SciQL

A Query Language for Science Applications

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CWI Amsterdam

Array Database Workshop

March 25th, 2011

CWI

monetdb

Planet Data

Who needs arrays anyway?

Seismology	– 1-D time-series, 3-D spatial data
Astronomy	– temporal ordered rasters
Climate simulation	– temporal ordered grid
Remote sensing	– images of 2-D or higher
Genomics	– ordered DNA strings

Scientists love arrays:

- *HDF5, NETCDF, FITS, MSEED, …*

but also use:

- *lists, tables, XML, ...*

Arrays In DBMS

- Research issues already in the 80's
- SQL language extension (add notion of order):
  - RasQL, AQuery, SRQL, ...
- SQL:1999, SQL:2003
  - collection type, C-style arrays
- Algebraic frameworks
  - (S)RAM, AQL, AML, ...

Arrays In DBMS

- DBMS support
  - OODB, multi-dimensional DBMS, Sequence DBMS, ...
  - the Longhorn Array Database
- RasDaMan
  - Array in chunks as BLOB
  - Array query optimisation on top of DBMS
  - Known to work up to 12 TBs!
- PostgreSQL 8.1
- SciDB
  - Array DBMS from scratch
  - Overlapping chunks for parallel execution

What is the problem with RDBMS?

- Appropriate array denotations?
- Functional complete operation set?
- Size limitations due to (BLOB) representations?
- Existing foreign files?
- Scale?
- …

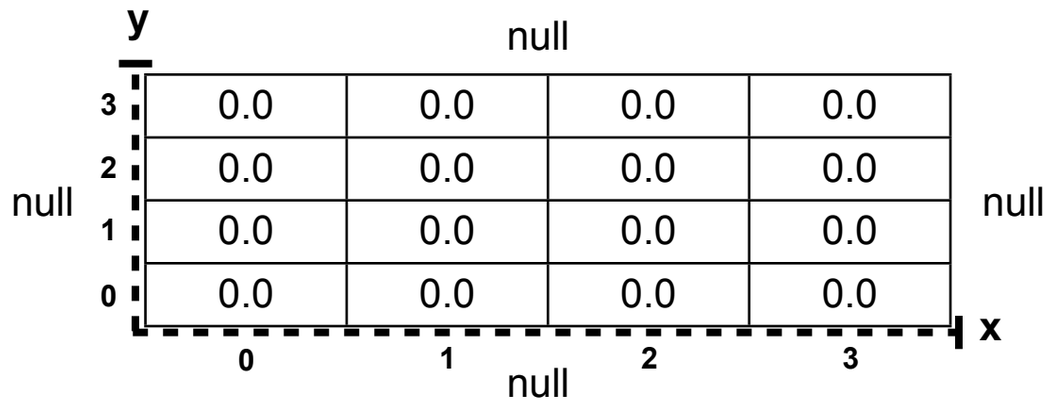
SciQL

- An extension of SQL:2003 (pronounced as ‘cycle’)
- *Array as first class citizens of DBMS*
- *Seamless integration of tables and arrays*
- *Named dimensions with constraints*
- *Flexible structure-based grouping*
- Seismology use case

Array Definitions

Fixed array

```
CREATE ARRAY A1 (
   x INT DIMENSION[0:4:1],
   y INT DIMENSION[0:4:1],
   v FLOAT DEFAULT 0.0
);
```



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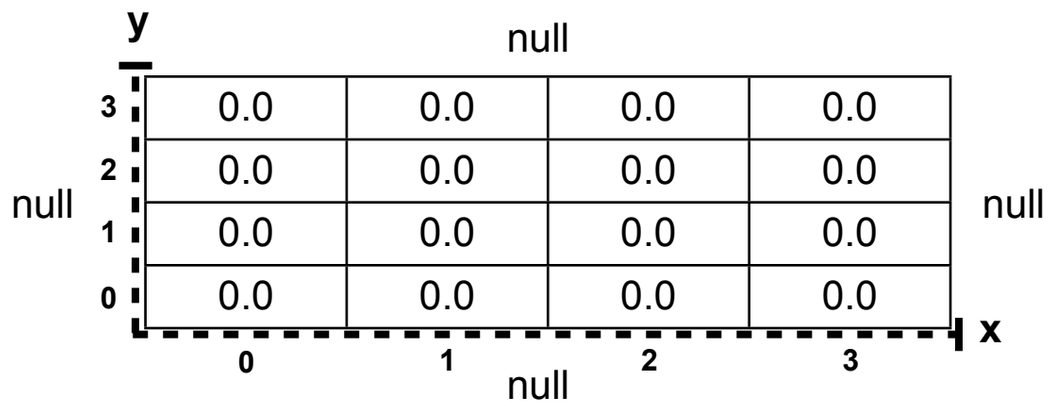

Unbounded array

```
CREATE ARRAY A2 (
   x INT DIMENSION,
   y INT DIMENSION,
   v FLOAT DEFAULT 0.0
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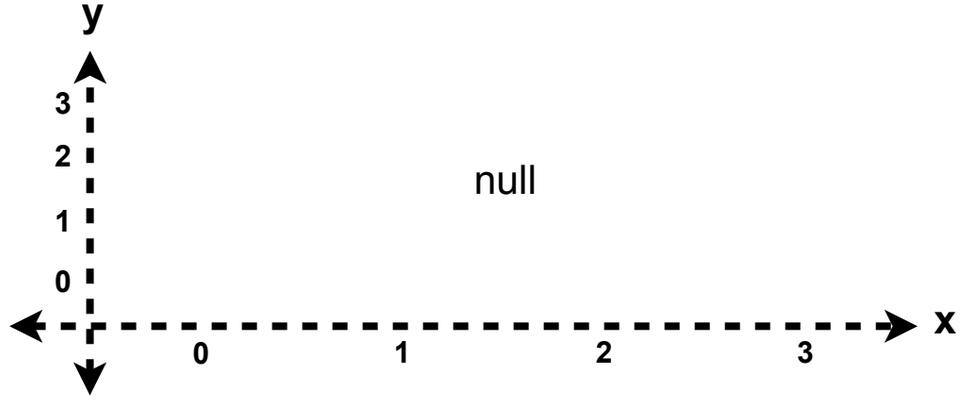

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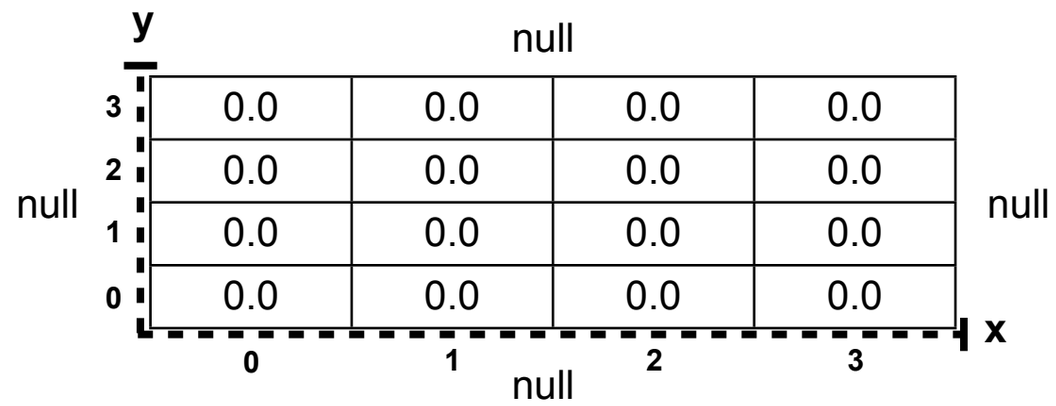

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INSERT INTO A2 VALUES
   (1,0,5.5), (1,1,0.4), (2,2,4.5);
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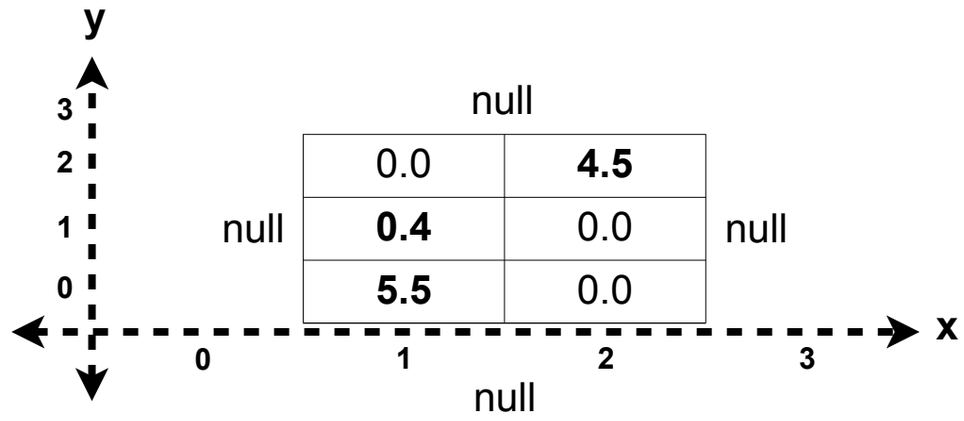

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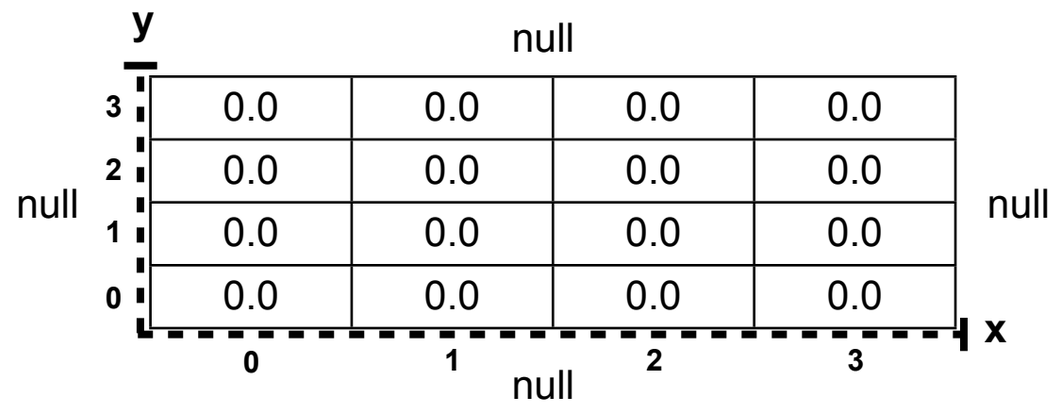

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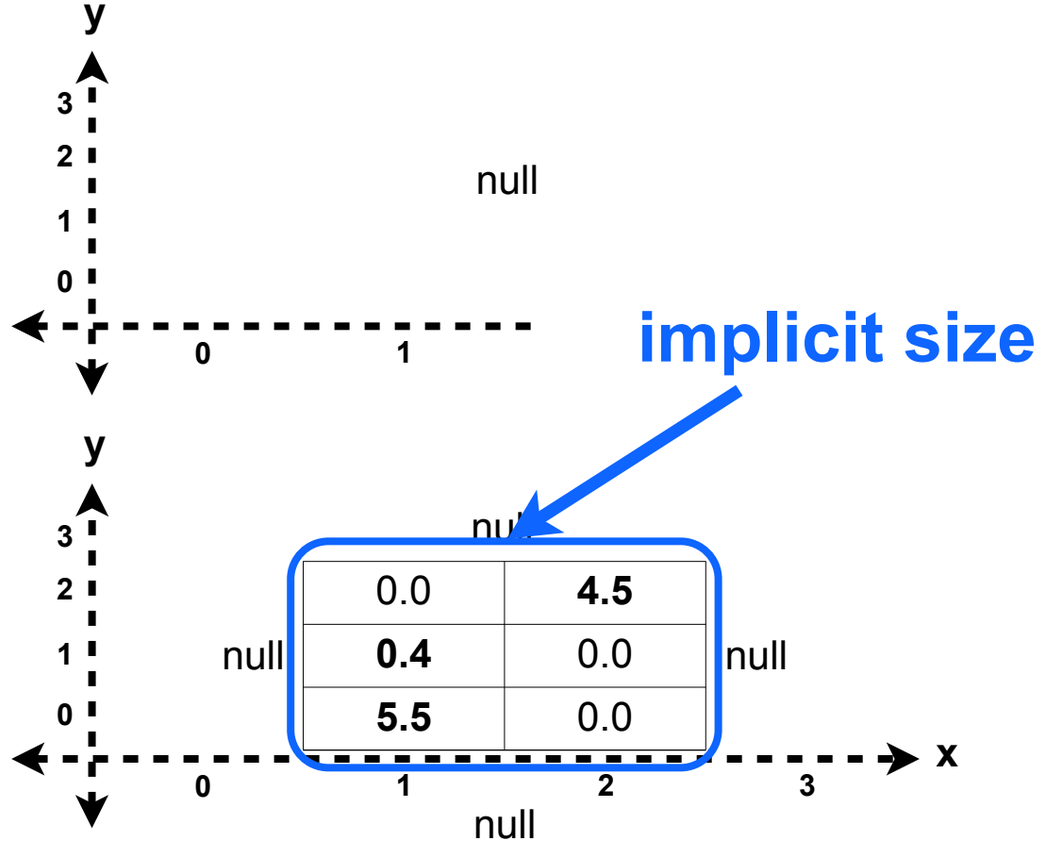

Array Dimensions

```
CREATE ARRAY A1 (
   x INT DIMENSION[0:4:1],
   y INT DIMENSION[0:4:1],
   v FLOAT DEFAULT 0.0
);
```

```
CREATE ARRAY A2 (
   x INT DIMENSION,
   y INT DIMENSION,
   v FLOAT DEFAULT 0.0
);
```

- Fixed dimensions: *[start:final:step]*
- INT dimension: *[size]*
- Unbounded dimensions: *[(start|∗) : (final|∗) : (step|∗)]*

- Dimension data type: scalar data types
- Time series:

```
CREATE ARRAY Experiment (
   time TIMESTAMP DIMENSION [TIMESTAMP '2011-03-25' : * :
      INTERVAL '1' MINUTE],
   data FLOAT );
```

Array versus Table

```
CREATE ARRAY A1 (
   x INT DIMENSION[0:4:1],
   y INT DIMENSION[0:4:1],
   v FLOAT DEFAULT 0.0
);
```

```
CREATE TABLE T1 (
   x INT,
   y INT, PRIMARY KEY (x,y),
   v FLOAT DEFAULT 0.0
);
```

Array versus Table

```
CREATE ARRAY A1 (
   x INT DIMENSION[0:4:1],
   y INT DIMENSION[0:4:1],
   v FLOAT DEFAULT 0.0
);
```

```
SELECT * FROM A1;
```

x	y	v
0	0	0.0
0	1	0.0
0	2	0.0
0	3	0.0
1	0	0.0
1	1	0.0
1	2	0.0
1	3	0.0
2	0	0.0
2	1	0.0
2	2	0.0
2	3	0.0
3	0	0.0
3	1	0.0
3	2	0.0
3	3	0.0

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```
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x	y	v

Array versus Table

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   v FLOAT DEFAULT 0.0
);
```

- A collection of **a priori** defined tuples
- To be **updated** with INSERT/DELETE (and UPDATE)
- Indexed by **dimension** expressions
- Default value for **non-dimensional** attributes (i.e., cells)

```
CREATE TABLE T1 (
   x INT,
   y INT, PRIMARY KEY (x,y),
   v FLOAT DEFAULT 0.0
);
```

- A collection of tuples
- Explicitly create/remove with INSERT/ DELETE
- Indexed by a (primary) key
- Default value for each column

Array & Table Coercions

```
CREATE ARRAY A1 (
   x INT DIMENSION[0:4:1],
   y INT DIMENSION[0:4:1],
   v FLOAT DEFAULT 0.0
);
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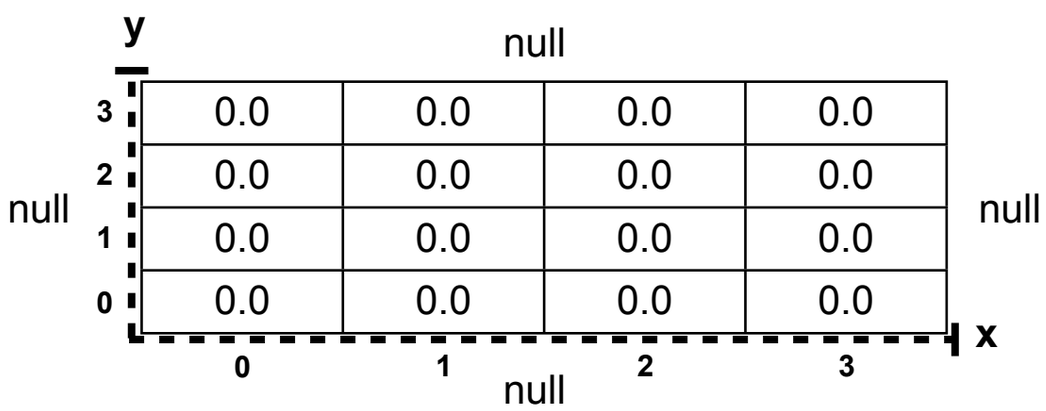

SELECT x, y, v FROM A1;

x	y	v
0	0	0.0
0	1	0.0
0	2	0.0
0	3	0.0
1	0	0.0
1	1	0.0
1	2	0.0
1	3	0.0
2	0	0.0
2	1	0.0
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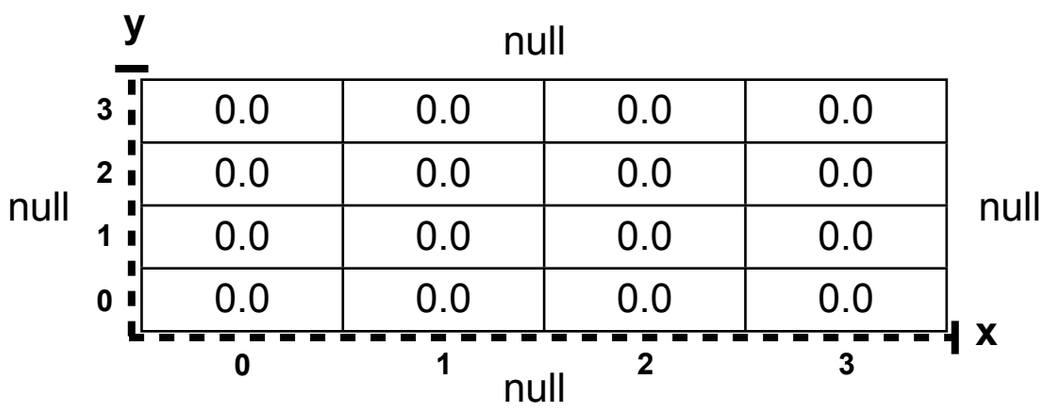

SELECT x, y, v FROM A1;

x	y	v
0	0	0.0
0	1	0.0
0	2	0.0
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full materialisation!

Array & Table Coercions

```
CREATE TABLE T2 (
   x INT, y INT, v FLOAT
);

INSERT INTO T2 VALUES
   (1,0,5.5), (1,1,0.4),
      (2,2,4.5), (1,1,1.3);
```

x	y	v
1	0	5.5
1	1	0.4
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Array & Table Coercions

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x	y	v
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```
SELECT [x], [y], v FROM T2;
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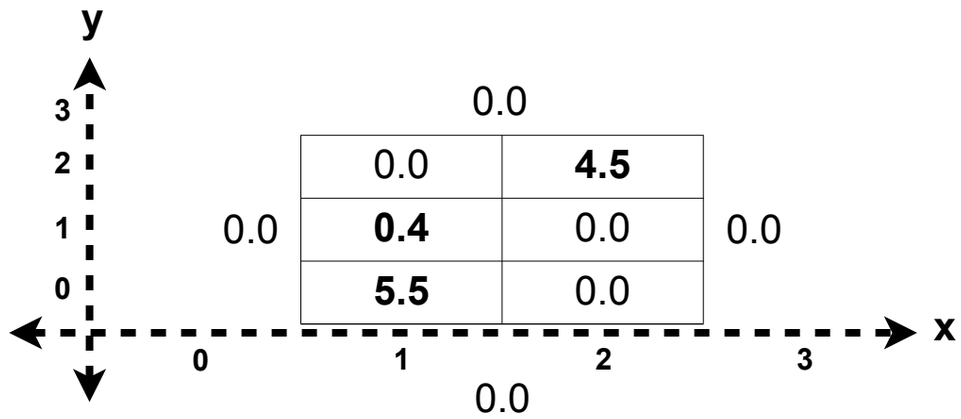
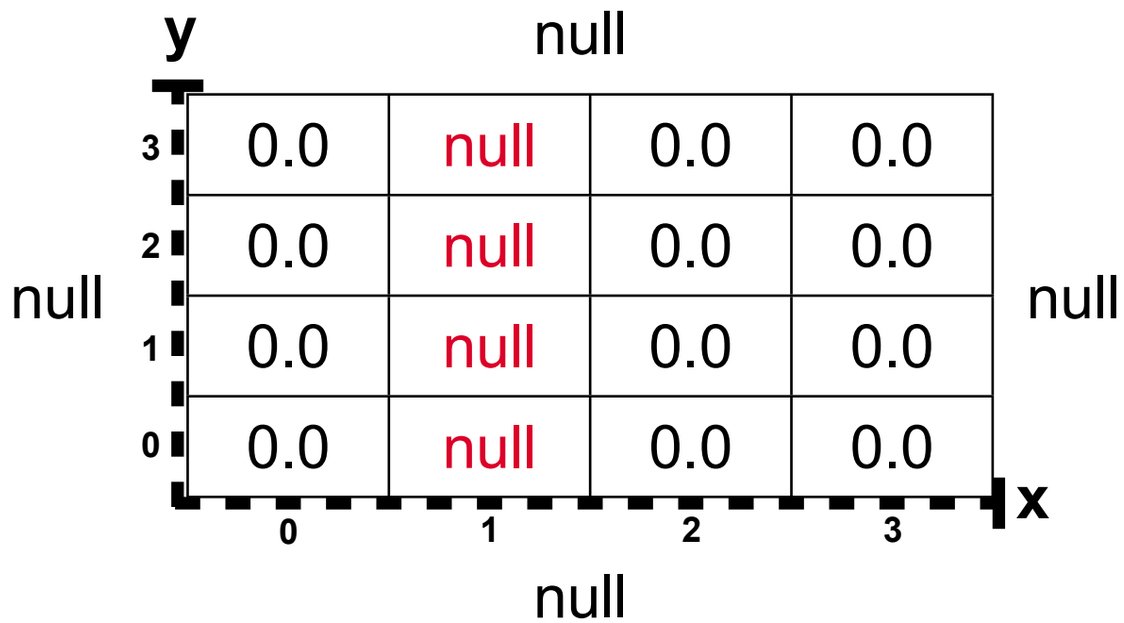


- An unbounded array
- min/max of dimensions are derived from the minimal bounding rectangle
- non-dimentional attributes inherit default column values
- duplicates are overwritten

Array Modifications

```
CREATE ARRAY A1 (
   x INT DIMENSION[0:4:1],
   y INT DIMENSION[0:4:1],
   v FLOAT DEFAULT 0.0
);
```

DELETE FROM A1 WHERE x = 1;



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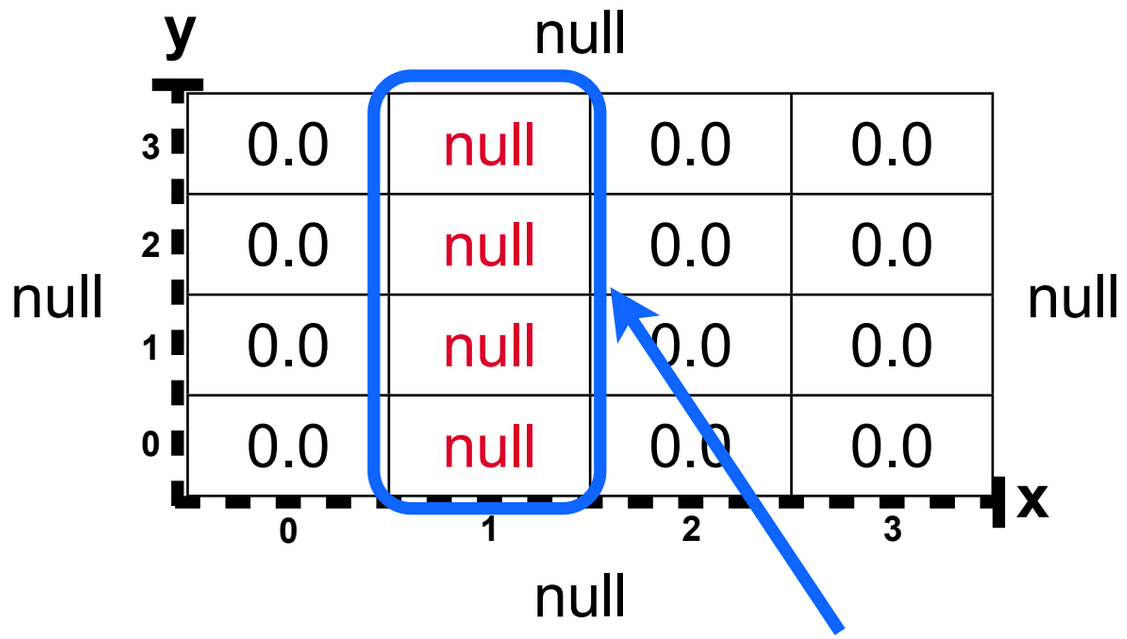

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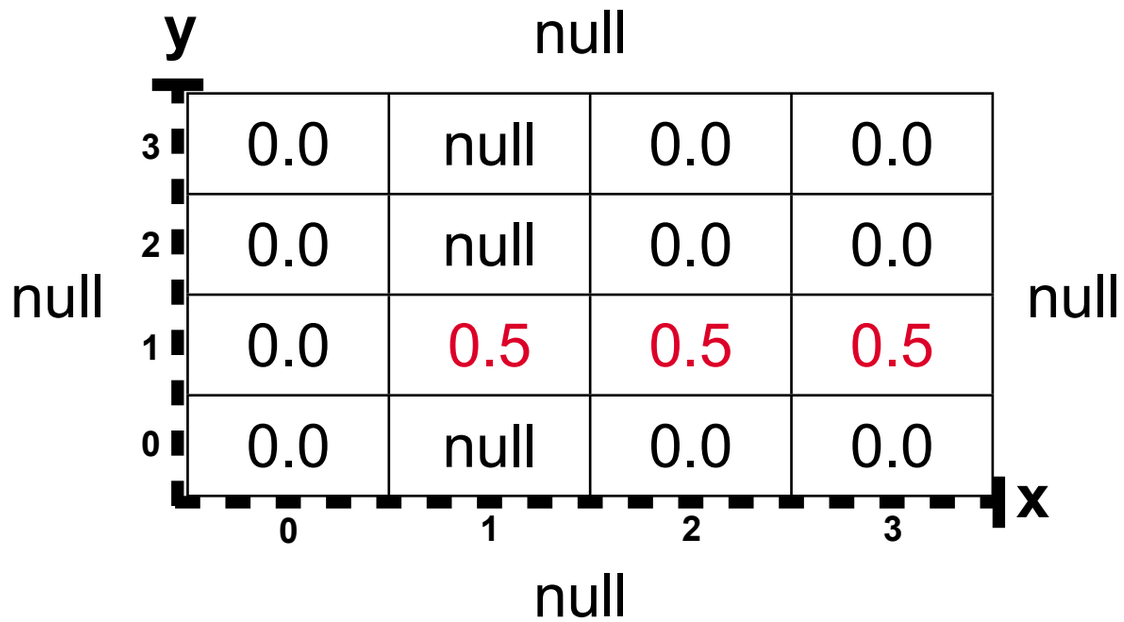

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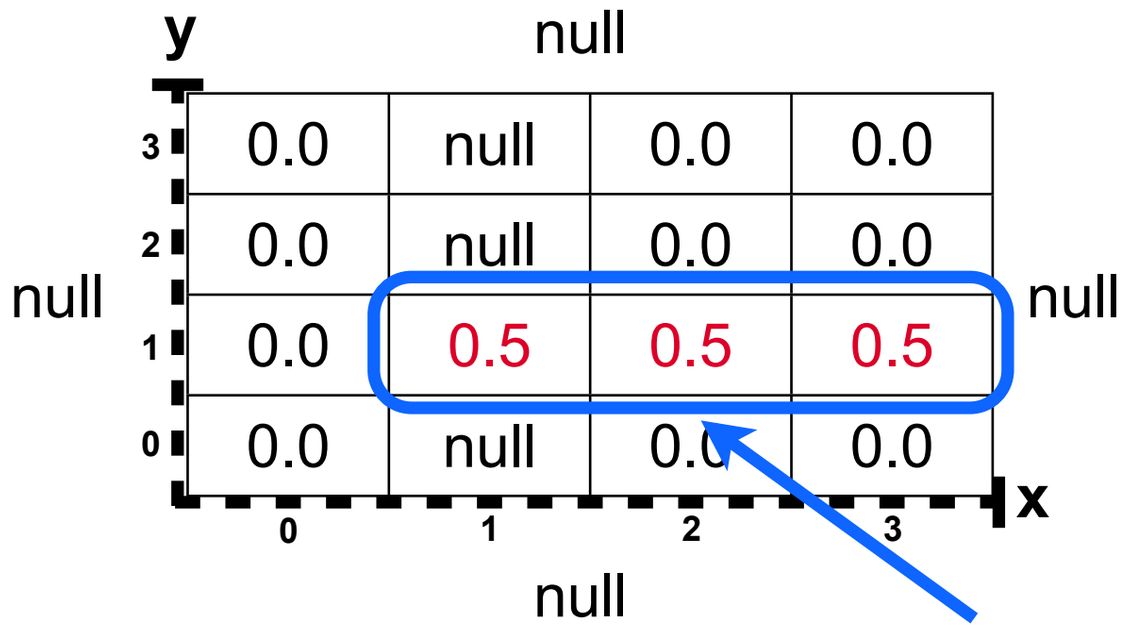

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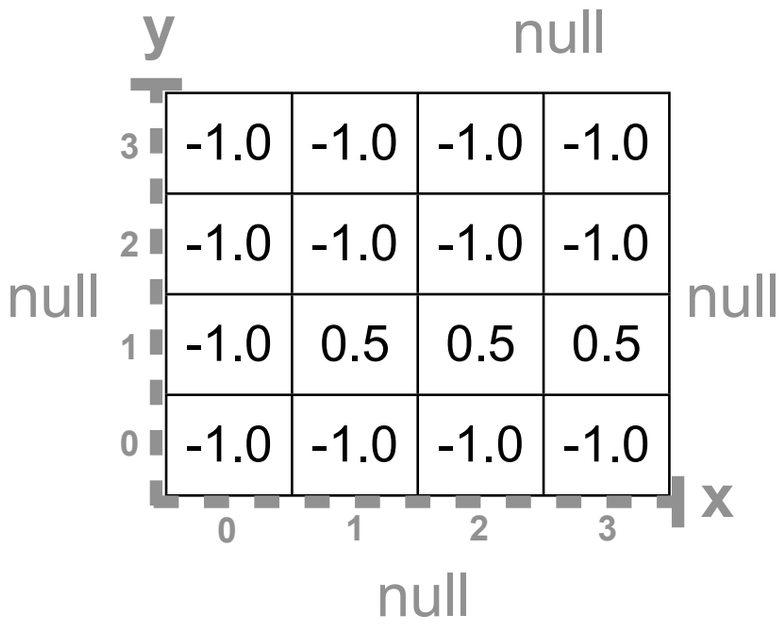

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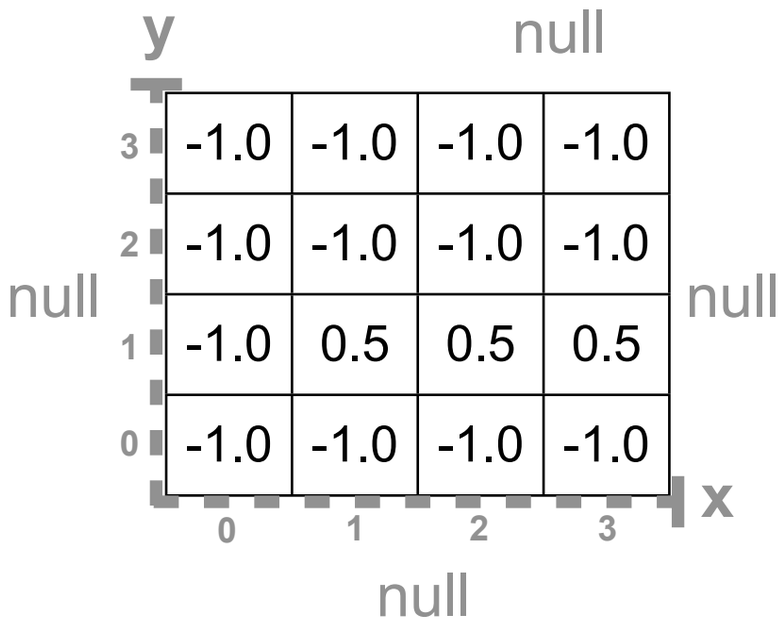

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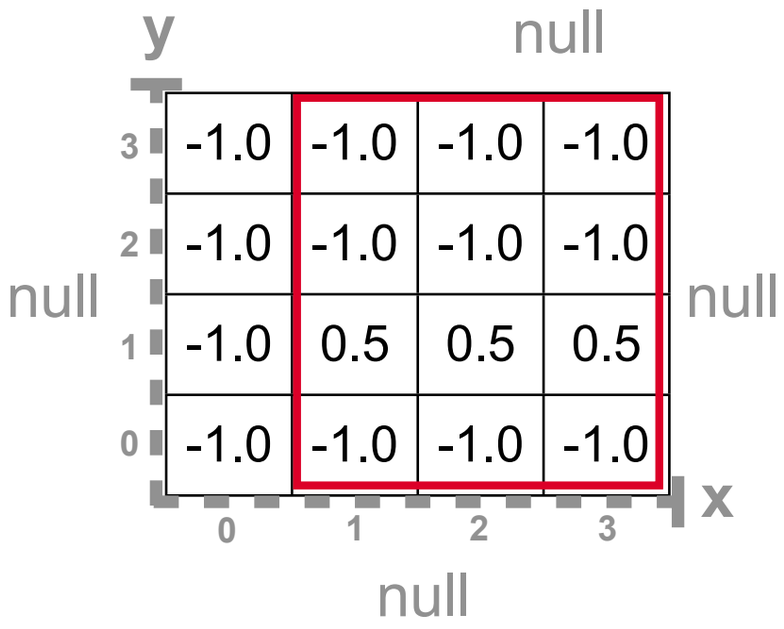

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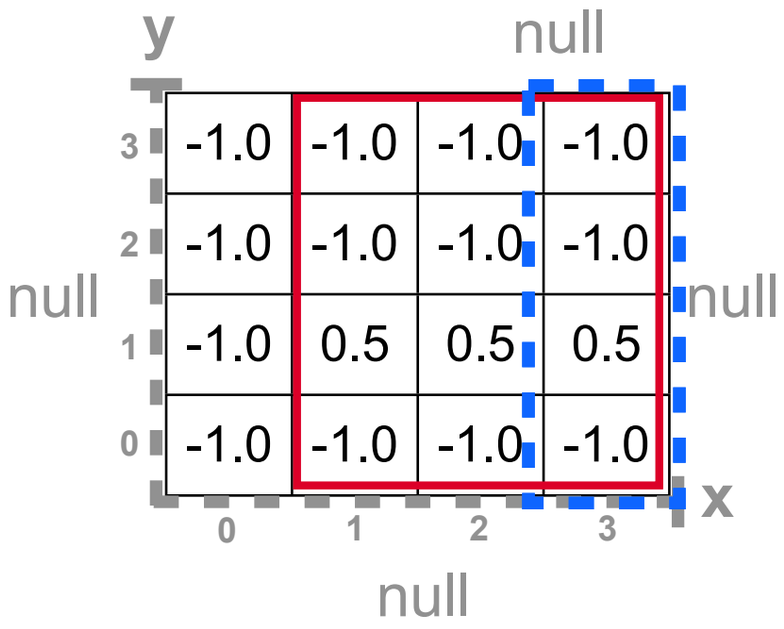

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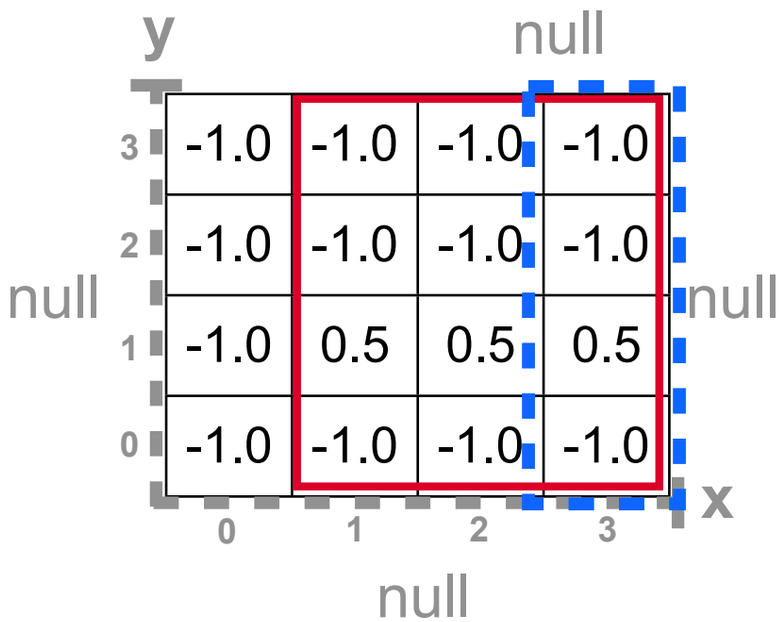

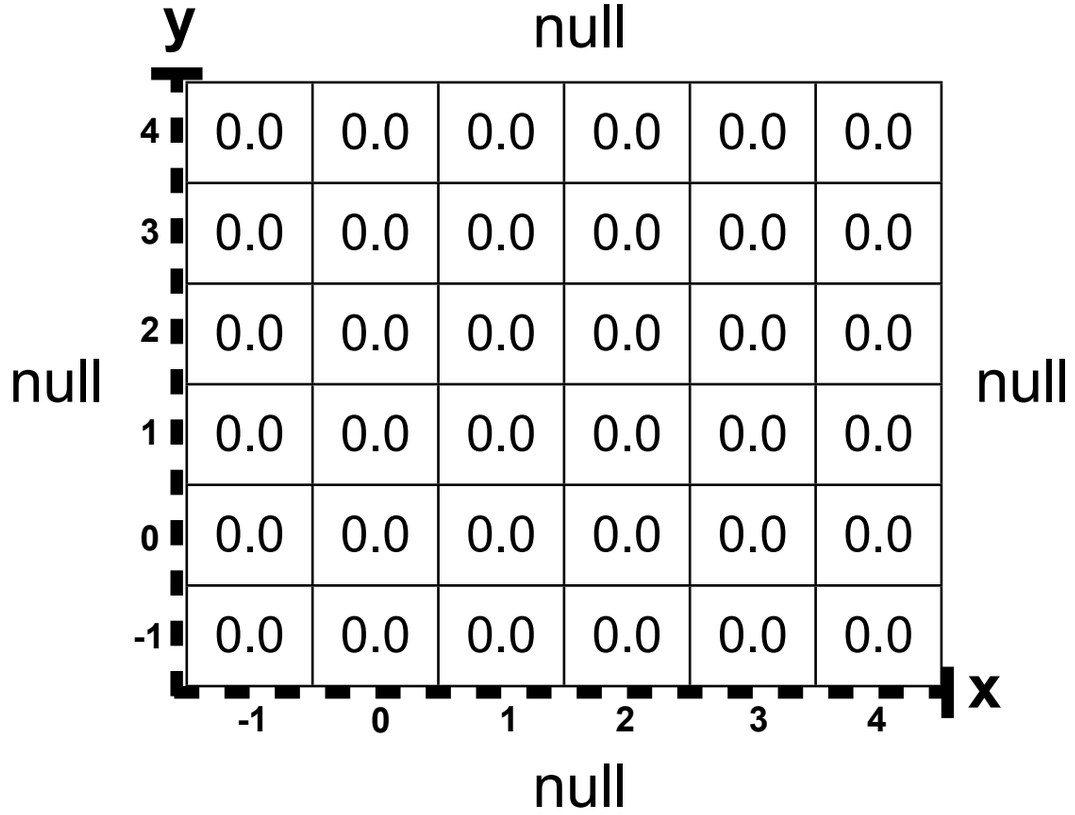

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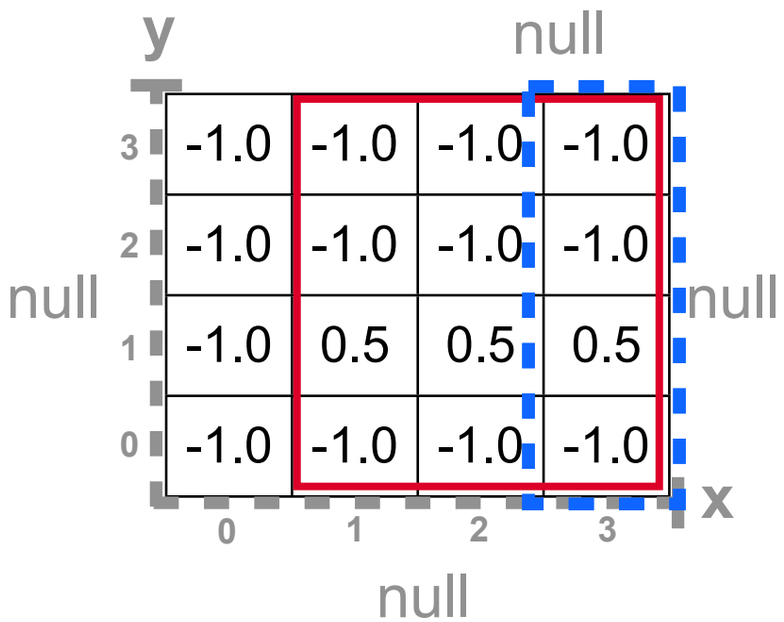

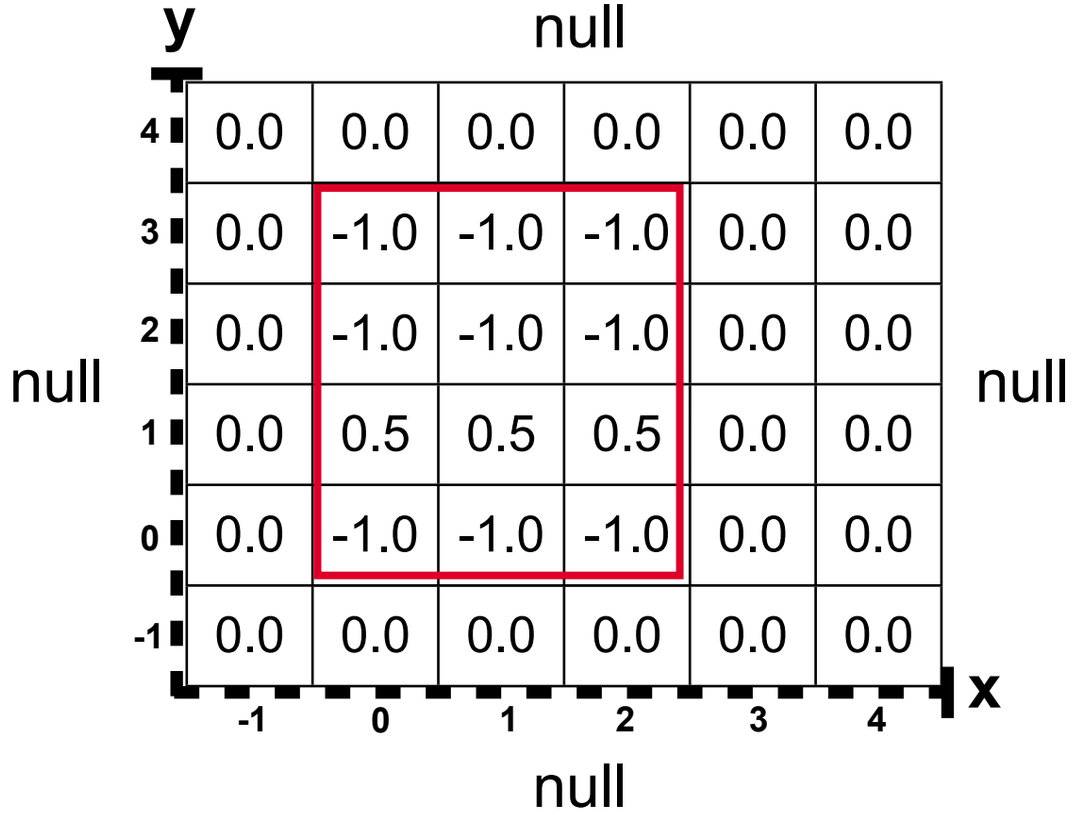

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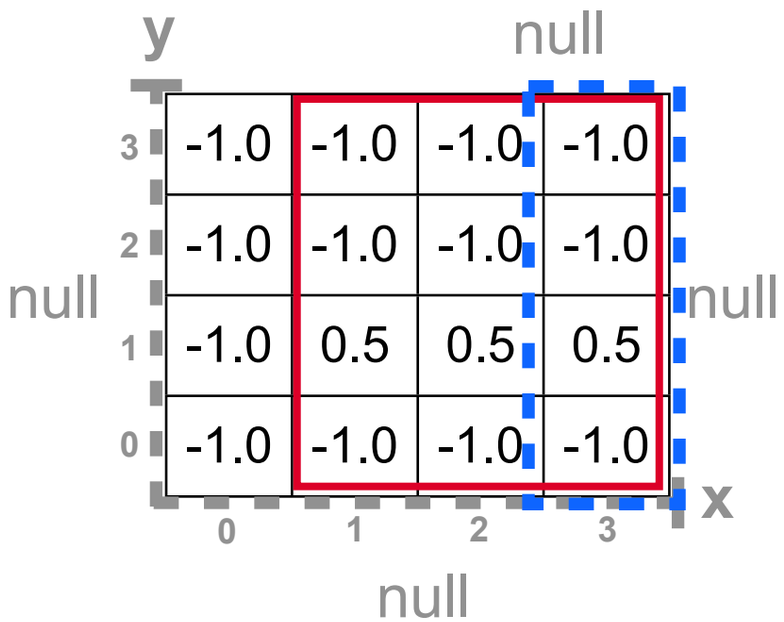

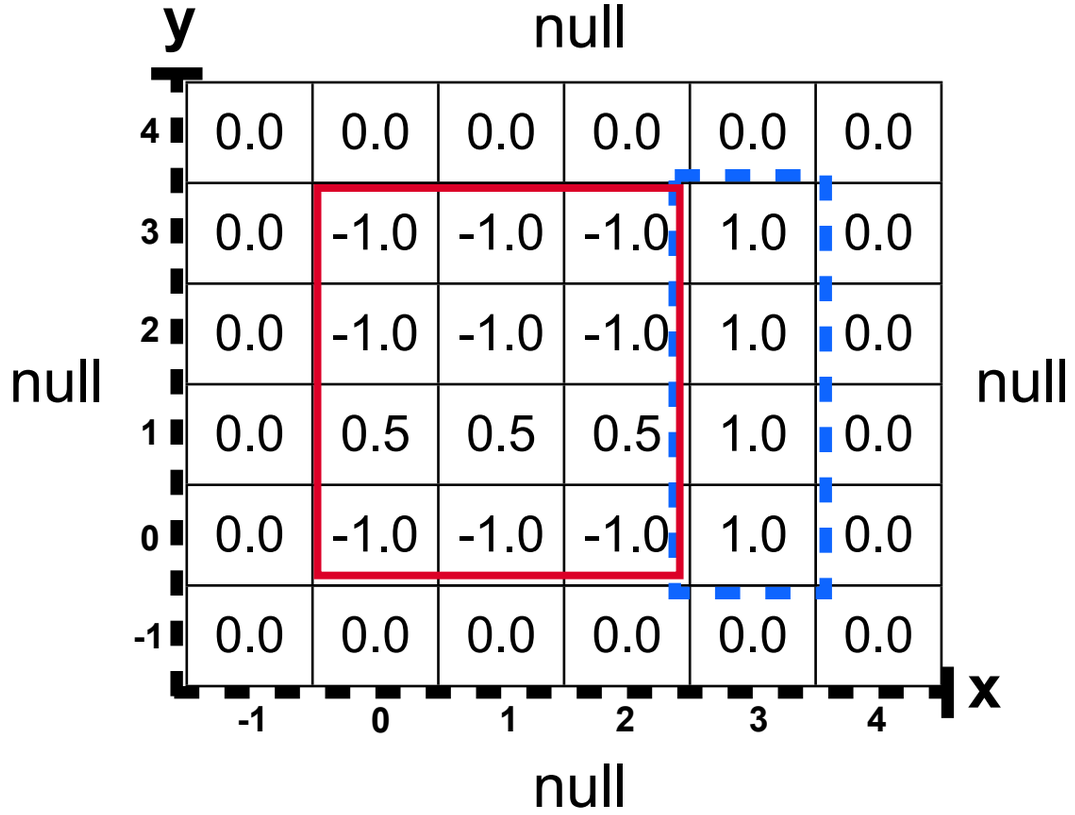

Array Tiling

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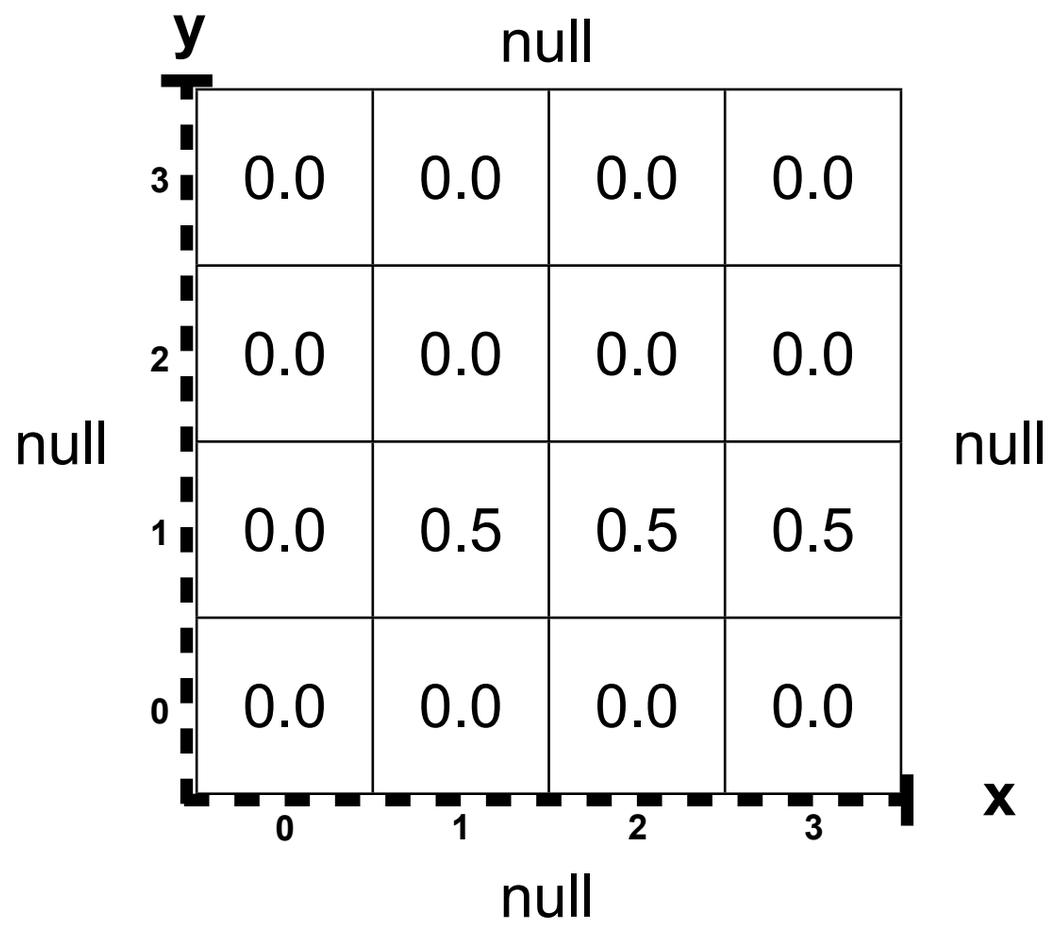
```

```
SELECT [x], [y], AVG(v) FROM A1
GROUP BY A1[x:x+2][y:y+2];
```



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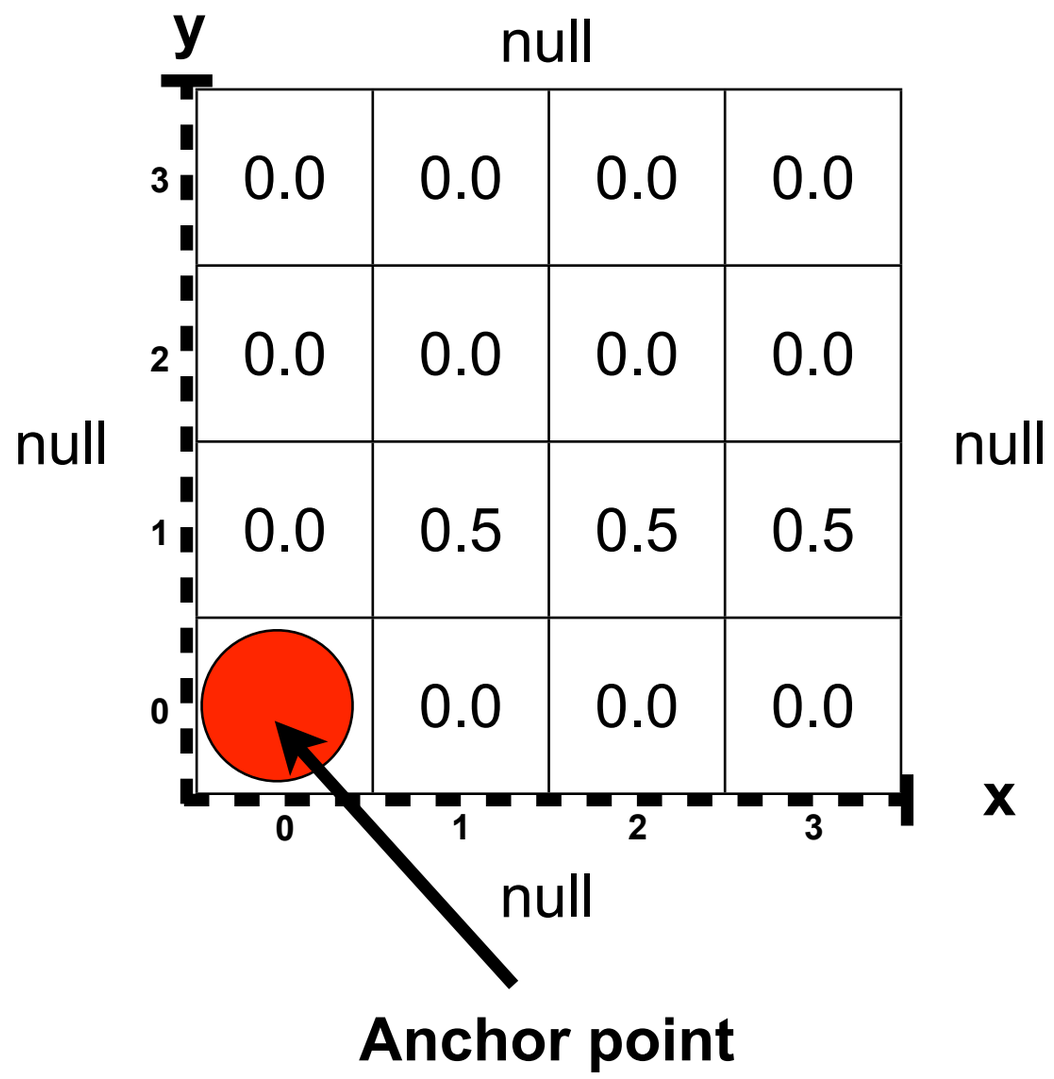

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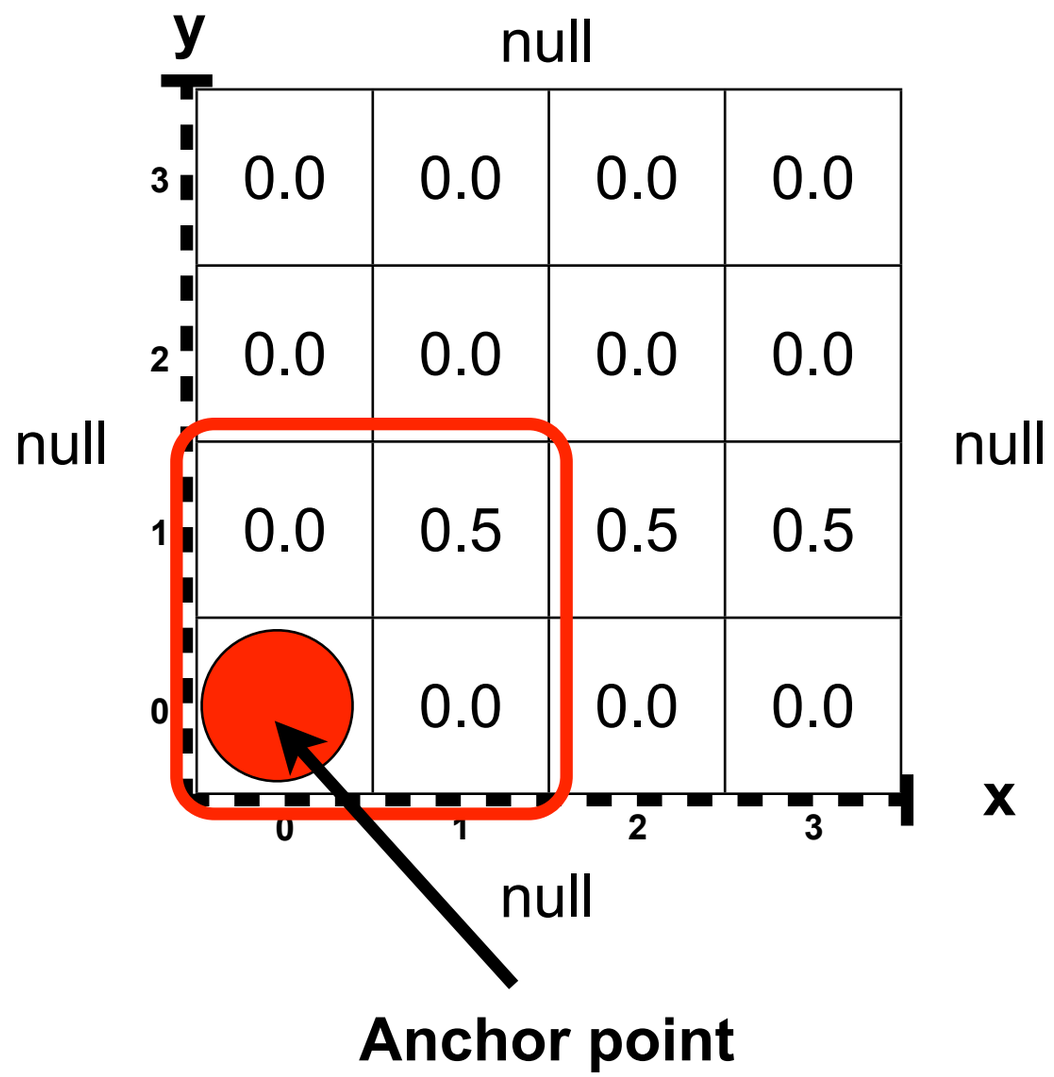

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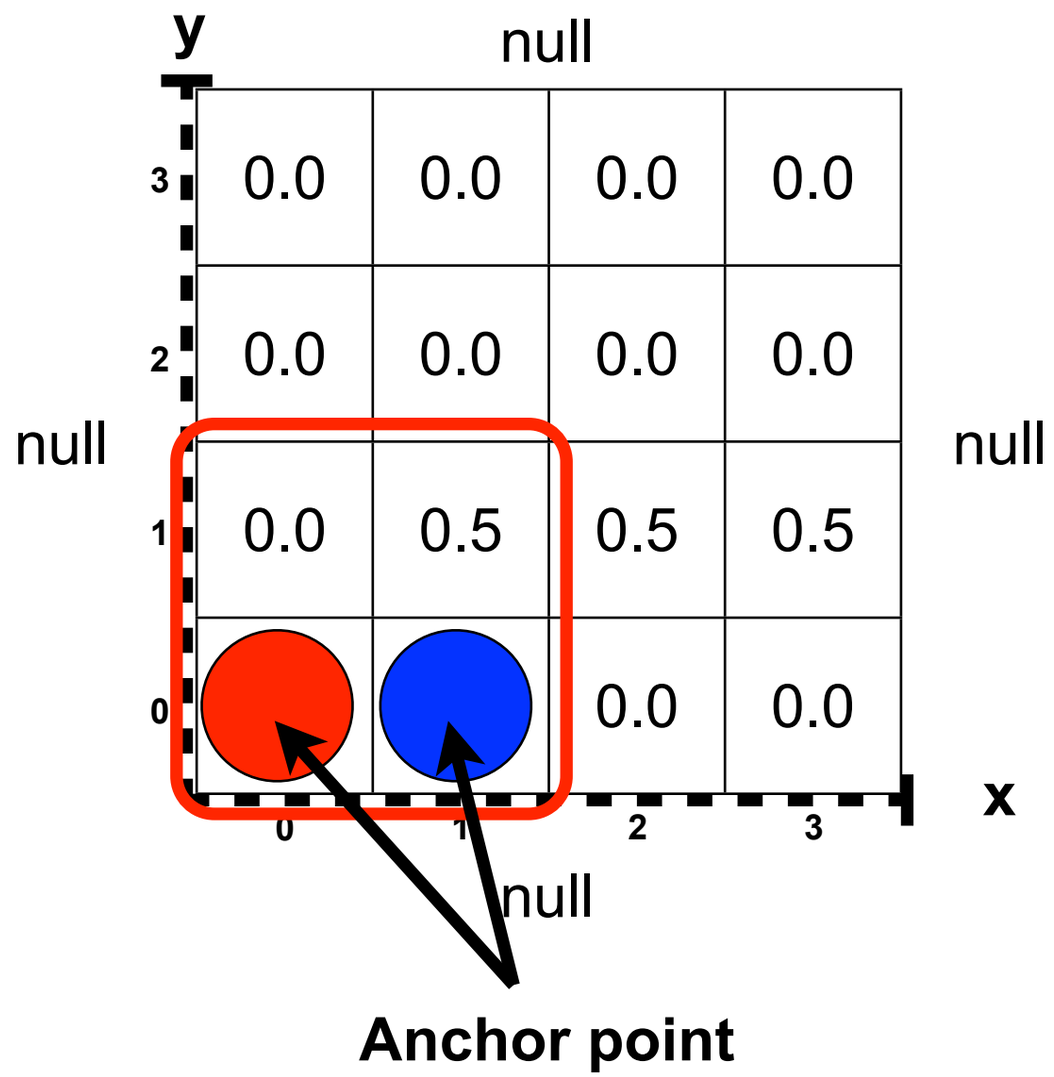

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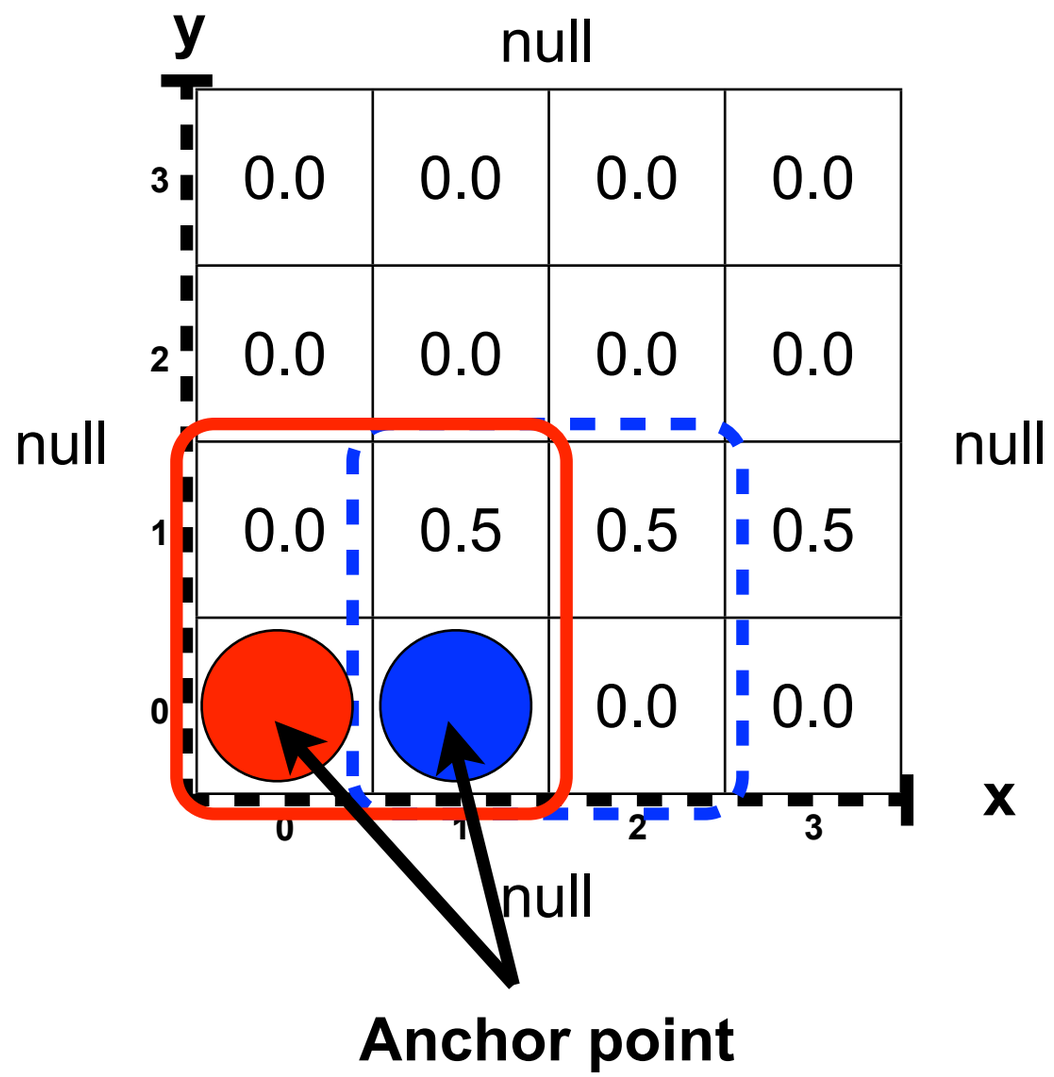

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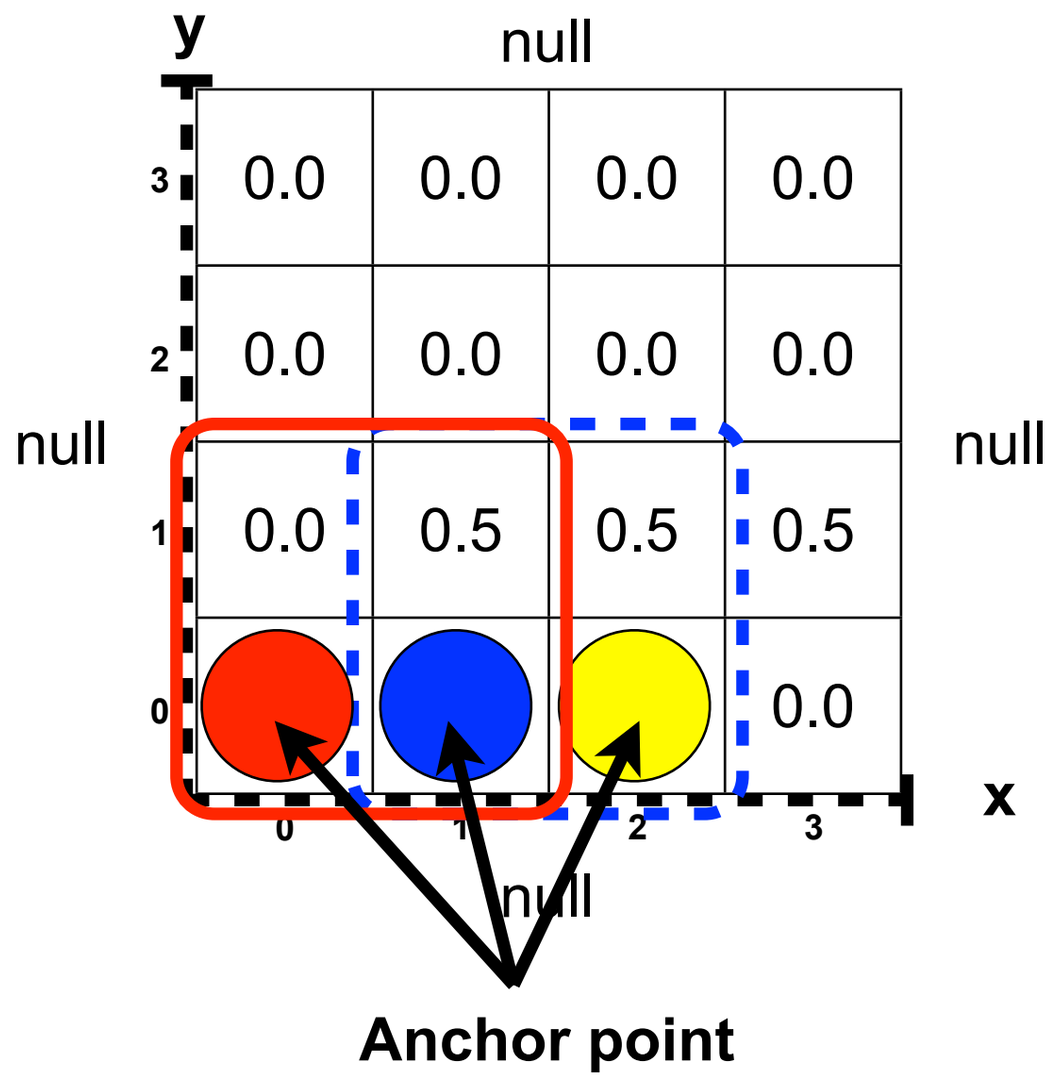

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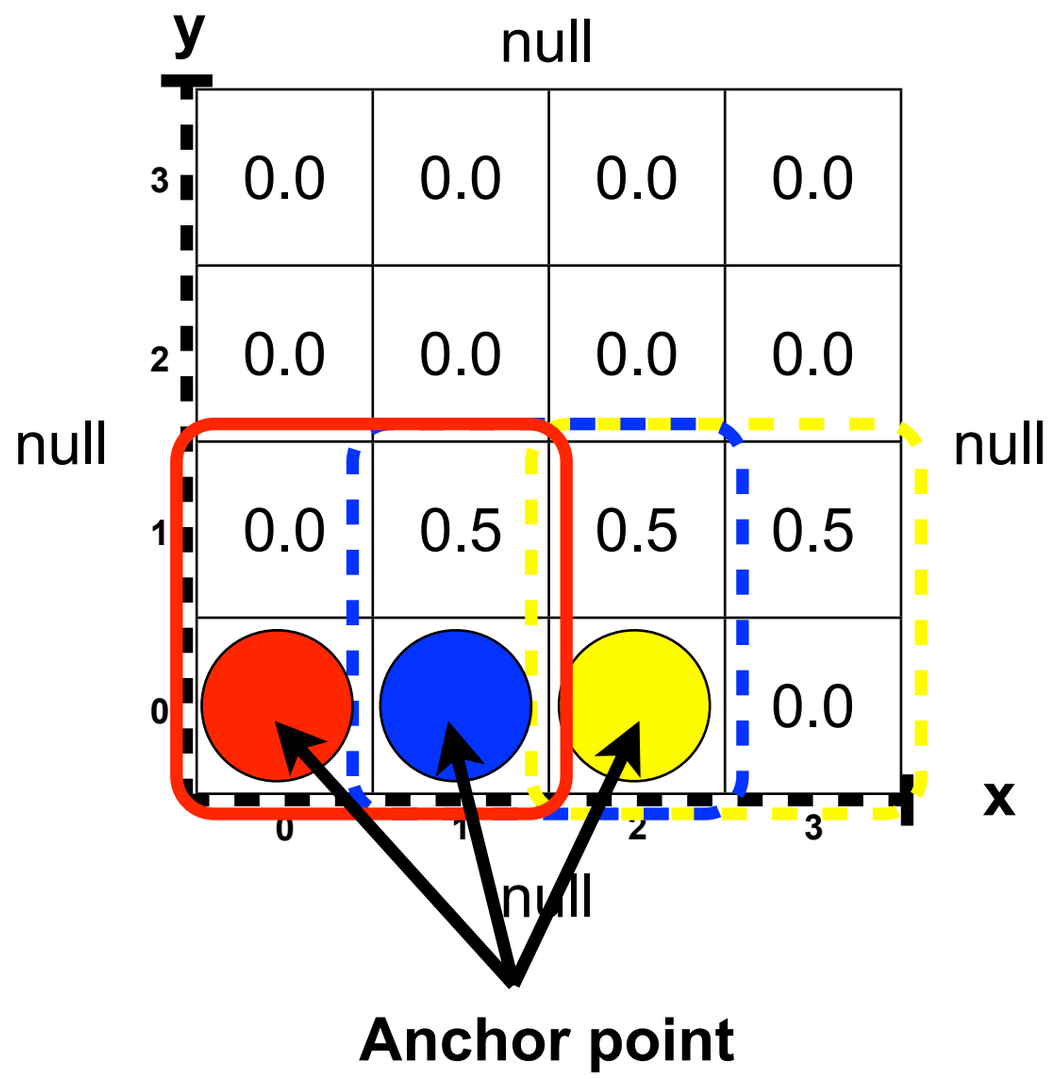

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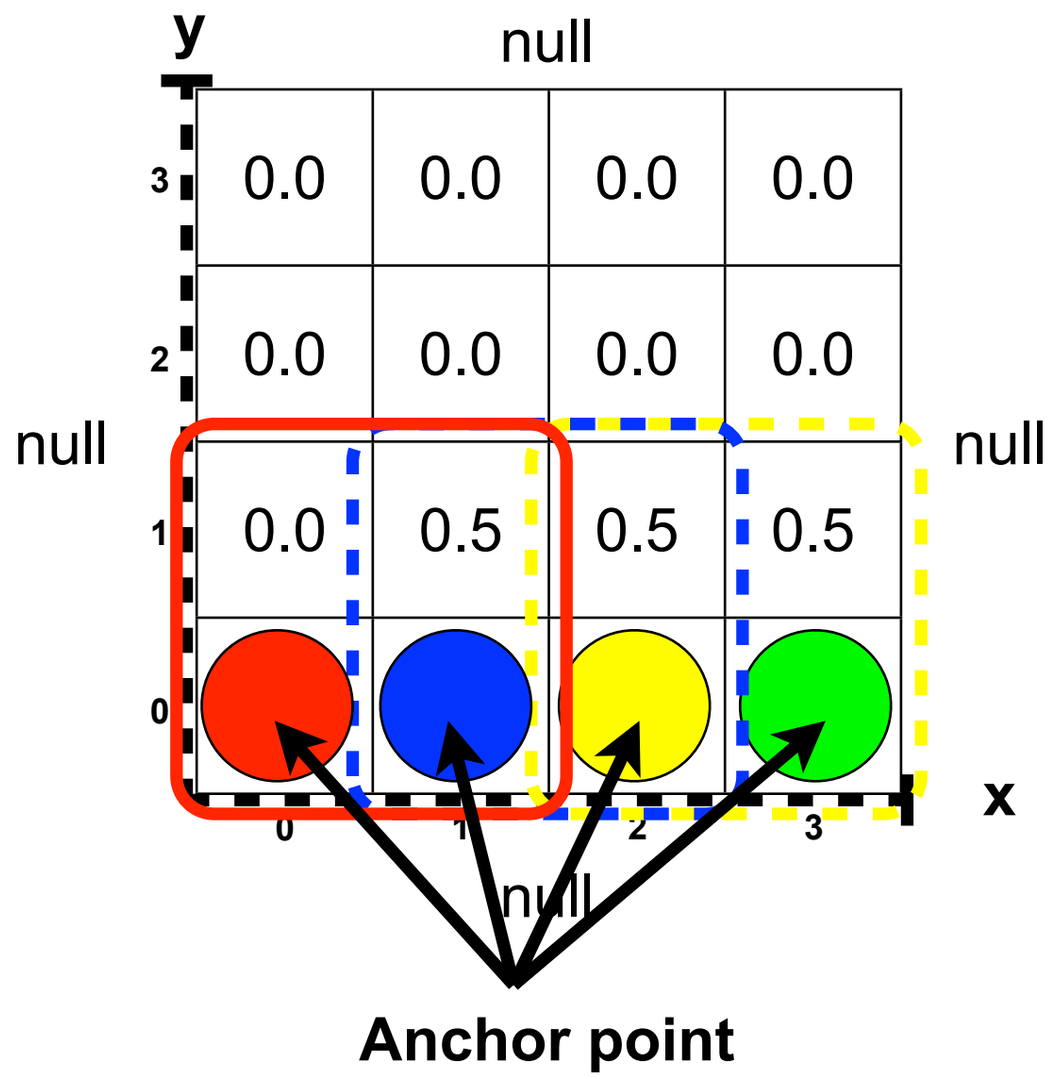

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```

tiling
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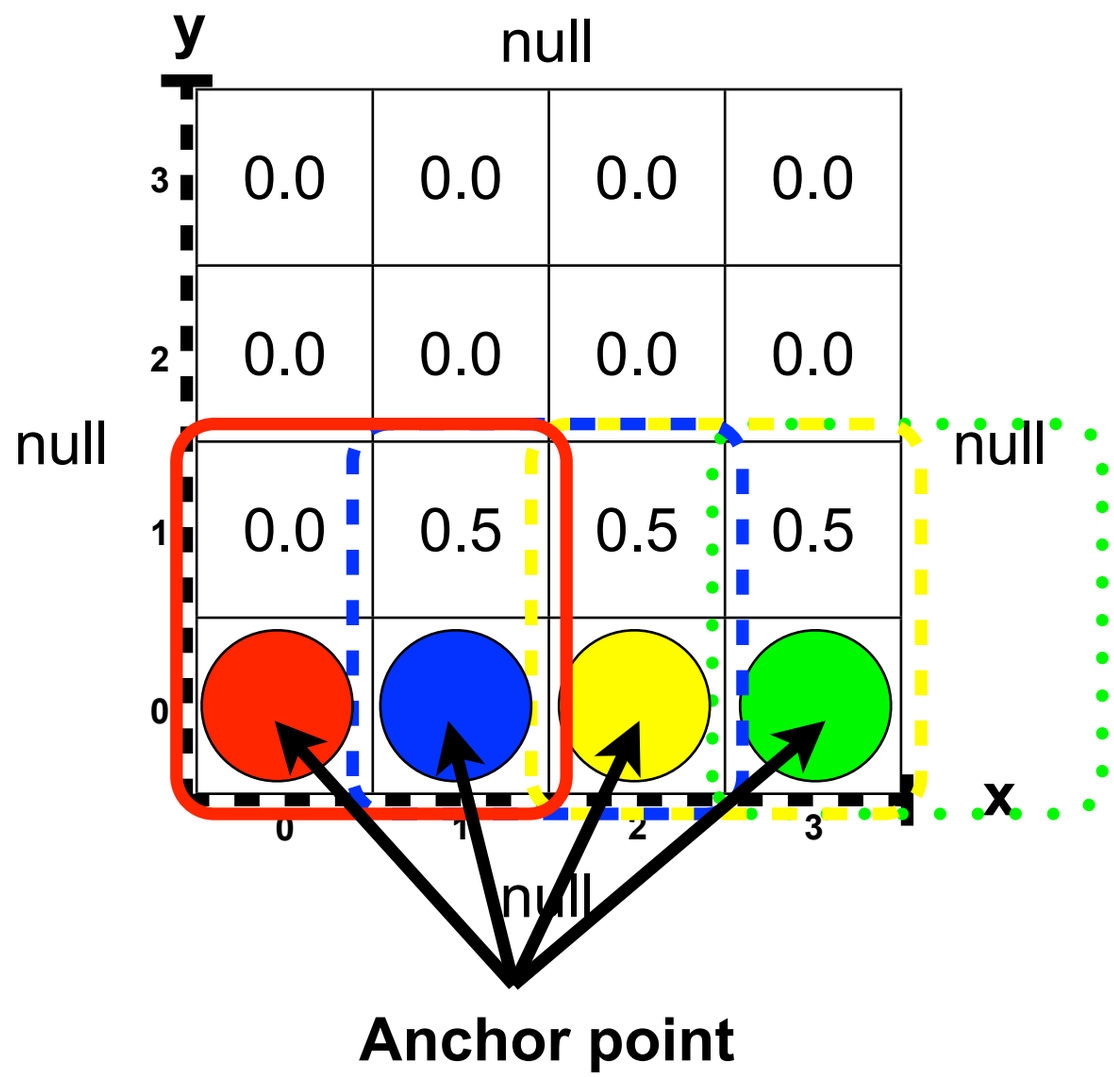
windowing



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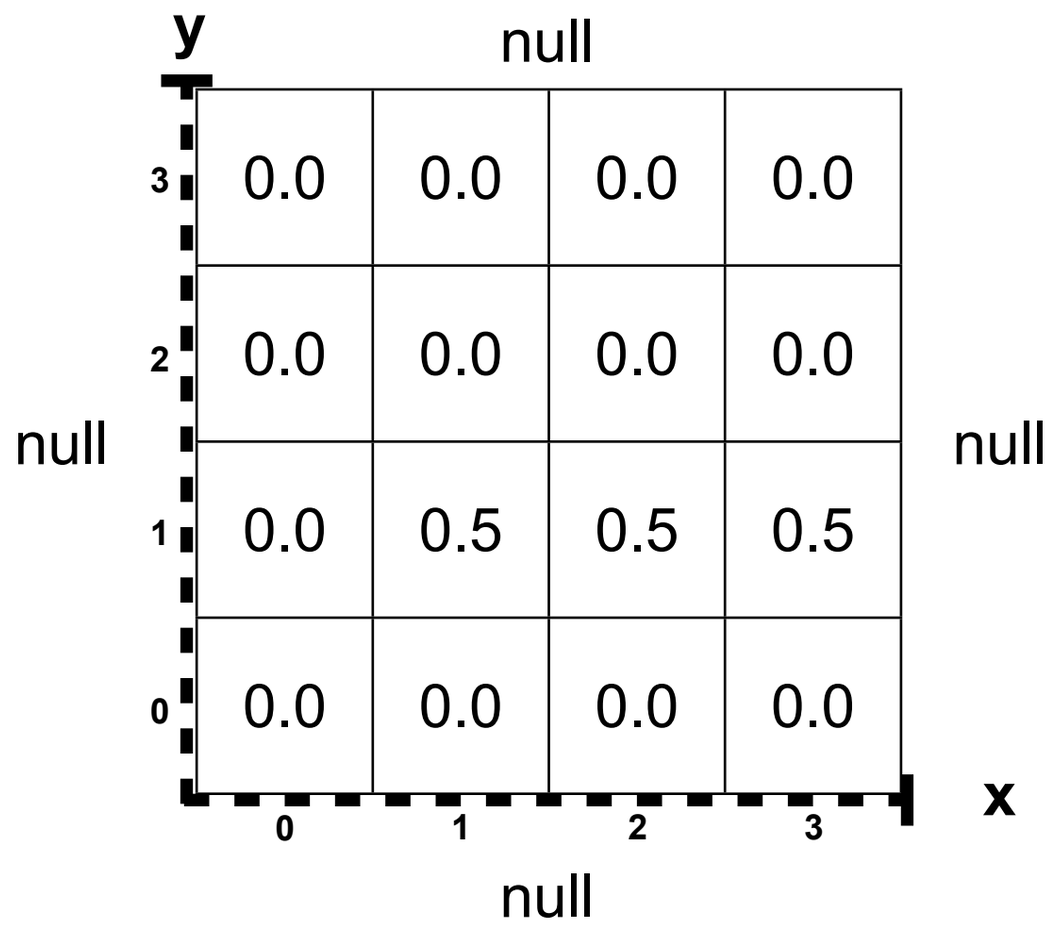

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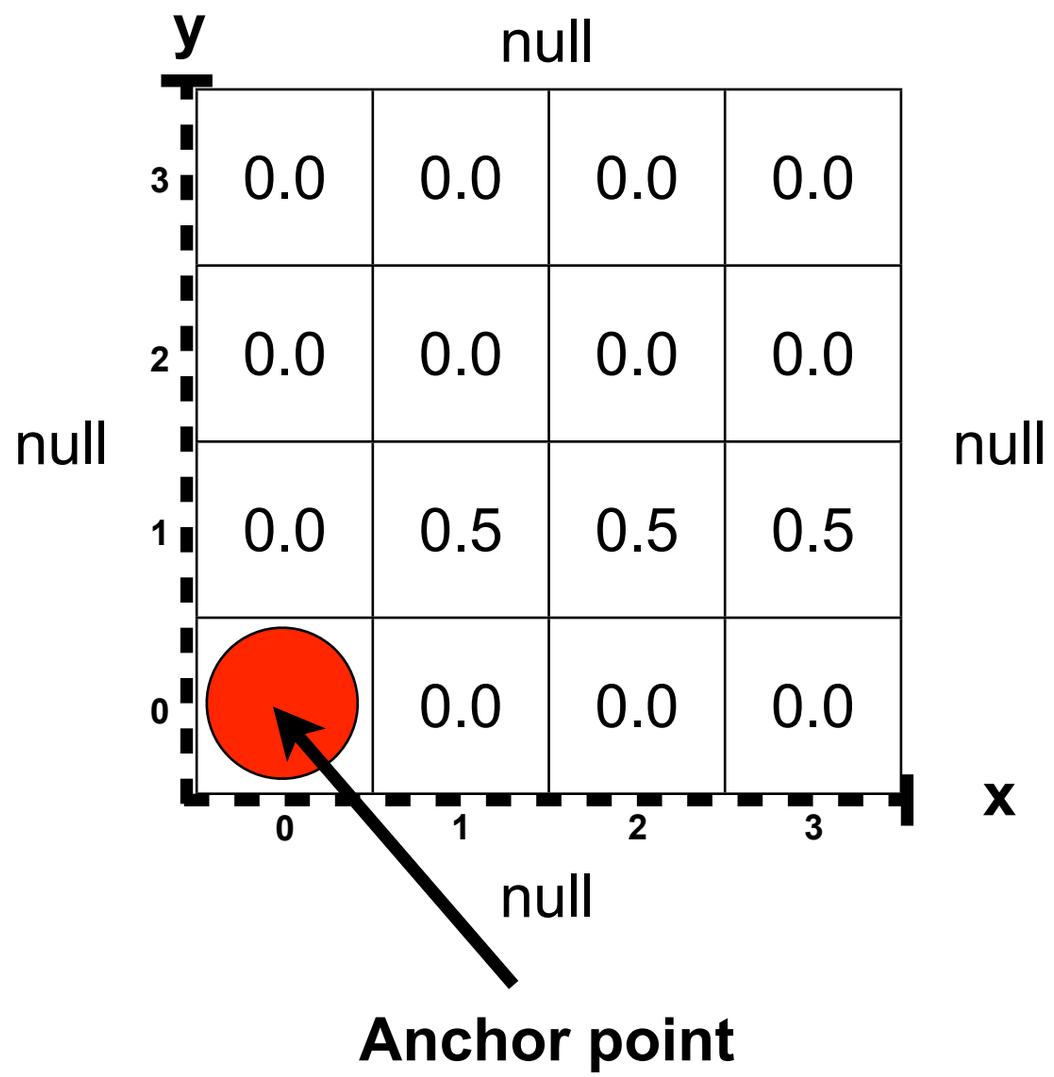

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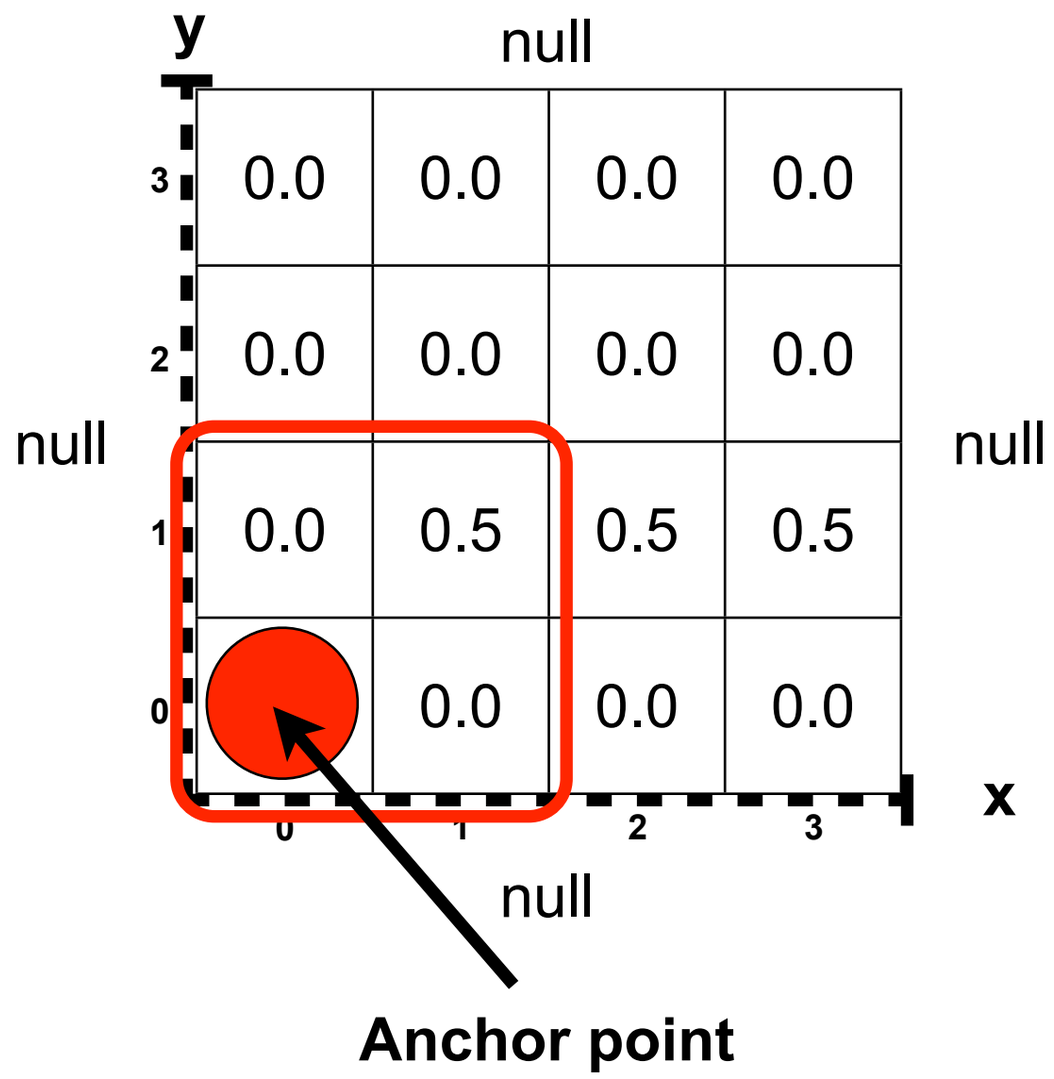

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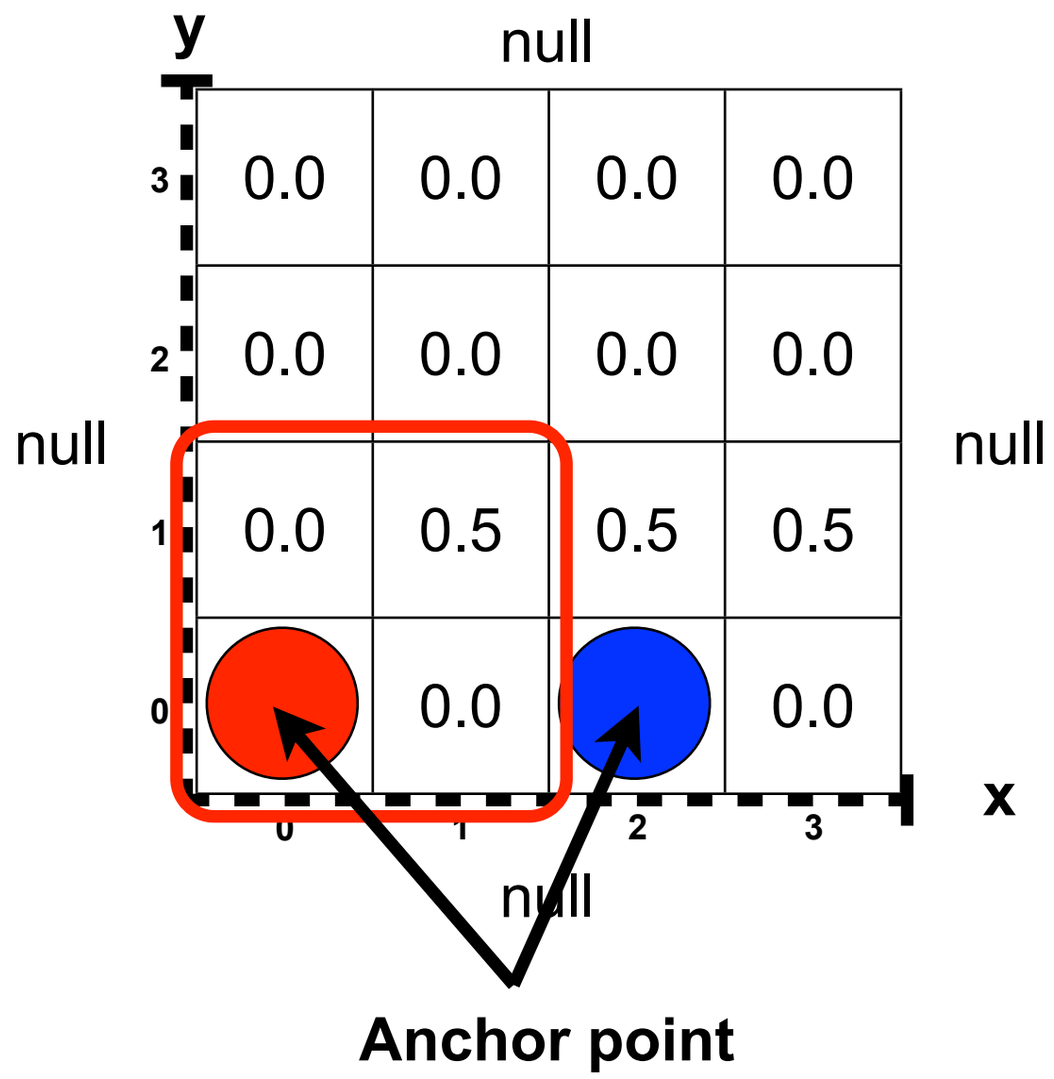

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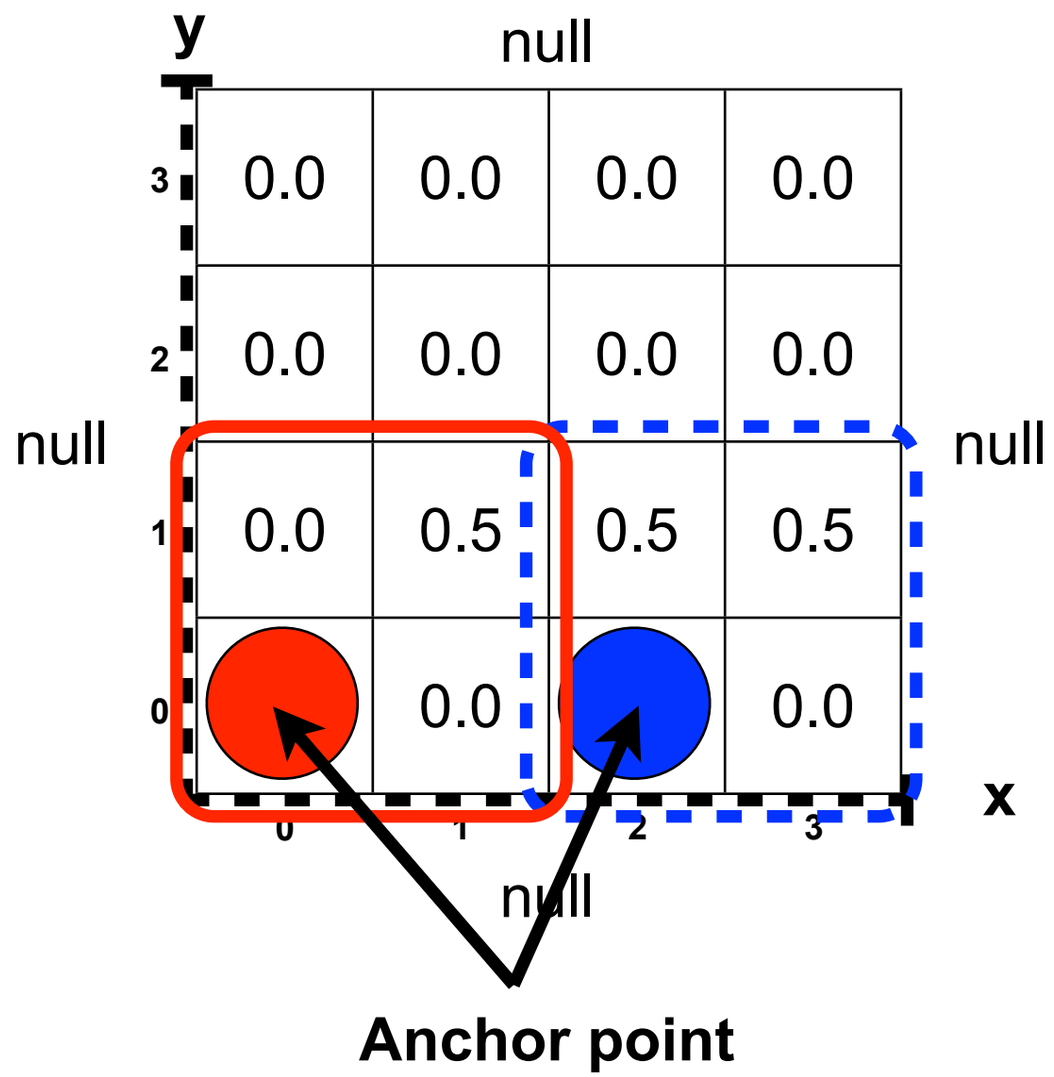

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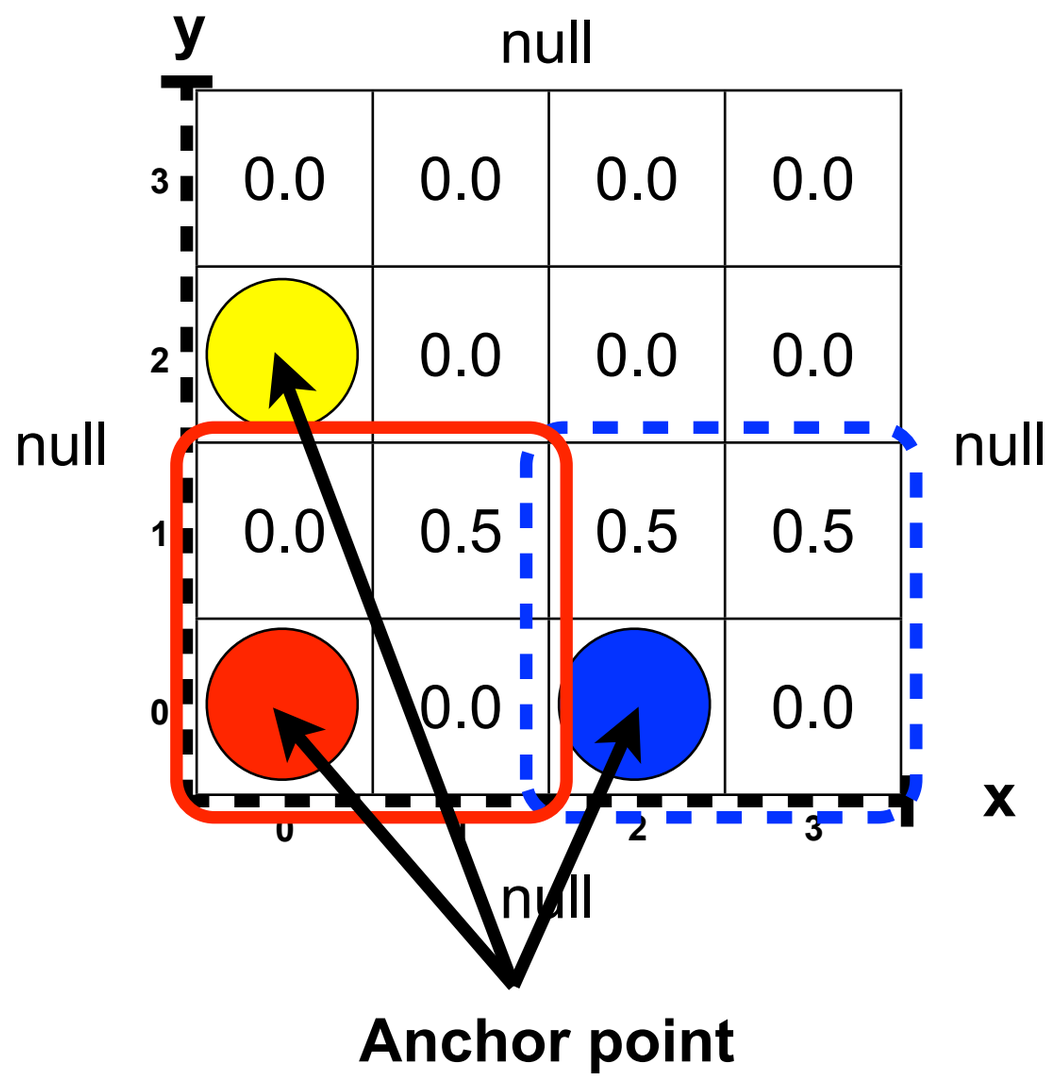

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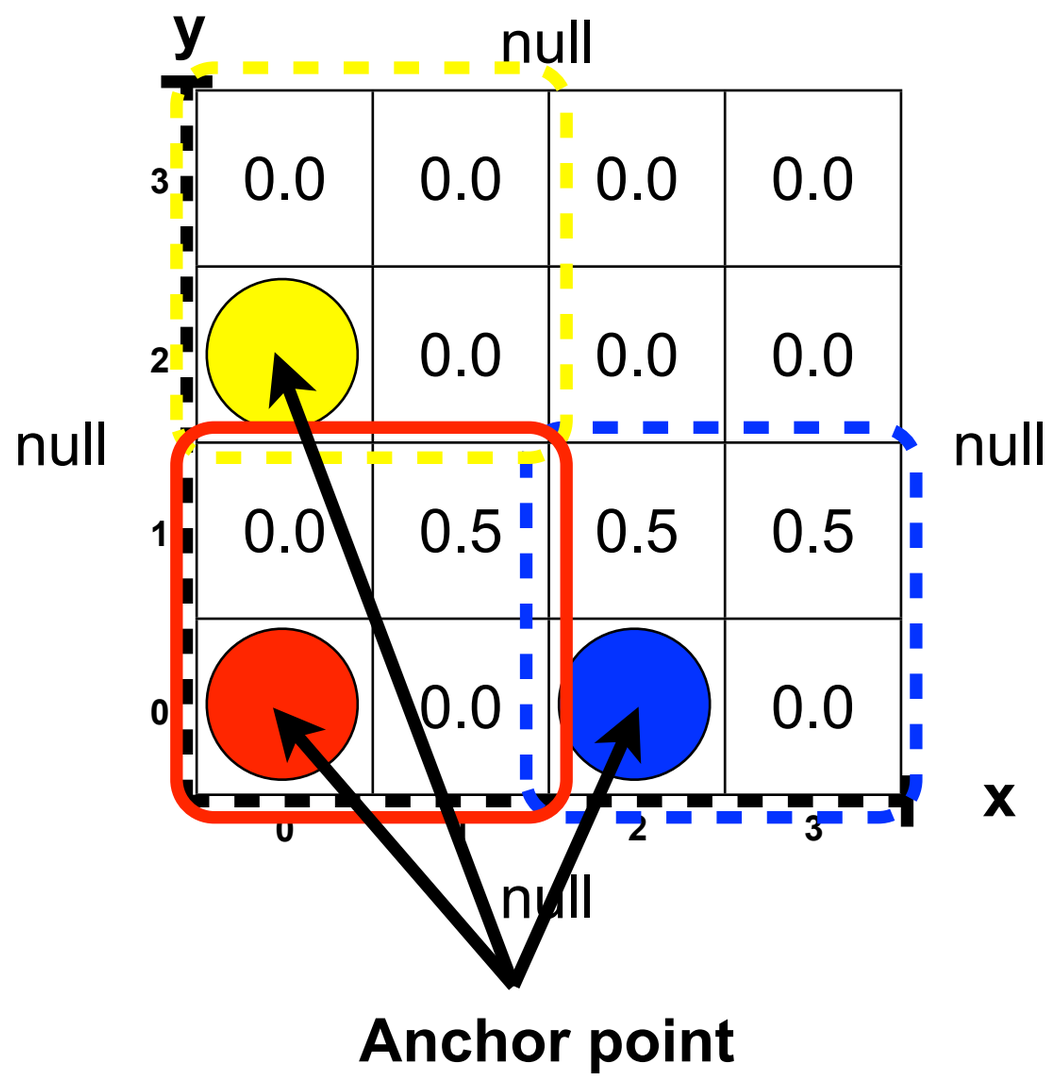

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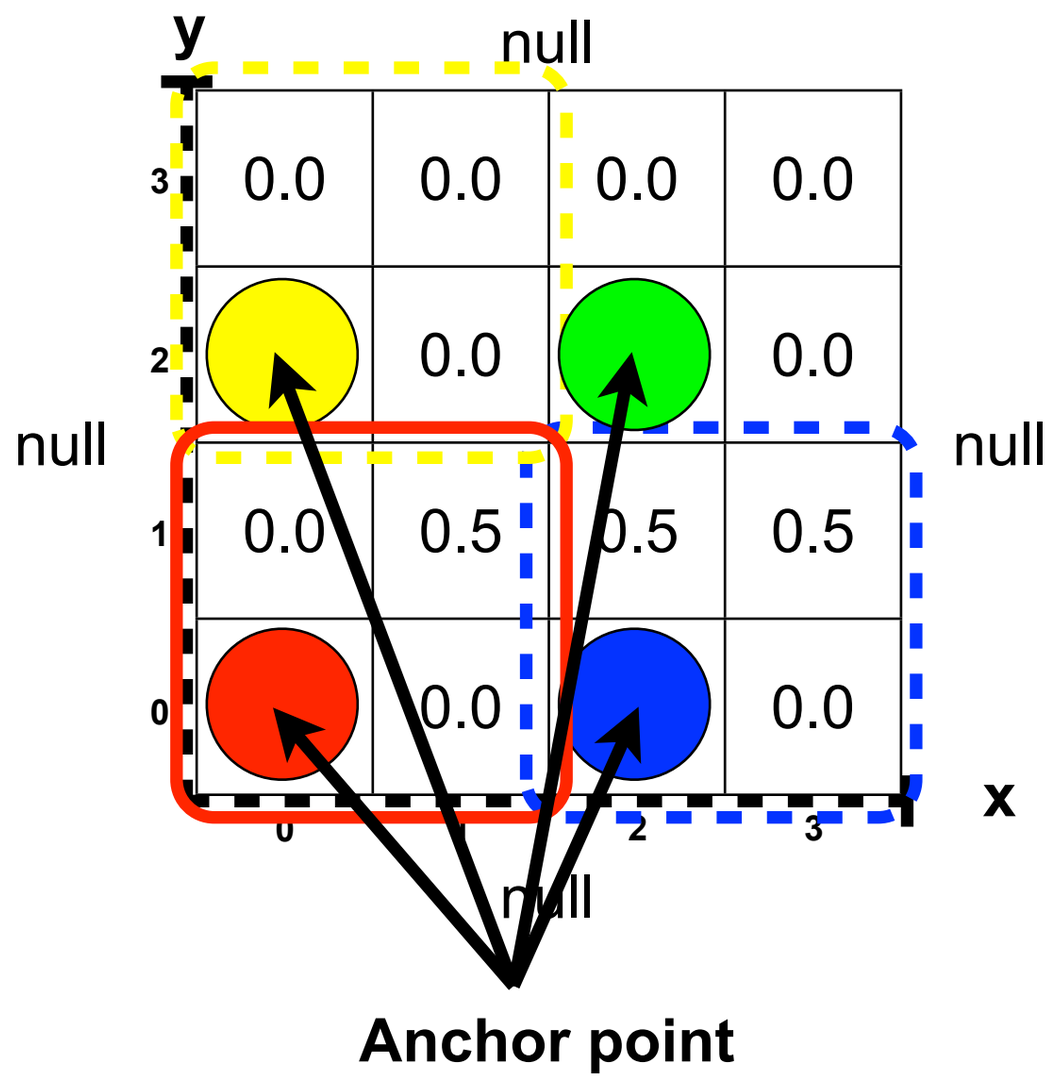

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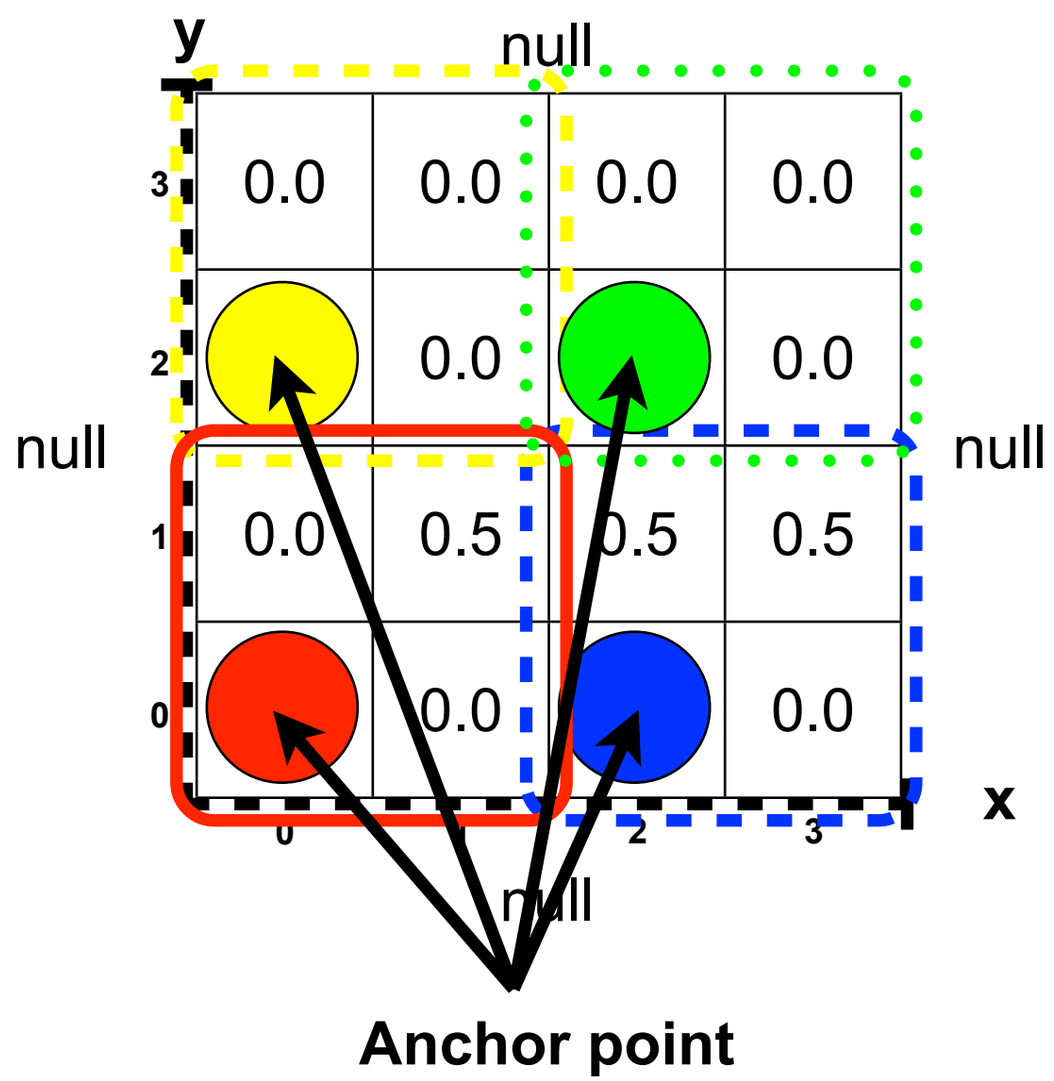

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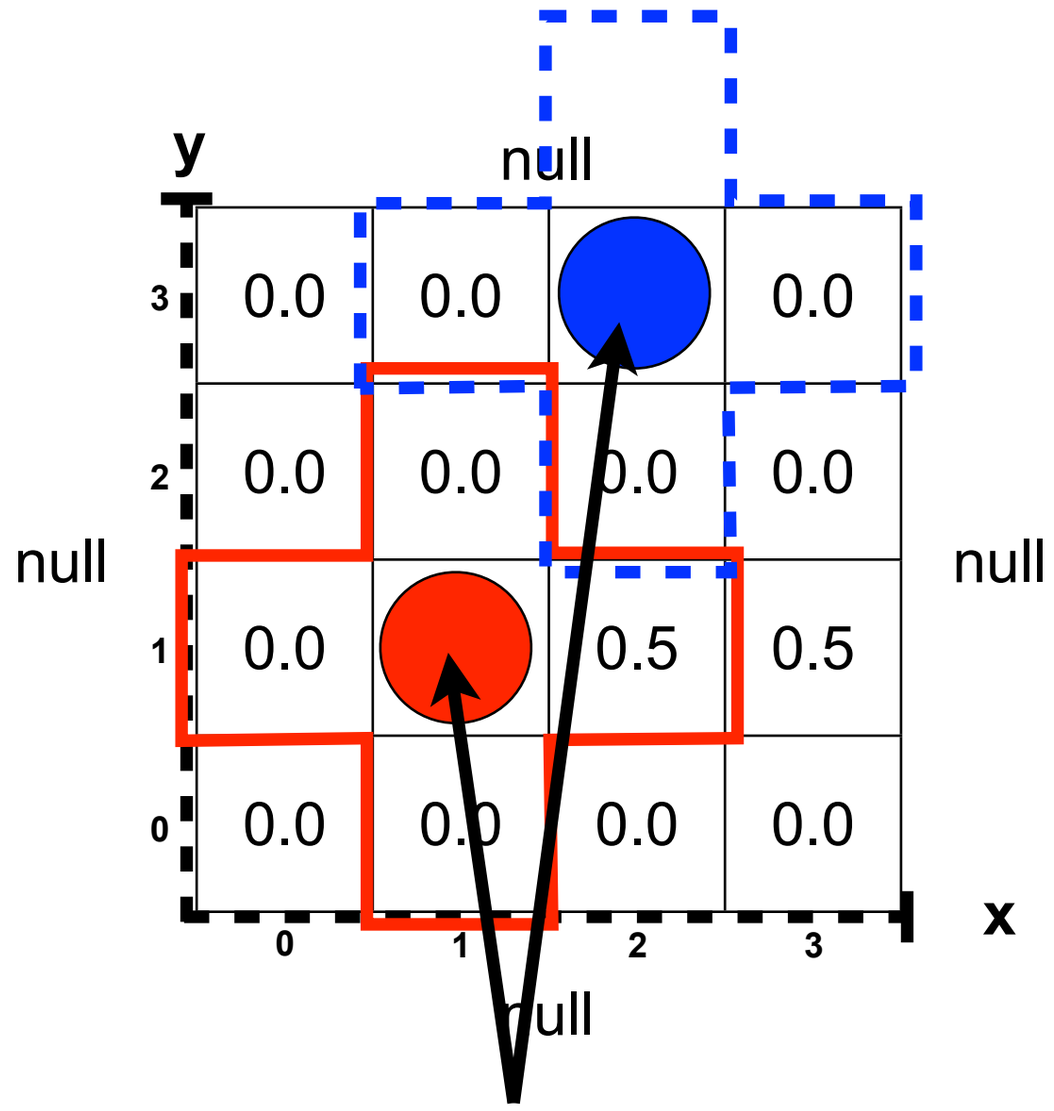
```

```
SELECT [x], [y], AVG(v) FROM A1[1:*][1:*]
GROUP BY DISTINCT A1[x-1][y], A1[x][y-1],
   A1[x][y], A1[x+1][y], A1[x][y+1];
```



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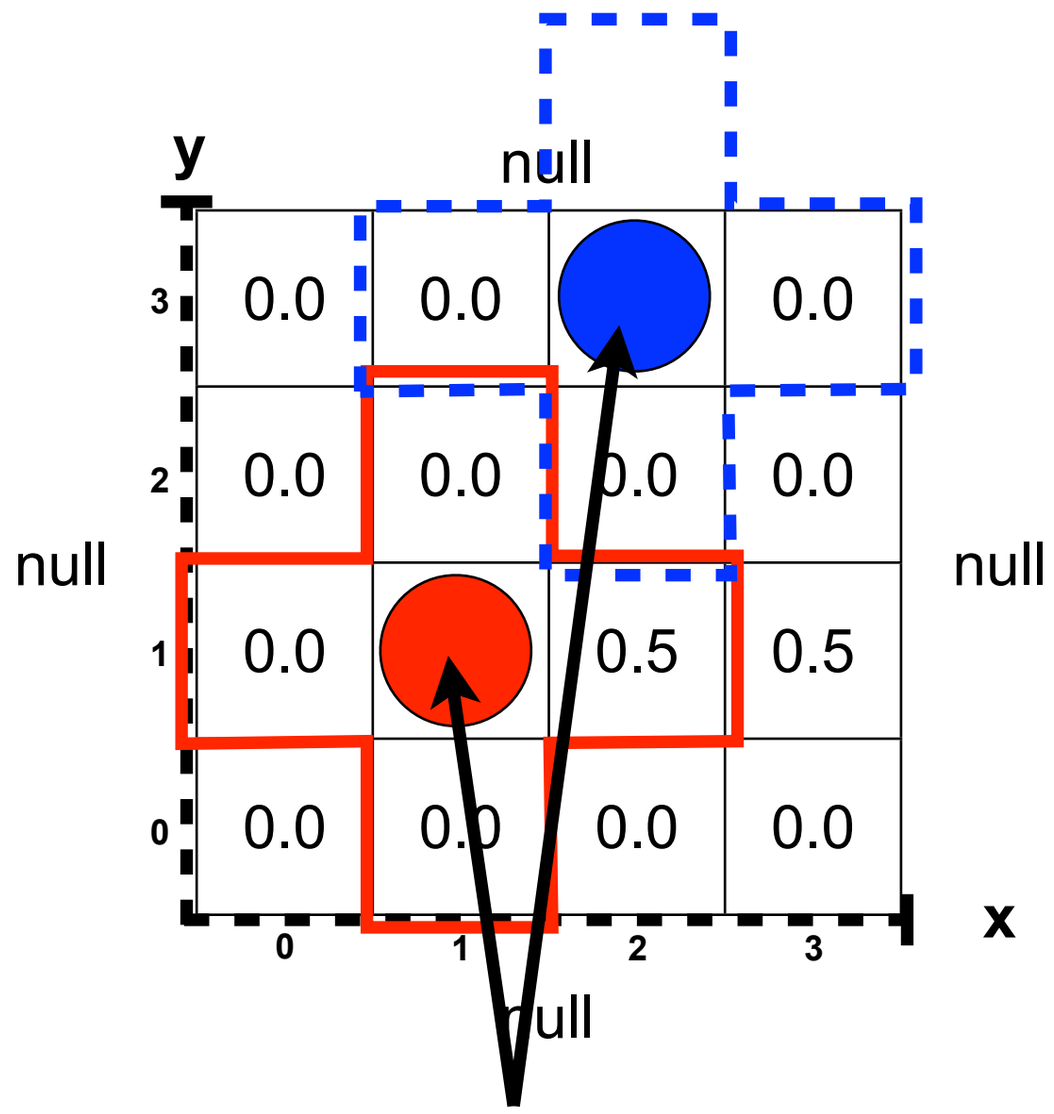
```

SELECT [x], [y], AVG(v) FROM A1[1:*][1:*]
GROUP BY **DISTINCT** A1[x-1][y], A1[x][y-1],
A1[x][y], A1[x+1][y], A1[x][y+1];



Seismology Use Case

- Recent aftershock in Chili
  - 2TB waveform data at 100Hz
  - detecting seismic events using STA/ LTA (e.g., 2 sec / 15 sec)
  - remove false positives
  - window-based 3 min. cuts
  - heuristic tests
- Current problems
  - accessing waveform files too slow
  - unpacking and positioning MSEED data takes too long

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```
CREATE TABLE MSeed (
   station VARCHAR(10);
   ts ARRAY (
      tick TIMESTAMP DIMENSION
         [* : * : INTERVAL '0.01' SECOND],
      data DECIMAL(8,6)
   )
);
```

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```
--- avg of 2 sec. windows:

SELECT A.station, A.ts.tick, AVG(A.ts.data)
FROM MSeed AS A
GROUP BY
     A.ts[tick - INTERVAL '2' SECOND : tick];
```

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```
CREATE TABLE Event(
   station STRING,
   tick      TIMESTAMP,
   ratio     FLOAT)
AS
SELECT A.station, A.ts.tick,
     AVG(A.ts.data)/AVG(B.ts.data) AS ratio
FROM MSeed AS A, MSeed AS B
WHERE A.station = B.station
     AND A.ts.tick  = B.ts.tick
GROUP BY
     A.ts[tick - INTERVAL '2' SECOND : tick],
     B.ts[tick - INTERVAL '15' SECOND : tick]
HAVING AVG(A.ts.data)/AVG(B.ts.data) > ?delta
WITH DATA;
```

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```
-- detect isolated errors by direct environment
-- using wave propagation statics

CREATE TABLE Neighbors(
   head STRING,
   tail STRING,
   delay TIMESTAMP,
   weight FLOAT
);
```

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```
-- detect false positives:

SELECT A.station, A.tick
FROM Event AS A, Event AS B, Neighbor AS N
WHERE A.station = N.head
      AND B.station = N.tail
      AND B.tick = A.tick + N.delay
      AND A.ratio > B.ratio * N.weight;

-- remove the false positives from Event
```

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```
-- pass time series to a UDF, written in, e.g., C:

SELECT A.station, myfunction(A.ts)
FROM MSeed A, Event B
WHERE A.station = B.station
      AND A.ts.tick = B.tick
GROUP BY DISTINCT
      A.ts[tick - INTERVAL '3' MINUTE : tick];
```

Conclusion

- **Appropriate array denotations**
- **Functional complete operation set**
- **Size limitations due to (blob) representations**
- Existing foreign files?
- Scale?

- An Array DBMS for sciences
  - Symbiosis of relational and array paradigms