Moving Objects Databases

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Moving Objects Data Abstraction

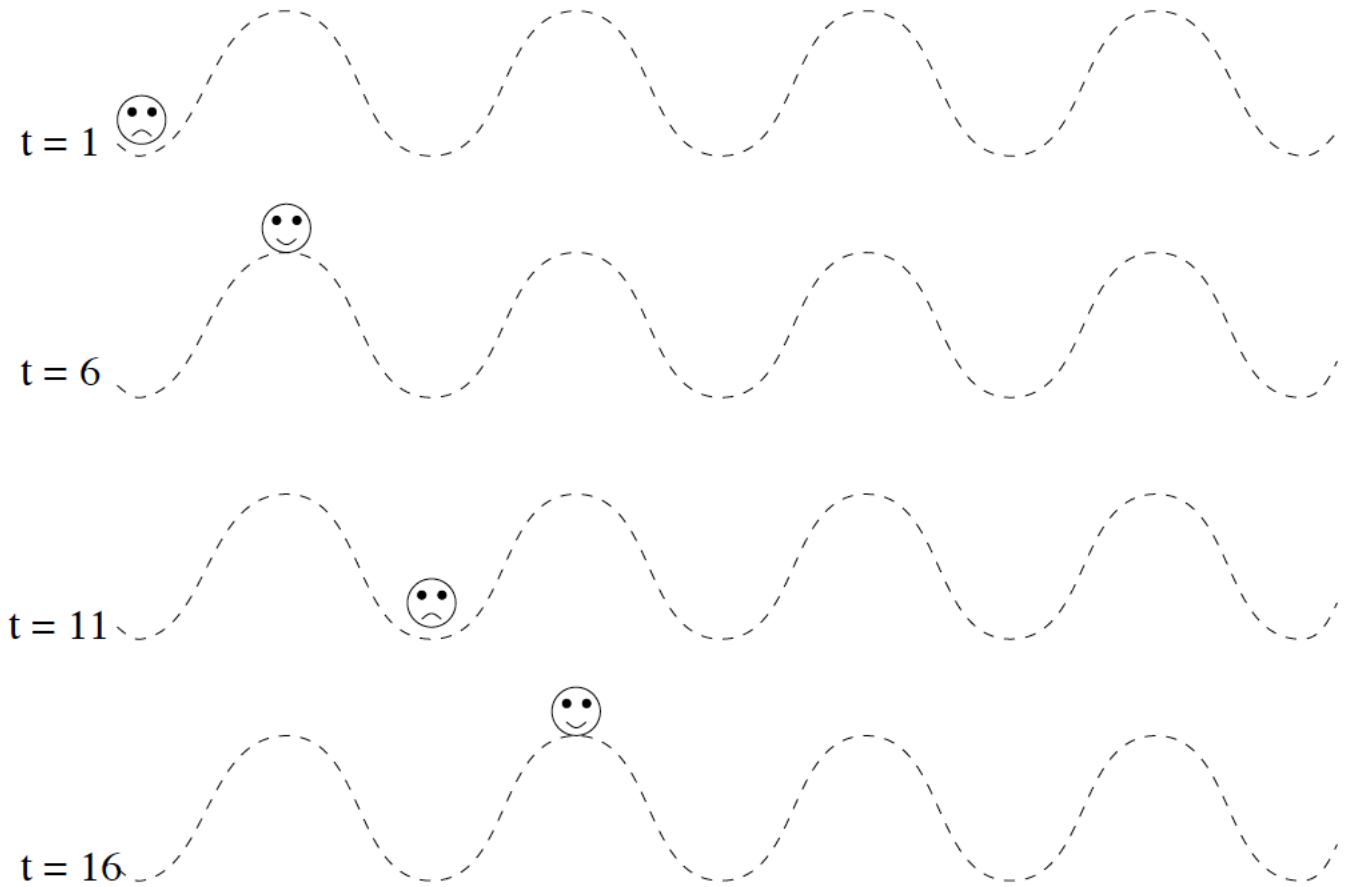
View Level: Animation of the moving objects or a series of snapshots.

Logical Level: Infinite relational database scheme.

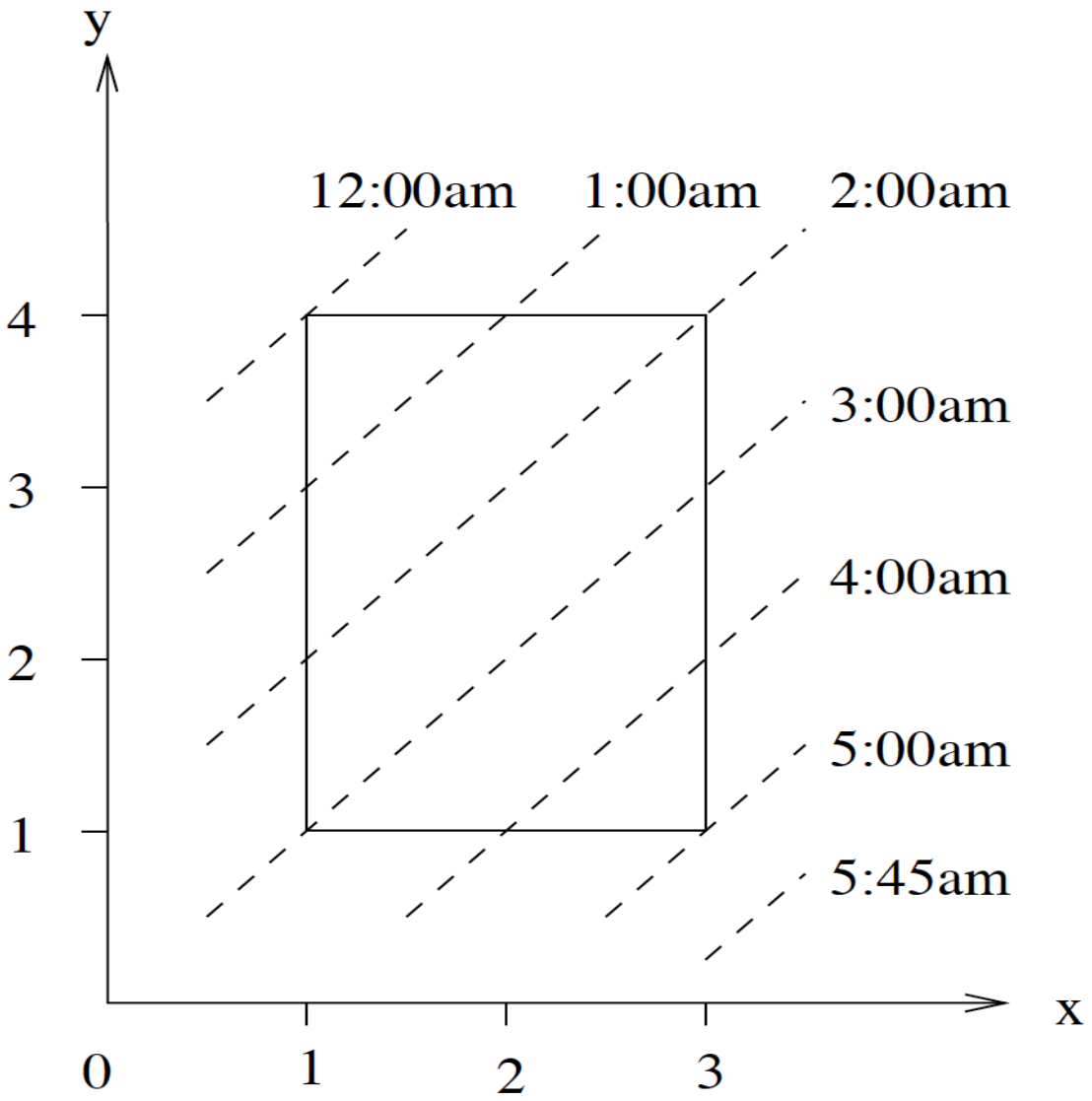
Constraint Level: Some finite representation.

Physical Level: The way data is actually stored in a computer.

View Level: waves and swimmer.



View Level: tide and parking lot.



Logical Level: parking lot area flooded by tide.

Tide

X	Y	T
1	4	0
1	3	1
⋮	⋮	⋮

Constraint Level

There are many proposals to finitely represent geographic data. Some options are:

Option 1: Moving Points Data Model

Boat

Id	X	Y	From	To
1	3	$3 - t$	0	10
2	$4 + 0.5t$	$4 - 0.5t$	0	10
3	$5 + t$	3	0	10

Option 2: Parametric Rectangles Data Model

Sailboat

X	Y	T
$[5t + 9,\ 5t + 19]$	$[10,\ 20]$	$[0,\ 10]$
$[10t - 41,\ 10t - 31]$	$[10t - 90,\ 10t - 80]$	$[10,\ 20]$
$[159,\ 169]$	$[8t - 50,\ 8t - 40]$	$[20,\ 25]$

Constraint Level

Option 3: Parametric Worboys Data Model

Net

Ax	Ay	Bx	By	Cx	Cy	From	To
3	$3-t$	$4+0.5t$	$4-0.5t$	$5+t$	3	0	10

Option 4: Periodic Parametric Worboys Data Model

Tide

Ax	Ay	Bx	By	Cx	Cy	From	To	P	End
1	4	1	$4-t'$	$t'+1$	4	0	2	11.5	∞
1	4	1	2	3	4	2	9.5	11.5	∞
1	2	3	4	3	$6-t'$	2	3	11.5	∞
1	2	1	$4-t'$	3	$6-t'$	2	3	11.5	∞
1	2	3	4	3	3	3	8.5	11.5	∞
1	2	1	1	3	3	3	8.5	11.5	∞
1	1	3	3	3	$6-t'$	3	5	11.5	∞
1	1	$t'-2$	1	3	$6-t'$	3	5	11.5	∞
1	1	3	4	3	1	5	6.5	11.5	∞
1	1	3	4	1	4	5	6.5	11.5	∞
1	1	3	3	3	t'-5.5	6.5	8.5	11.5	∞
1	1	9.5-t'	1	3	t'-5.5	6.5	8.5	11.5	∞
1	1	3	4	3	t'-5.5	8.5	9.5	11.5	∞
1	2	1	t'-7.5	3	t'-5.5	8.5	9.5	11.5	∞
1	4	1	t'-7.5	12.5-t'	4	9.5	11.5	11.5	∞

Constraint Level

Option 5: Constraint Data Model

Net2

X	Y	T	
x	y	t	$y \leq x - t$ $y(t+2) \geq xt - t^2 - 2t + 6,$ $y(t+2) \geq x(t-2) - t^2 + 16$

Tide2

X	Y	T	
x	y	t	$1 \leq x,\ x \leq 3,\ 1 \leq y,\ y \leq 4,\ 0 \leq t',\ t' \leq 5.75,\ y \geq x - t' + 3.$
x	y	t	$1 \leq x,\ x \leq 3,\ 1 \leq y,\ y \leq 4,\ 5.75 \leq t',\ t' \leq 11.5,$ $y \geq x + t' - 8.5.$

where $t' = (t \bmod 11.5)$.

Expressive Power

Comparing the expressive power of various constraint level moving objects data models:

Moving Points Data Model <

Parametric Rectangles Data Model <

Parametric Worboys Data Model <

Periodic Parametric Worboys Data Model <

Constraint Data Model

Question: Why?

Moving Objects Queries

1. Query Constraint Level Representation using SQL extended with operators

Example: Find the area flooded at any time between 12:00 am (midnight) and 5 am on the first day.

First we need to define *area_temporal* operator that returns the area as a function of time.

```
SELECT   area_temporal(X,Y,T)
FROM     Tide
WHERE    0 ≤ T  AND  T ≤ 5
```

Moving Objects Queries

2. Query Logical Level Representation using SQL

Example: Suppose that it snows when a cloud with greater than or equal 80 percent humidity moves into an area with less than or equal 32 Fahrenheit degrees temperature. Find the areas where it will snow.

```
SELECT      X, Y, T
FROM        Clouds
WHERE       Humidity ≥ 80
INTERSECT
SELECT      X, Y, T
FROM        Region
WHERE       Temperature ≤ 32
```

Moving Objects Queries

2. Query Logical Level Representation using SQL

Example: Find the Id numbers of the cars (assumed to park at point locations) that may be flooded between 33 and 36 hours.

```
SELECT   Car.Id
FROM     Car, Tide
WHERE    Car.X = Tide.X  AND
         Car.Y = Tide.Y  AND
         Car.T = Tide.T  AND
         33 ≤ Tide.T  AND  Tide.T ≤ 36
```

Moving Objects Queries

2. Query Logical Level Representation using SQL

Example: Find the area flooded at any time between 12:00 am and 5 am.

```
SELECT   T, 0.5T^2
FROM     Tide
WHERE    0 ≤ T  AND  T ≤ 2
UNION
SELECT   T, 2 + 2(T − 2)
FROM     Tide
WHERE    2 ≤ T  AND  T ≤ 3
UNION
SELECT   T, 6 − 0.5(5 − T)(5 − T)
FROM     Tide
WHERE    3 ≤ T  AND  T ≤ 5
```

Practice Problems
(for the moving objects data models in Chapter 7)

Practice

1. Represent using a parametric rectangle a unit square, which at time $t = 0$ starts at the first square of the first quadrant of the plane and moves to the northeast with a speed of one unit to the north and one unit to the east per second.

4. Suppose an eagle nest sits at location $(0, 0)$. At time $t = 0$ an eagle leaves the nest and flies northeast with a speed of 15 feet per second north and 10 feet per second east for 10 seconds. Another eagle leaves the same nest at time $t = 0$ and flies west with a speed of 8 feet per second for 5 seconds and then flies south with the same speed for 5 more seconds. Represent by a parametric Worboys relation the triangular area of the nest and the two birds between times $t = 0$ and $t = 10$.

16. Suppose that relation $Town(Name, X, Y)$ represents towns and $Airplane\_Shadow(Id, X, Y, T)$ represents the shadow of the airplanes on the earth as they fly. Write an SQL query that finds when the shadow of airplane 123 will leave the town of Chicago.

Solutions

1. Represent using a parametric rectangle a unit square, which at time $t = 0$ starts at the first square of the first quadrant of the plane and moves to the northeast with a speed of one unit to the north and one unit to the east per second.

1. Moving Square

X	Y	T
$[t, t+1]$	$[t, t+1]$	$[0, \infty]$

A CDB solution for the same would be:

Moving Square

X	Y	T	
x	y	t	$x \geq t, x \leq t+1, y \geq t, y \leq t+1, t \geq 0$

Solutions

4. Suppose an eagle nest sits at location $(0, 0)$. At time $t = 0$ an eagle leaves the nest and flies northeast with a speed of 15 feet per second north and 10 feet per second east for 10 seconds. Another eagle leaves the same nest at time $t = 0$ and flies west with a speed of 8 feet per second for 5 seconds and then flies south with the same speed for 5 more seconds. Represent by a parametric Worboys relation the triangular area of the nest and the two birds between times $t = 0$ and $t = 10$.

4. **Eagles**

Ax	Ay	Bx	By	Cx	Cy	From	To
0	0	$10t$	$15t$	$-8t$	0	0	5
0	0	$10t$	$15t$	-40	$-8(t-5)$	5	10

Solutions

```
SELECT   Max(Airplane_Shadow.T)
FROM     Town, Airplane_Shadow
WHERE    Town.X = Airplane_Shadow.X AND
         Town.Y = Airplane_Shadow.Y AND
         Town.Name = 'Chicago' AND
         Airplane_Shadow.ID = 123
```