CompSci 590.6

Understanding Data:

Theory and Applications

Lecture 20

Crowd Sourcing:
Max Operator

Instructor: Sudeepa Roy

Email: *sudeepa@cs.duke.edu*

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Today's Reading

1.

So Who Won? Dynamic Max Discovery with the Crowd

Guo-Parameswaran- Garcia-Molina

SIGMOD 2012

(slides available online)

2.

Top-k and Clustering with Noisy Comparisons

Davidson-Khanna-Milo-Roy

ICDT 2013/TODS 2014

(following slides)

Humans intelligence in performing database tasks

Data collection
Data curation
Integration
Join
Search
Top K/Max
Clustering (Group-By)
.....

Example

Q. Group the photos of individual players

Q. Find their most recent photos

How a DBMS Thinks

Q. Group the photos of individual players

Group-By Queries

Use "Name" attribute

Q. Find their most recent photos

Max/Top-k Queries

Use "Date" attribute

> What if name/date is missing
>
> Image processing? Photo forensics?

Ask the “Crowd”!

How the Crowd Thinks

Q. Group the photos of individual players

How the Crowd Thinks

Q. Find their most recent photos

Crowd Sourcing

- Using human intelligence to do tasks which are harder to automate
- Many crowdsourcing platforms
- Many recent crowd-powered databases
  - Qurk, CrowdDB, Deco

Top-K and Group-By Queries with Crowd

This lecture: Max

Top-k/max

A possible query

```
SELECT    TOP 1    R.picture
FROM   SoccerPlayerPhotoTable   AS   R
GROUP BY   R.player
ORDER BY   R.date   DESC
```

Group By / Clustering

Fixed but <u>unknown</u> attributes: R.player, R.date

Framework at a Glance

Internal Computation (Top-K/ Group-By)

Crowd-sourced DBMS

Value(a) > Value(b)

Yes/No

Value(b) > Value(c)

Yes/No

Crowd

Comparison Error

Crowd's answer may be wrong with some prob.

Cost Model

Asking questions costs money

- Additive
- Count #comparisons

We still want the correct answer w.h.p.

Our Goal

Minimize the total #comparisons

while outputting the correct max

w.p. $\geq 1 - \delta$ (given constant $\delta > 0$)

Elements: Type and Value

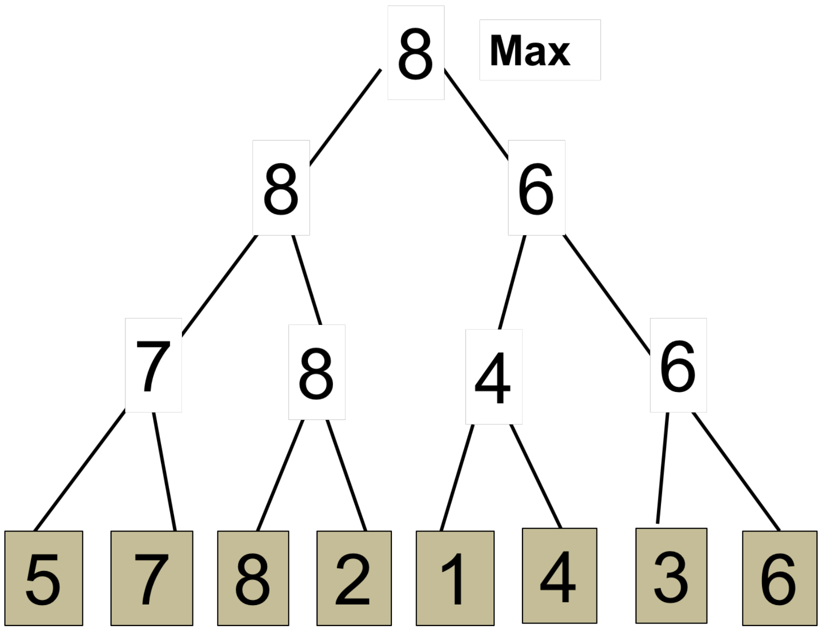
- #Elements = n
  - (n = 16)
  - Two attributes: Type and Value
- Type
  - e.g. Name = "Maradona"
  - used in Group-By
  - **#Types = J** (J clusters, J = 4)
- Value
  - e.g. Date when photo was taken
  - used in Top-K
- Unknown, but "ground-truth" exists for Types and Values

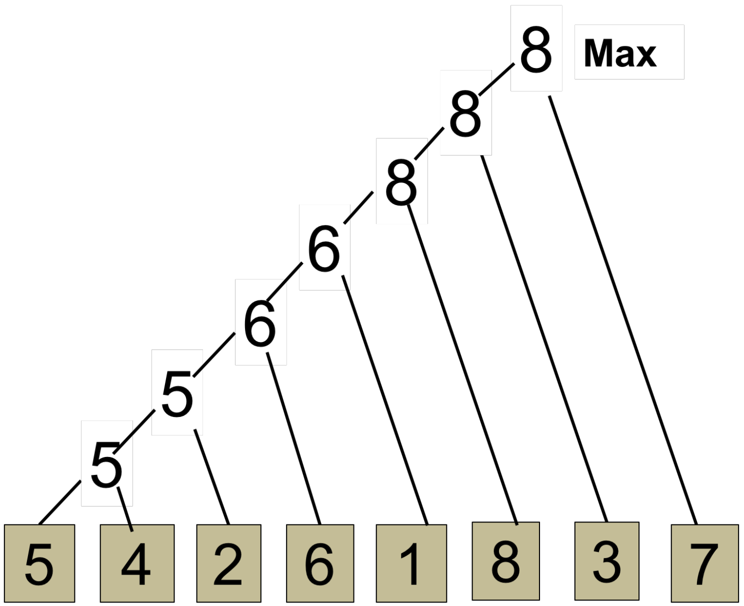
Type and Value Comparisons

- DB Queries vs.
  Comparisons (questions to the crowd)
- Type Comparisons:
  - Type(x) = Type(y)?
- Value Comparisons:
  - Value(x) > Value(y)?
  - Assumes same type
- Answer is Boolean
  - Cannot ask
    “What is Type(x)/Value(x)?”

First, assume no comparison error

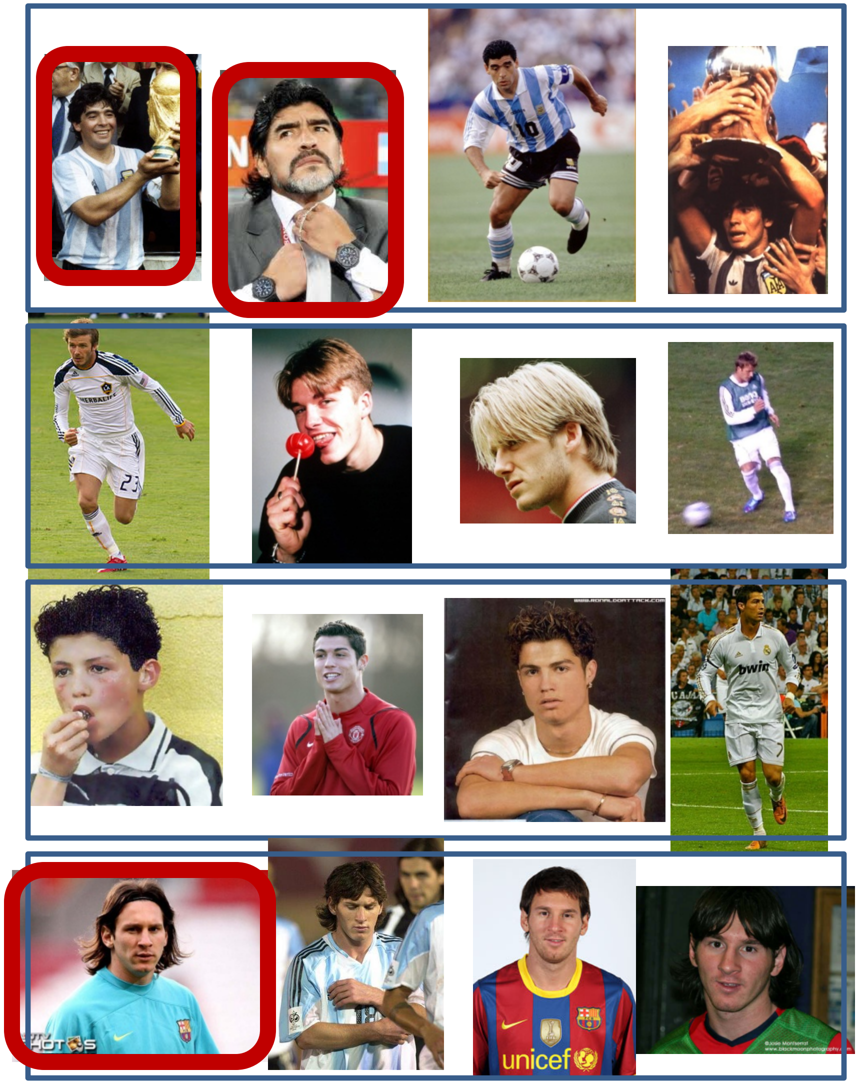
Comparison Tree





- How many comparisons for n elements (at least and at most)?
- What are the pros and cons for the above two trees?

Type and Value Comparisons

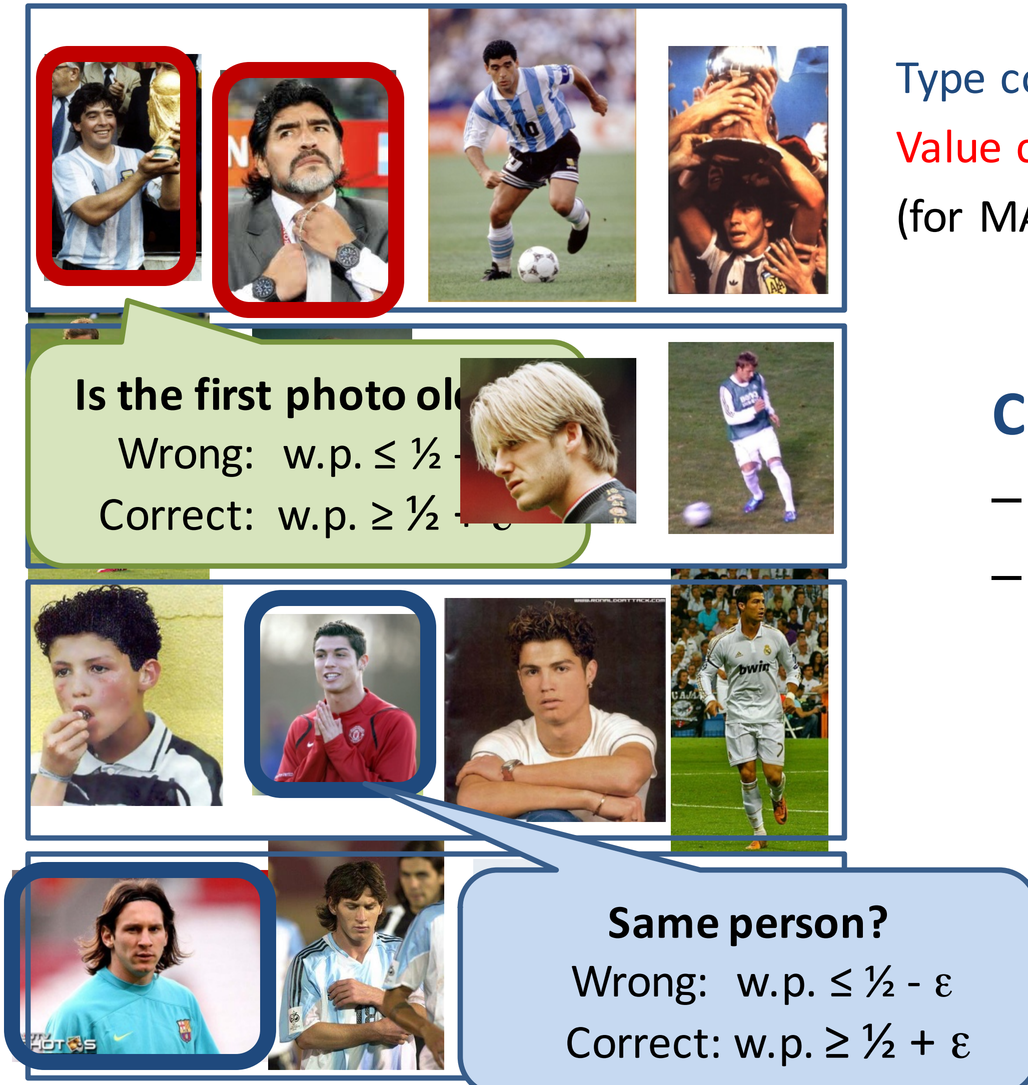


- DB Queries vs. Comparisons (questions to the crowd)
- Type Comparisons:
  - Type(x) = Type(y)?
- Value Comparisons:
  - Value(x) > Value(y)?
  - Assumes same type
- Answer is Boolean
  - Cannot ask "What is Type(x)/Value(x)?"

But, answers are not always correct

- Crowd makes mistakes
- Next, error model

Constant Error Model



Type comparisons: Type(x) = Type(y)?

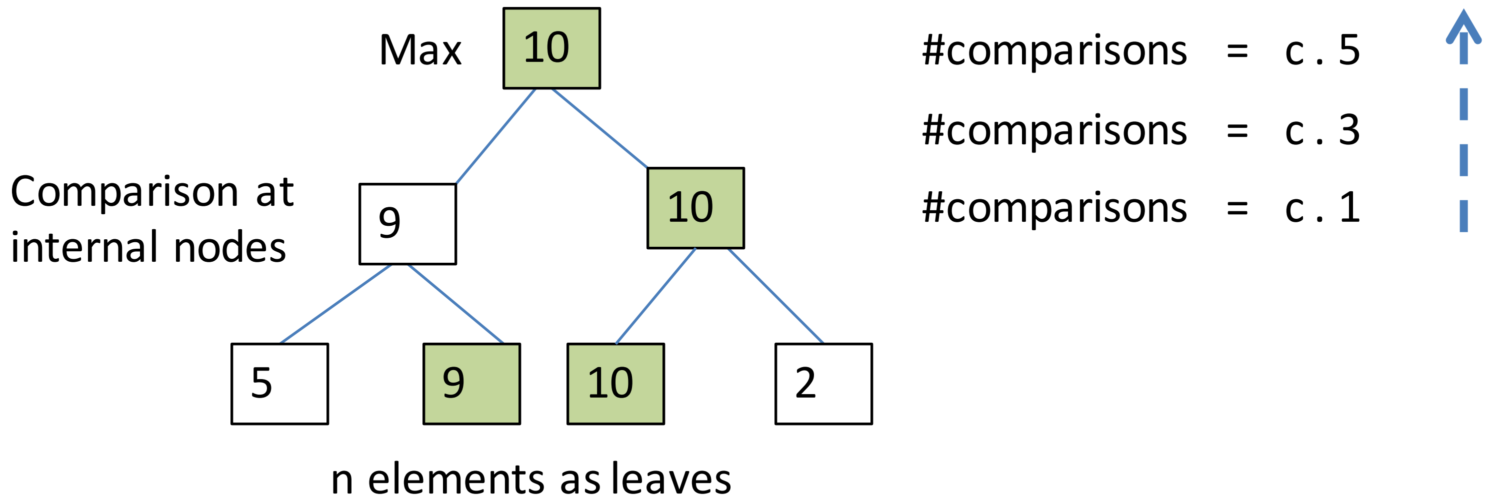
Value comparisons: Value(x) > Value(y)?

(for MAX – value comparisons only)

Constant error model:

- Standard model
- Probability of wrong answer $\le \frac{1}{2} - \varepsilon, \quad \varepsilon > 0$

Algorithm for Constant Error Model



- Exact comparisons: Binary tree structure is not necessary
- Noisy comparisons: Repeat comparison + majority vote
- Constant error model: θ(n) algorithm (Feige et. al. ’94)
- Our goal: Total no. of comparisons = n + o(n)

cannot repeat even twice in most of the internal nodes

Analysis of algorithm for constant error model on board

Variable Error Model

Is the first photo older? - Harder

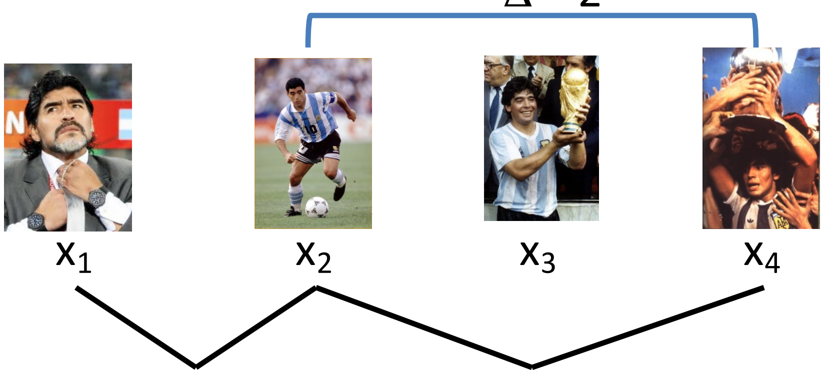
Is the first photo older? – Easier

For value comparisons only : Value(x) > Value(y)?

- Error probability < $1/f(\Delta)$, f = a strictly growing function

  Δ = Distance of x, y in sorted order

$\Delta = 2$



$\leq 1/e$ $\leq 1/e^2$ e.g. Error probability when $f(\Delta) = e^{\Delta}$

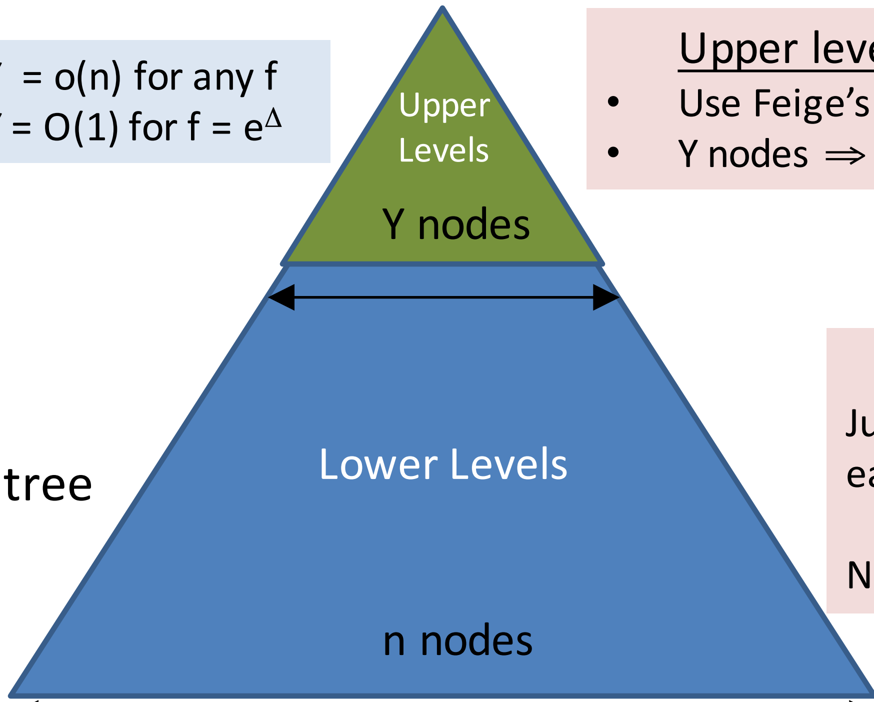
For "any" strictly monotone function f, n + o(n) comparisons suffice to find max under variable error model

- n + O(1) for $f(\Delta) = e^{\Delta}$

Main Steps for Max

Goal: n + o(n)

Y = o(n) for any f
Y = O(1) for f = e^{Δ}



Upper levels

- Use Feige's algorithm
- Y nodes $\Rightarrow \Theta(Y)$ cost

Binary tournament tree

Lower levels

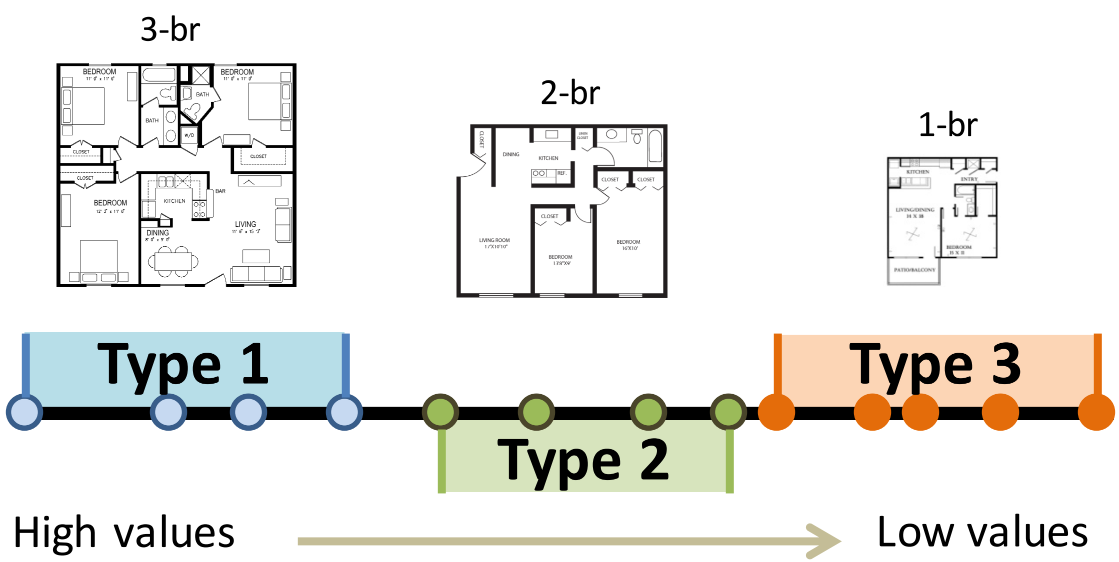
Just 1 comparison at each internal node

No majority vote

Key idea:
Start with a random permutation of elements at the leaves

- **Max does not lose in the lower levels w.h.p.**
- Intuition: Max does not meet 2nd Max in the lower levels w.h.p.
- Total no. of comparisons = $n + \Theta(Y) = n + o(n)$

Clustering with Correlated Types and Values



Apts. in a building

Type = #bedrooms

Value = rent

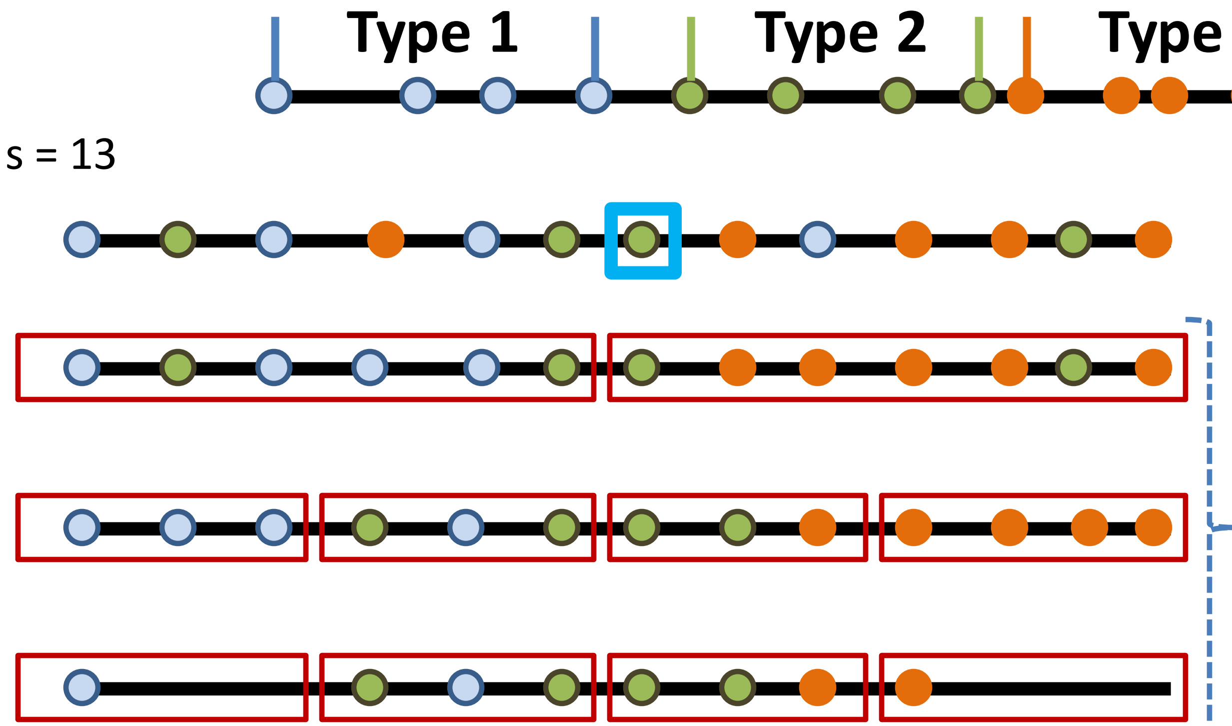
Full correlation:

- Elements of same type form <u>contiguous blocks</u> in the sorted order on values

O(n log J) value and type comparisons suffice to find the clusters

For no correlation and no error: lower bound: Ω(nJ), upper bound O(nJ)

Algorithm



J = 3

- Find median and partition

- If ≥ 2 types in a block, **Repeat**

- Same type in a block, keep only one element

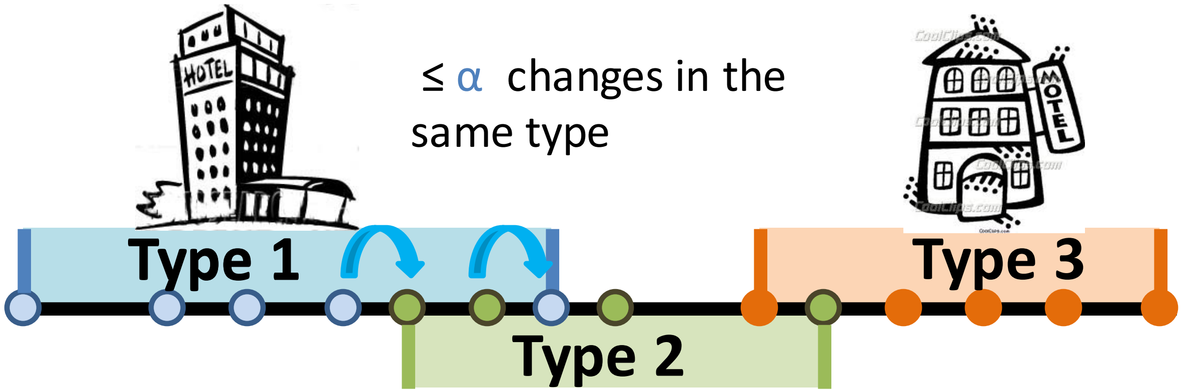
- **Until** #elements ≤ s/2

Repeat Until each block has one type

- Linear cost in total in each inner iteration
- #Inner iterations = O(log J)
- Cost: $C(n) \le C(n/2) + O(n \log J)$
- **$C(n) = O(n \log J)$**

4J blocks $\Rightarrow$ each block has ≤ s/4J elements, s/4J >= 1
$\Rightarrow$ at most J blocks contain ≥ 2 types (active)
#remaining elements $\Rightarrow \le s/4 + s/4 \le s/2$
O(log J) iterations

Extension to Partial Correlation



Hotels in a city

Type = Star-rating

Value = Avg. price

Partial correlation:

— Elements of same type form <u>almost contiguous blocks</u>

O(n log (α J) + αJ) value and type comparisons suffice

- Next paper:

- “So who won…”
  – using slides available online

- Constant error model & pair-wise comparisons
  – like before