:00:00, ...]’
- **Weekly**
  - ’[A#Monday 00:00:00, B#Monday 10:00:00, ...]’

Some common issues...

- **Irregular months**
  - 28, 29, 30, 31 days

- **Time Zones**
  - Daylight saving time (**DST**) changes (Summer ⇔ Winter)
  - Use Coordinated Universal Time (**UTC**)

- ...

Operations - Categories

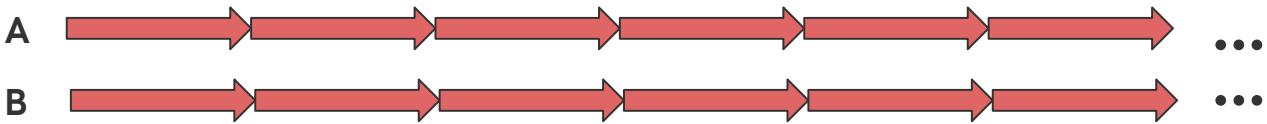
- **Basic**
  - no periodicity
  - e.g. minValue( ), trajectory( )

- **Extended**
  - modified output
  - e.g. periodic_length = length( ) x nb_of_repetitions

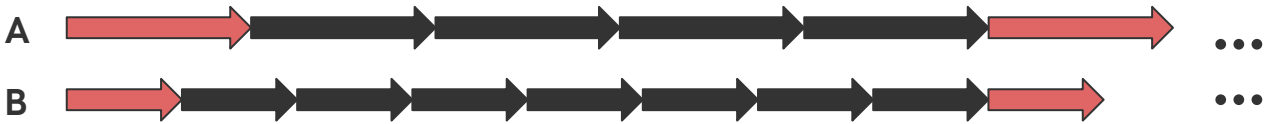
- **Advanced**
  - modified code
  - e.g. valueAt( ), tdistance( )

Operations - Periodic_TDistance

- Compute distance between trajectory points
- Same periods:



- Different periods:
  - Can be stopped when synchronised (Least Common Multiple of periods)



Operations - Anchor

- Relative sequence → Classic temporal

  [A#14 hours, B#1 day 14 hours 30 minutes, C#2 days 15 hours]
  Anchor(seq, 2024-09-04)
  [A@2024-09-04 14:00:00, B@2024-09-05 14:30:00, C@2024-09-06 15:00:00]

- Also repeats the sequence in time using
  - Period
  - Timestamp Span

Operations - PeriodicValueAt

- Value of periodic sequence at **any** chosen timestamp
- *f (timestamp modulo period)*
- As Anchor( ) it requires
  - Period
  - Timestamp Span

Case Study
STIB/MIVB GTFS

Import

- GTFS → MobilityDB
  - Imported GTFS.csv as PostgreSQL tables
  - Processed into MobilityDB trajectories
    - Group GPS coordinates into MobilityDB sequences
  - Reduced to relative trajectories

Days of the week: Monday → Friday
Start and end dates: 2023-03-24, 2023-04-16
[POINT(4.352683 50.849673)#Monday 16:14:00,
POINT(4.352794 50.849594)#Monday 16:14:04.593401,
...
POINT(4.405075 50.816745)#Monday 16:52:00]

Weekly Repetition (1/2)

2000-01-01
[POINT(4.352683 50.849673)#Monday 16:14:00,
  POINT(4.352794 50.849594)#Monday 16:14:04.593401,
  ...
  POINT(4.405075 50.816745)#Monday 16:52:00]
...
2000-01-05
[POINT(4.352683 50.849673)#Friday 16:14:00,
  POINT(4.352794 50.849594)#Friday 16:14:04.593401,
  ...
  POINT(4.405075 50.816745)#Friday 16:52:00]

Weekly Repetition (2/2)

```
SELECT anchor(
        trip, --relative_sequence
        span(c.start_date, c.end_date + '1 day'), --anchor
        '1 week', --period
        true --strict_pattern
) as anchor_trip

 FROM trips_mdb_week_shifted t
 INNER JOIN calendar c ON t.service_id = c.service_id
 WHERE trip_id = '1166219082506540 60';
```

“Daily” Repetition

```
SELECT anchor_array(
        trip, --relative_sequence
        span(c.start_date, c.end_date + ‘1 day’), --anchor
        ’1 day’, --period
        true, --strict_pattern
        ARRAY[monday, tuesday, wednesday, thursday, friday, saturday, sunday], --exception_array
        EXTRACT(DOW FROM c.start_date::timestamptz)::int + 6 % 7 --array_shift
) as anchor_trip

 FROM trips_mdb_day t
 INNER JOIN calendar c ON t.service_id = c.service_id
 WHERE trip_id = ‘1166219082506540 60’;

-- note: reduces nb of stored trips, BUT limits periodic functions
```

Identical Trips (Group)

- Same
  - transportation line
  - spatial trajectory
  - day

- … but different
  - start times + overlap
  - delays between stops
- “*duplicate trips*”

- Delays often grouped per day period (e.g. morning)
  - Compare as relative sequences + group similar
  - Store start times separately
  - Purely for storage optimization

Performances (1/2)

- Storage size reduction

Relation	Classic	Week	Daily	Group
Sequence count	506,689	197,401	68,309	13,837
Disk Size	4792 MB	1873 MB	1012 MB	146 MB
		-61%	-79%	-97%

Performances (2/2)

- Query: Quickest travel between A and B points using public transport

Query time	**Avg**	**Std**	**Min**	**Max**
periodic classic	**3.7s** 15.6s	**0.4s** 0.6s	**3.4s** 15.0s	**4.9s** 17.5s
periodic (seqscan=off) **classic** (seqscan=off)	4.1s **1.3s**	0.2s **0.05s**	3.7s **1.2s**	4.5s **1.4s**

Limitations

- Efficiency depends on repetition span (GTFS trip date coverage week buckets)

Range	1W	2W	3W	4W	≥ 5W	Total
March 2023	20.95%	5.99%	7.01%	66.05%	0%	68,309
July 2024	70.73%	17.85%	11.4%	0%	0%	123,480

- Exception dates
- GPS inaccuracies in real-data
- Assumptions + data abstraction + simplification
- ...

Future work

- Better implementation and other periodic concepts
  - Nested, Acyclic, more functions, ...
- Locale support
- NPoints
- Scheduling tools
- Periodic Pattern Mining
- Prediction and anomalies
- Study other use cases
- ...

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Thank you for your attention

Q&A