SM (SMX)

32 THREADS = 1 WARP

N WARPS = 1 BLOCK

& 32

N = N + K

READ N

ADD K

WRITE N

RACE

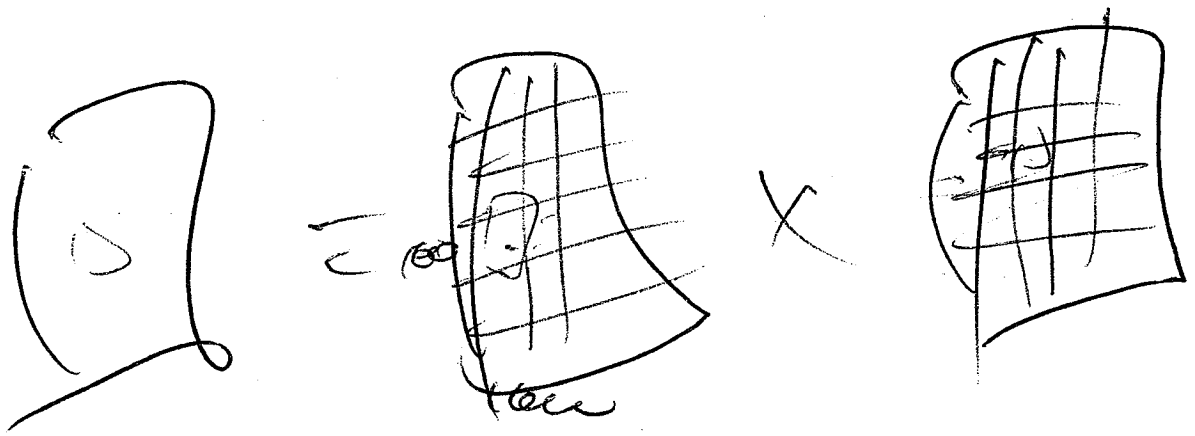
INTERLEAVING

0 1 2 3

t_0:0 T_1:0 T_2:0 T_3:0 T_0:1

S_0 S_1 S_2 S_3

T_0 T_1 T_2 T_3



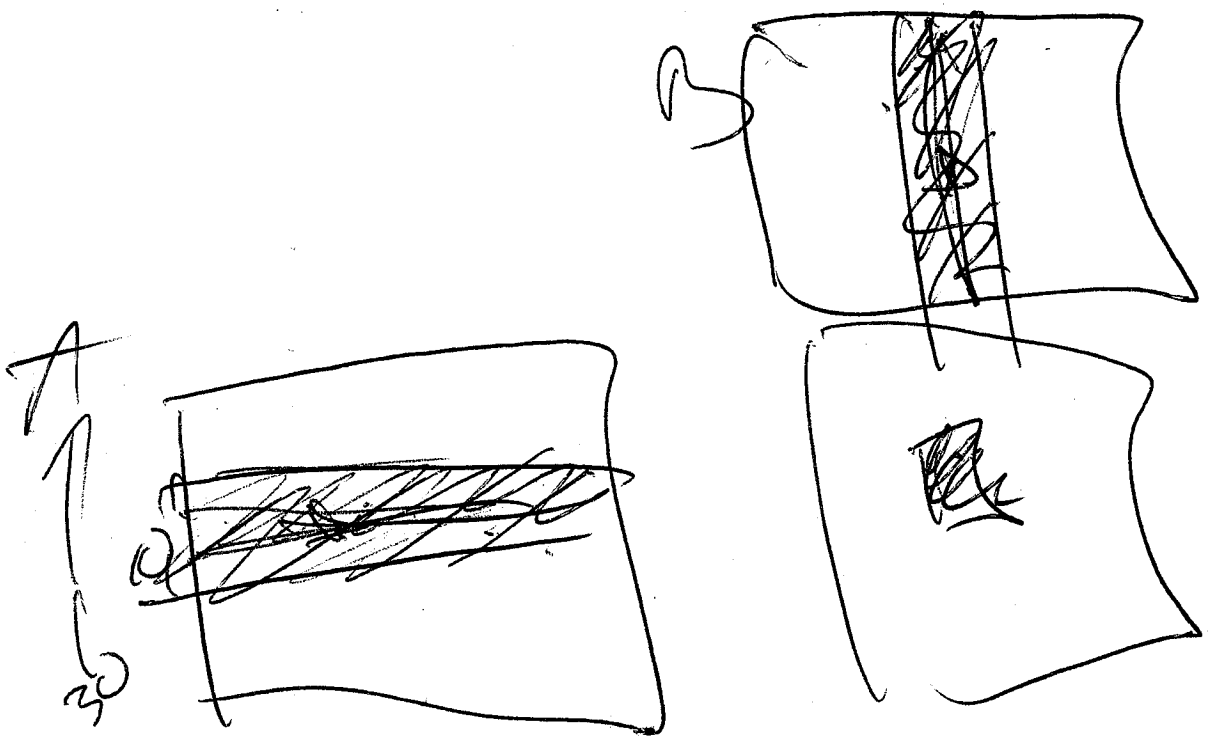
ADD 400M PAIRS = 30msec

$$\frac{3\times10^{2}}{4\times10^{8}} = \frac{3}{4}\times10^{-10} = .07\ \text{NSEC}$$

```
const int n = 1000;
const int n2 = n*n;
int a[n][n];
int *p = malloc(n2*sizeof(int));
if (p==0) exit(1);

int f2(int i, int j){
    return i*n+j; }

int *p = f2(0,0) =
```



$$AD_{ij} = \sum_k A_{ik} B_{kj}$$

TILE_WIDTH = 10

WIDTH = 30

3/2/15

THREAD — 32 — WARP

|

≤ 1024 — BLOCK

|

SM: 48KB SHARE

RESOURCE LIMITS

REGS

SHARED MEM.

TRANSFORM

VECTORS

$$w_i = v_i + v_i$$

COPY

$$w_i = v_i$$

COPY IF

SUPPOSE YOU WANT TO COPY EVEN # FROM

3 1 4 1 5 9 2 6 5

→ 3 1 4 1 5 9 2 6 5

→ 0 0 1 0 0 0 1 1 0

→ 4 2 6

IN 0 1 2 3 4 5 6 7

STENCIL 0 1 0 0 1 0 0 1

OUT 1 2 5 7

3/12/15 -2

IN 3 1 4 1 5 9 2 6 5

TAKE (3,3) (1,1) (4,4) (1,1) (5,5) (9,9) (2,2) (6,6) (5,5)

REDUCE (1,3) (1,4) (5,9) (2,6)

(1,4) (2,9)

(1,9)

MIN MAX

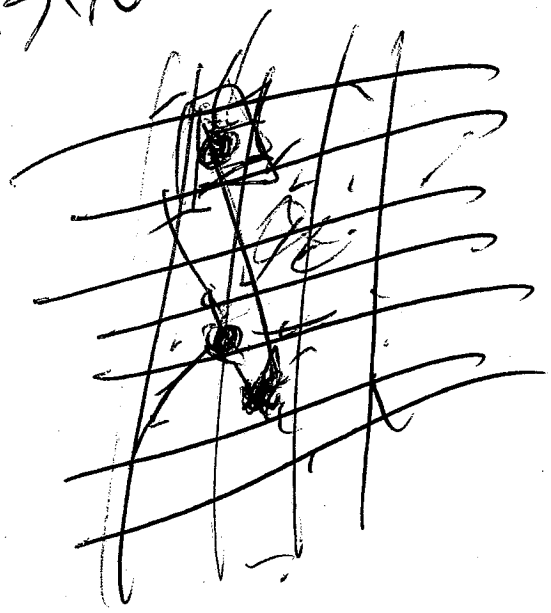
auto f=[]{};

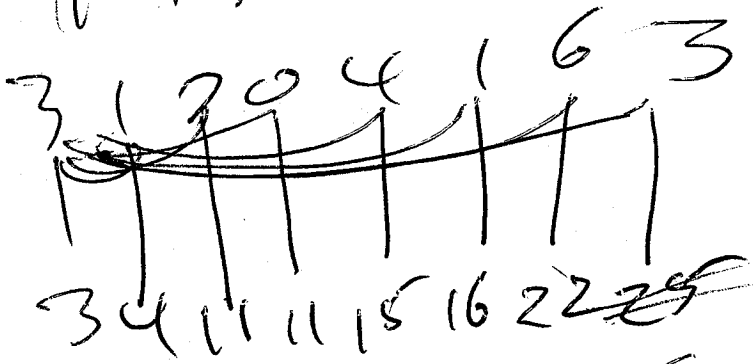
3/5/15

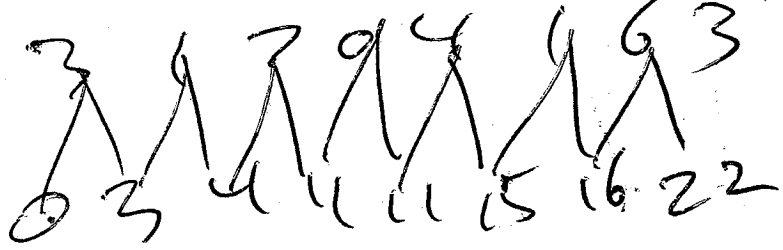
TREE

COMPACT

BIN APP: COSMOLOGY







RADIX SORT

TO SORT 103, 123, 231, 001, 323,
232, 112, 201, 303, 220

BASE 4

FORM 4 OUTPUT Q, DIVIDE ON LAST DIGIT

0 220
1 231, 001, 201
2 232, 112
3 103, 123, 323, 303

REPEAT ON 2nd LAST DIGIT

0 001, 201, 103, 303
1 112
2 220, 123, 323
3 231, 232

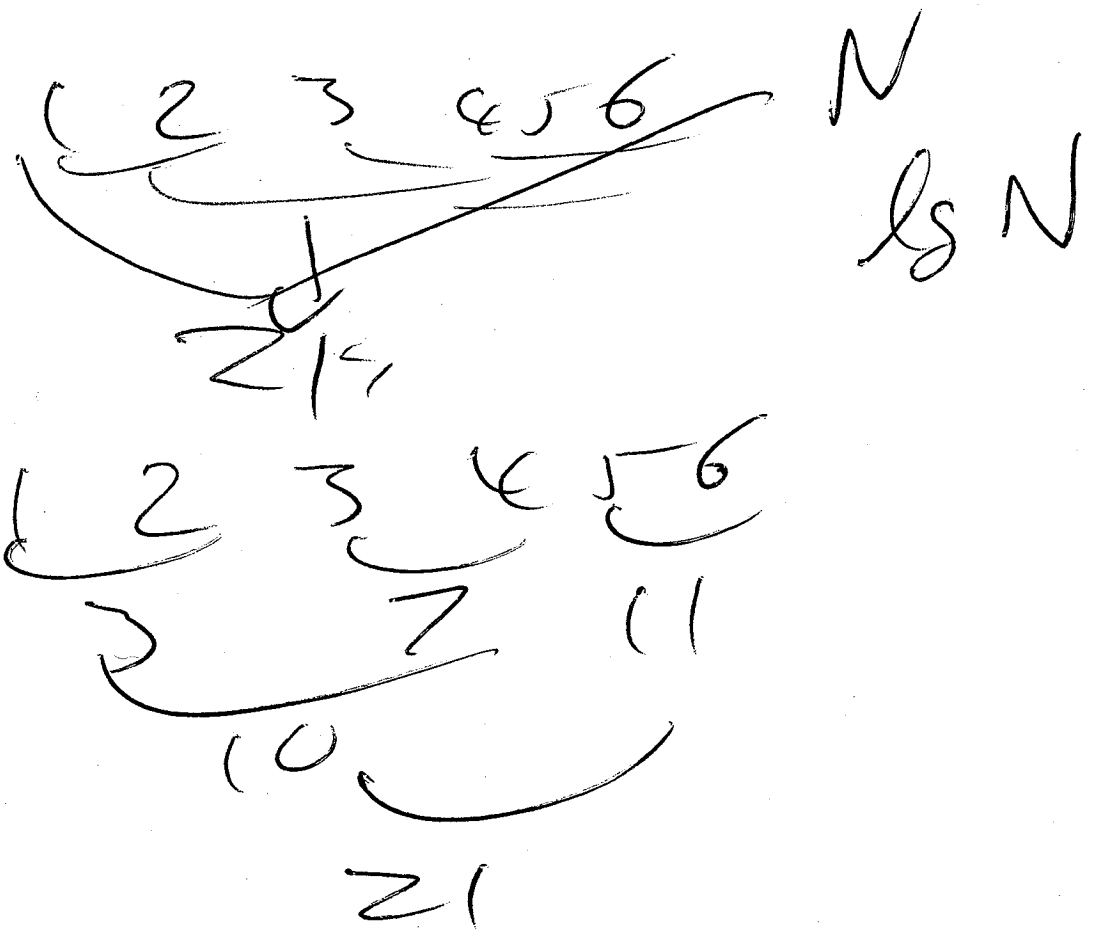
REPEAT ON 1ST D

0 001
1 103, 112, 123,
2 201, 220, 231, 232
3 303, 323

ARRAY IS NOW SORTED

COST
3N
17 MN

REDUCE



SPLIT

3 1 4 1 5 9 2 6 5

3 1 4 1 5 | 2 5 | 9 6

QUICK SORT

HISTOGRAM

IN: 3 1 4 1 5 9 2 6 5

OUT: 0 1 2 3 4 5 6 7 8 9

0 2 1 1 1 2 1 0 0 1

---

1 2 3 0 1 6 3 7 1

0 1 3 6 10 15 21 28

SEGM SCAN: BARRIER

1 2 3 4 5 6 7 8 9

0 1 3 6 10 15 0 6 13 21 30

1 2 3 4 5 6 7 8 9

0 1 3 6 0 4 0 5 11 18 26 35

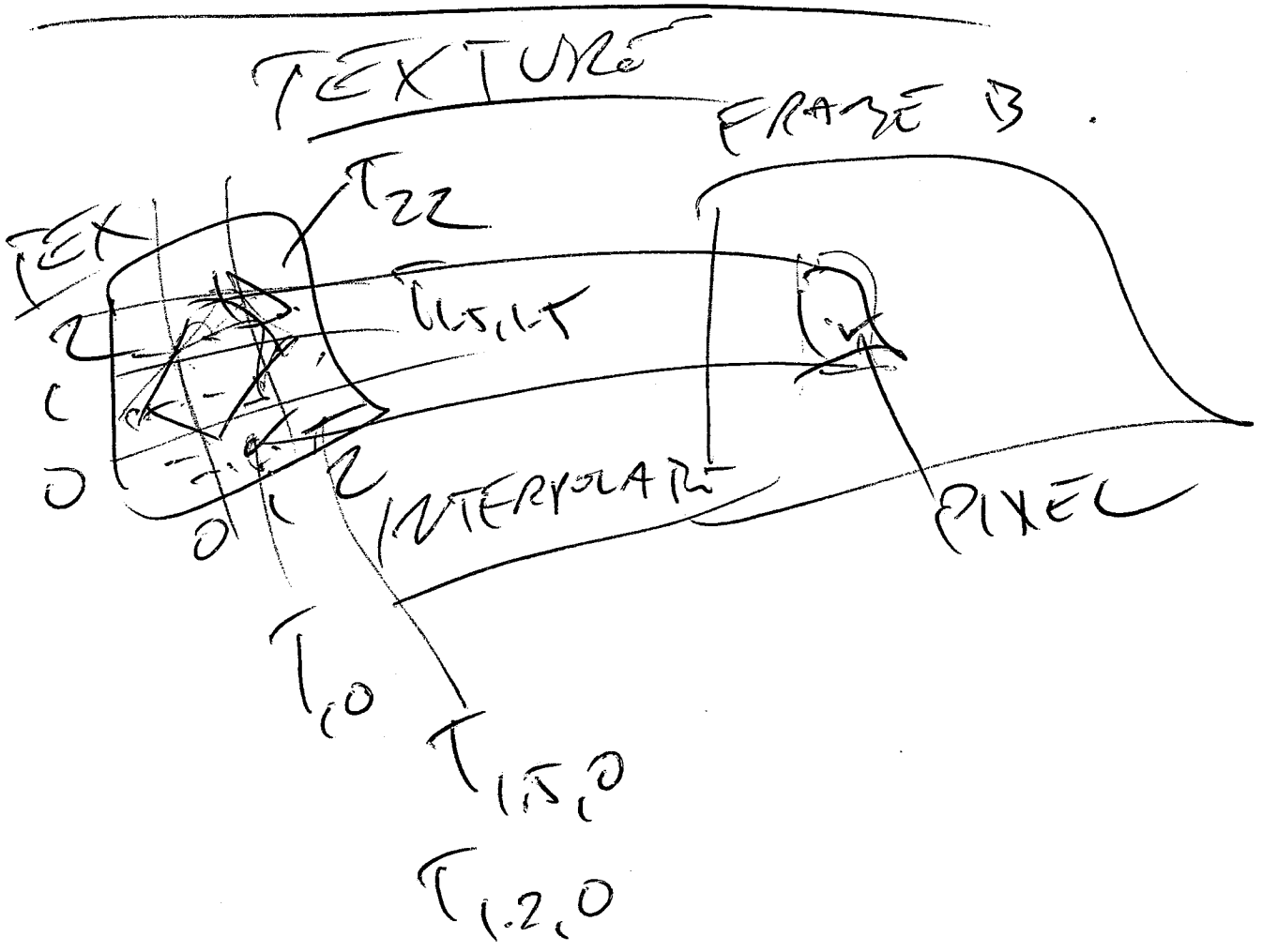
USE SORT TO HISTO

2 1 4 1 5 9 2 6 5

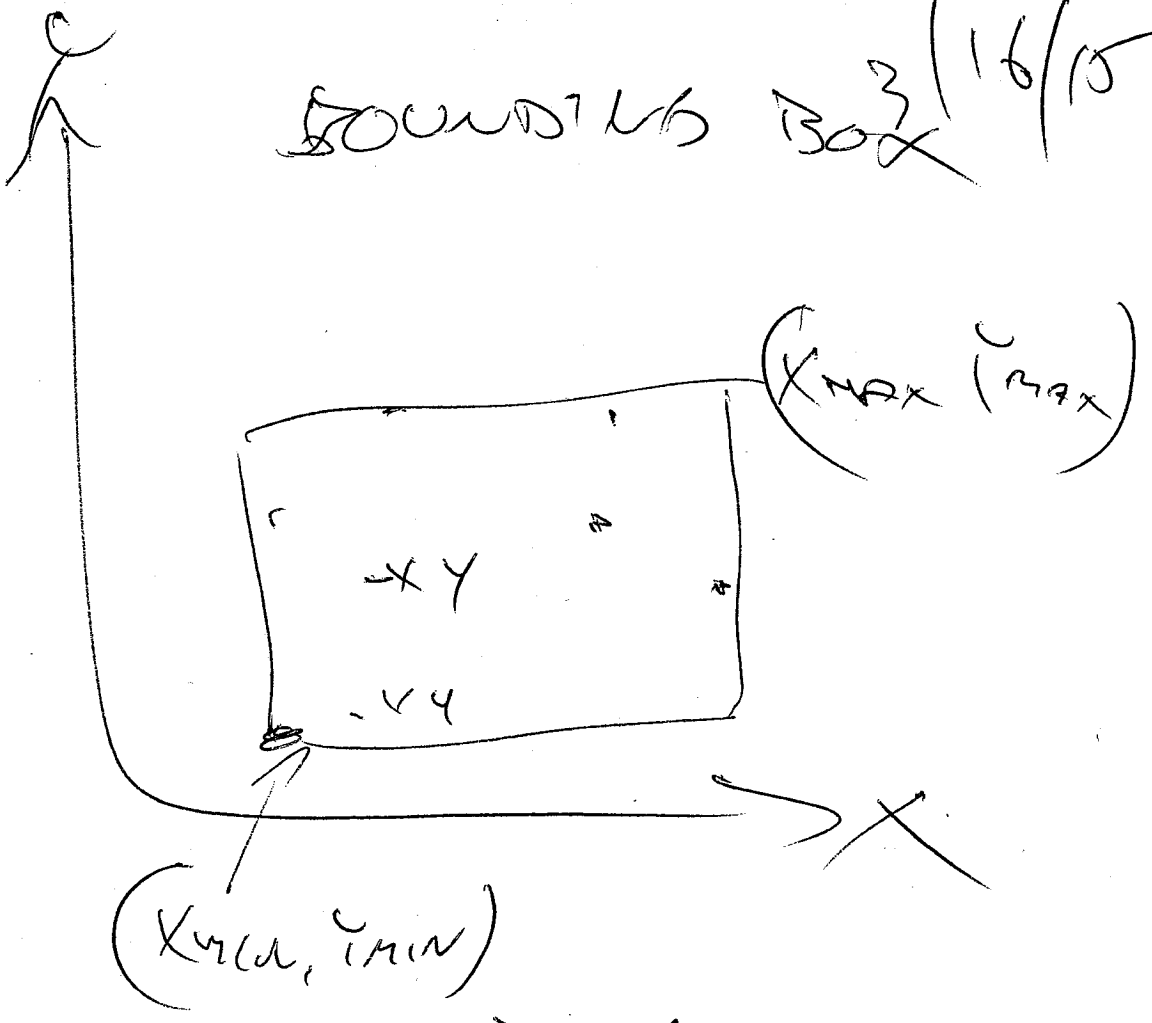
1 SORT

1 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 9

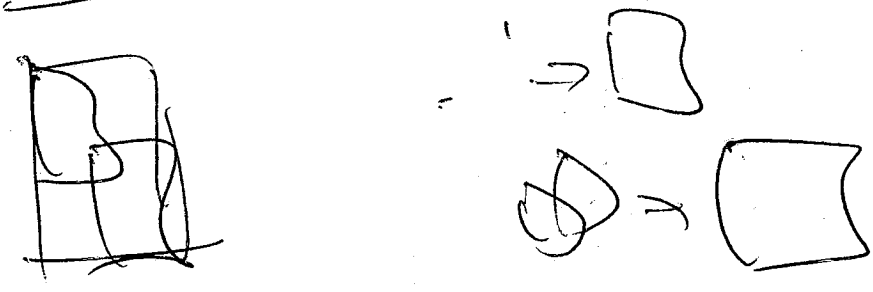
2 1 1 1 2 1 0 0 1



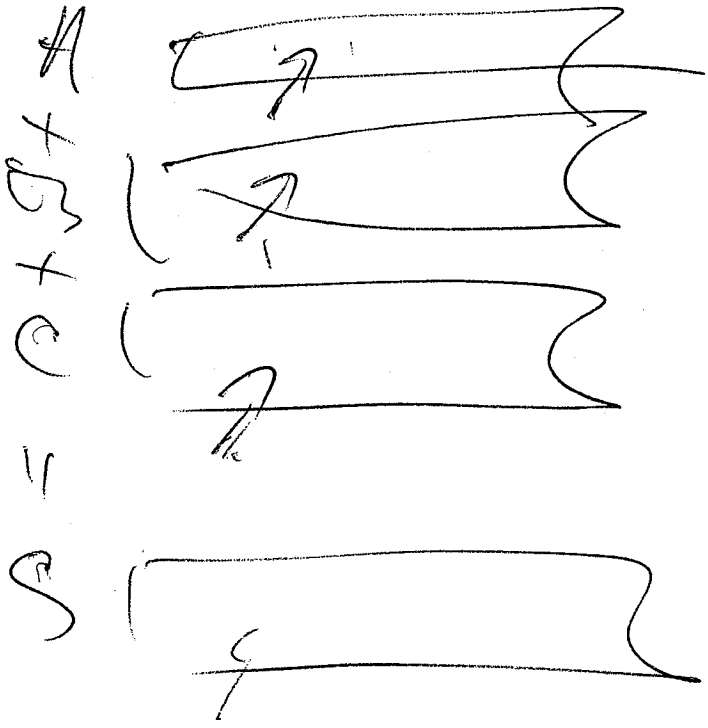
BOUNDING BOX (16/15



REDUCTION



3/16/15 2

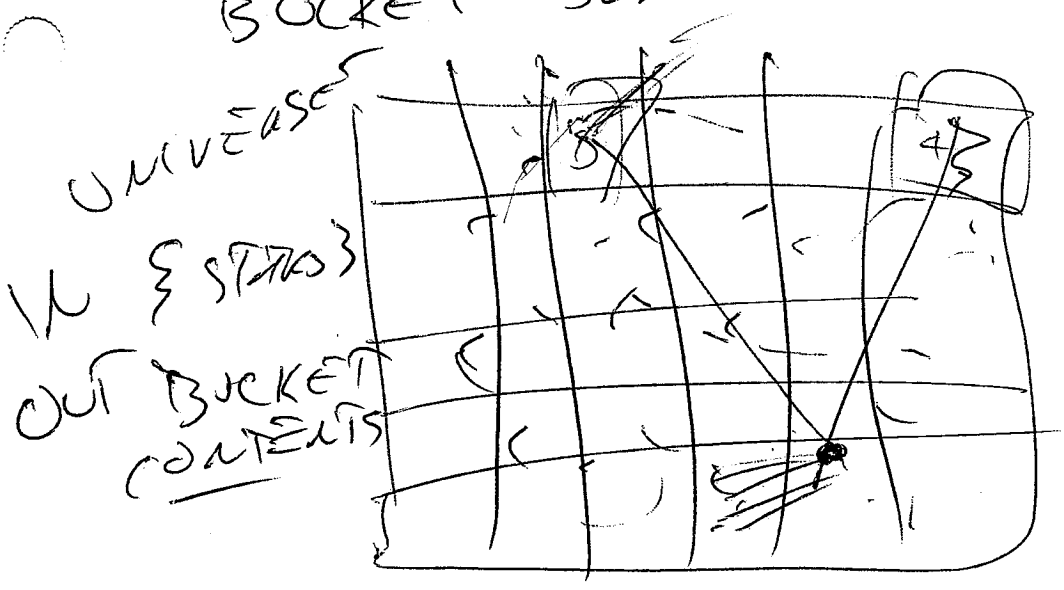


OLD STRUCT {INT A, B, C;} S;
VECTOR S(100).
ARRAY OF STRUCT SOA
SLOW
STRUCT OF ARRAY SOA FAST
ZIP ITERATOR

TUPLE; PAIR, TRIPLE --- GET<
get<0> (t)
1
2
MEMORY COALESCE
$X_0 X_1 X_2 X_3 \cdots X_{31}$
$Y_0 Y_1 Y_2 Y_3 \cdots$

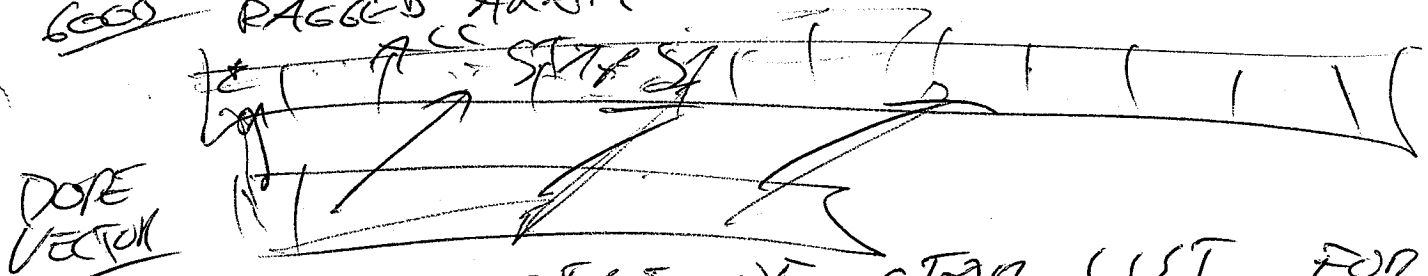
EXPAND APP.

BUCKET SORT



~~BAD~~ LINKED LIST VECTORS

~~GOOD~~ RAGGED ARRAY



POINTS TO START OF STAR LIST FOR EACH BUCKET.

3/19/15 - 1

INNER PRODUCT

$\sum a_i b_i$

a: 2 3

b: 4 5 6

* 4 10 18

\+ 32

CAN GENERALIZE *, +

/ ≠

q 1 1 2 2 2 3 4 4

c 1 2 2 2 3 4 4 — 4 UNIQUE KEYS

f 0 1 0 0 1 1 0

+ → 3

REDUCE (2 3 4) → 15

REDUCE_BY_KEY REDUCES BLOCKS.

KEY: 1 1 2 2 3

TO REDUCE: 1 2 3 4 5

3 7 5

KEY: 1 2 3 4 5 6 — 1 1 1 1 1 1

V. 3 1 4 1 5 9 — 3 1 4 1 5 9

3 1 4 1 5 9 — 23

SORTED VEC 1 1 2 2 2 3 4 4
-> LETS
TO REID 1 1 1 1 1 1 1 1
MULTIPLICITIES 2 3 1 2

SET OPS

A: 3 1 4 5 9
B: 2 7 1 8 3

$5 \leq |A \cup B| \leq 10$

EXPAND

V 0 10 20 30 40
C 2 1 0 3 1

OUT: 20 10 30 30 30 40 40

REDUCE C TO GET OUT SIZE: 7

EX SCAN C: 0 2 3 3 6

SCATTER V: 3 1 4 1 5 9
M: 2 1 7 8 3 0
S:

O: 7 1 3 5 0 0 = #1

EXPAND

V 0 10 20 30 40

C 2 1 0 3 1

OUT 0 0 10 30 30 30 40

EX SCAN 0 2 3 3 6

SCATTER 0 1 2 3 4

WITH 0 2 3 3 6

0 0 10 30 30 40

0 0 1 3 3 3 4

GATHER 0 0 10 30 30 30 40

600 →

314	134
159	159
265	256
395	359

PAIRS (ROW#, ELT CONTENTS)

(1,3),(1,1),(1,4), (2,1),(2,5),(2,9),
(3,2),(3,6),(3,5),(4,3),(4,9),(4,5)

SORT ON 2nd

(1,1),(2,1),(3,2),(1,3),(4,3),(1,4),(2,5),
(3,5),(4,5),(3,6),(2,9),(4,9)

STABLE SORT ON 1ST

(1,1),(1,3),(1,4),(2,1),(2,5),(2,9),(3,2),
(3,5),(3,6),(4,3),(4,5),(4,9)

1: 1,3,4 3: 2,5,6

2: 1,5,9 4: 3,5,9

HOW RADIX SORT WORKS

12, 23, 13, 31, 22, 33 | |

STABLE SORT ON UNITS

31, 11, 12, 22, 23, 13, 33

STABLE SORT ON TENS

11, 12, 13, 22, 23, 31, 33

REDUCE

IN 1 2 3 4 5

OUT: 15

REDUCE BY KEY

IN 1 2 3 4 5

KEYS 1 1 2 3 3

OUT 3, 3, 9

IN 1 1 1 1 1 1

KEYS: A A B C C C

OUT 2, 1, 3, 1

DENSE HISTO

DATA 3 1 4 1 5 9 2 6 5 3 5 9

SORT 1 1 2 3 3 4 5 5 5 6 9 9

~~NEED 10 BINS~~

0 1 2 3 4 5 6 7 8 9 10

0 2 3 5 6 9 10 10 10 12

ADJ DIFF 2 1 2 1 3 1 0 0 2 ← HISTO