

Solving the Knapsack Problem with Recursive Queries and PostgreSQL

Knapsack Problem





10 ❤️ - 3 ⚖️

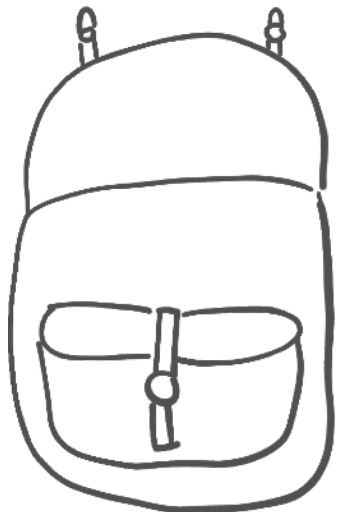
20 ⚖️



15 ❤️ - 5 ⚖️



5 ❤️ - 15 ⚖️

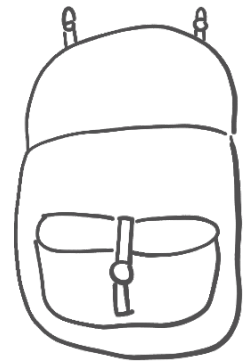


8 ❤️ - 10 ⚖️



7 ❤️ - 10 ⚖️

20 



+



=

20  - 20 

5  - 15 

15  - 5 



+



+



=

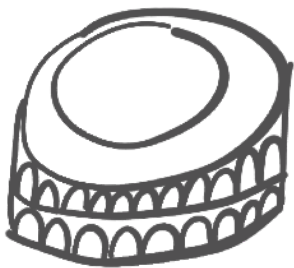
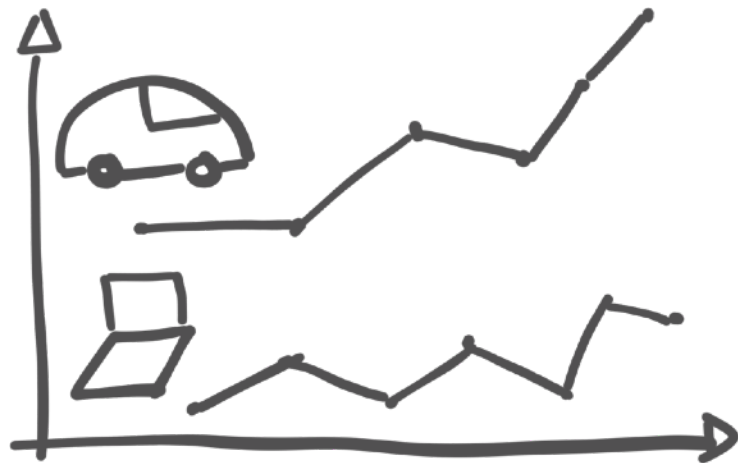
32  - 18 

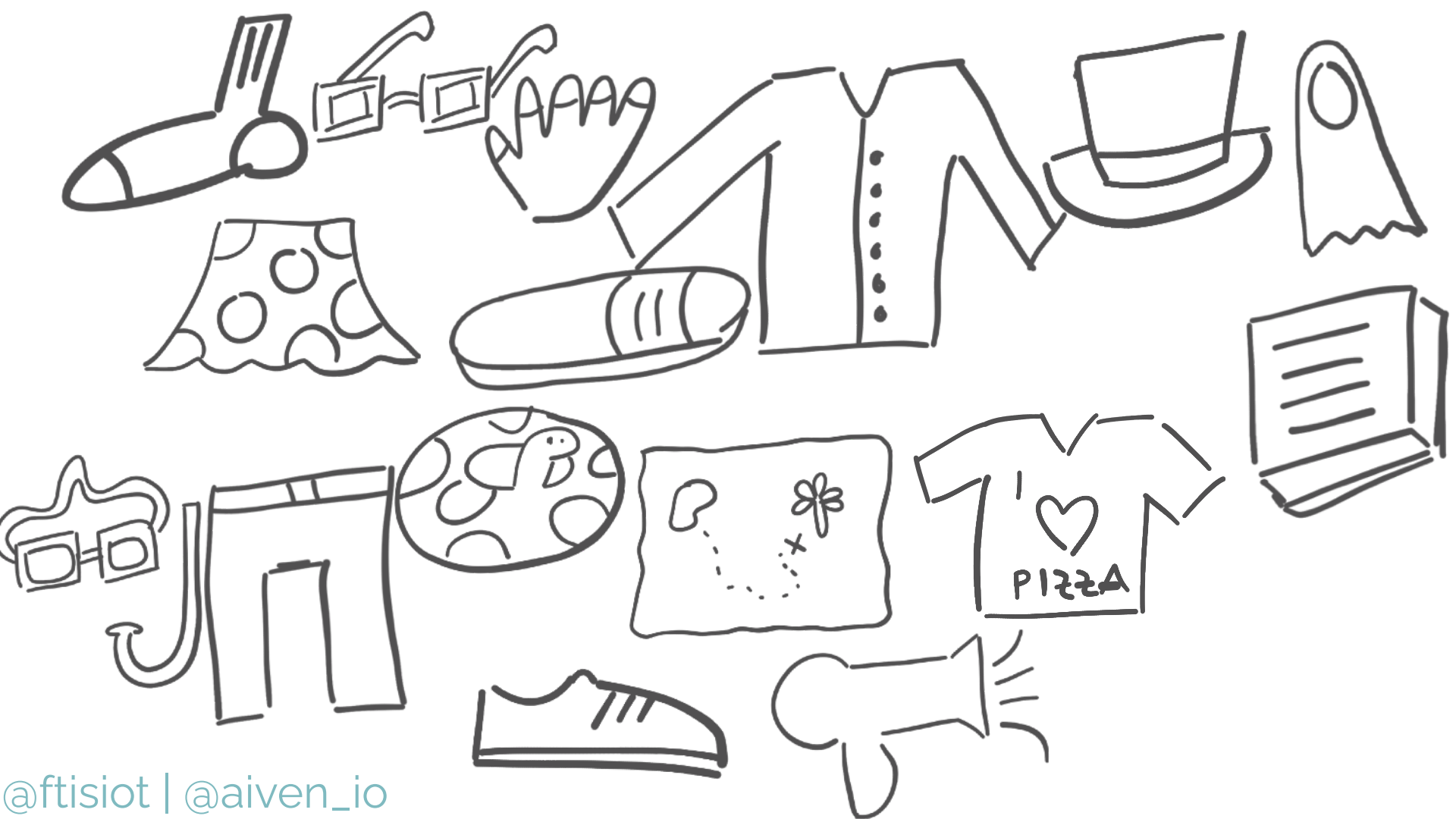
10  - 3 

7  - 10 

15  - 5 









10 ❤️ - 5 🍀

3 ⚖️ - 1 🧊

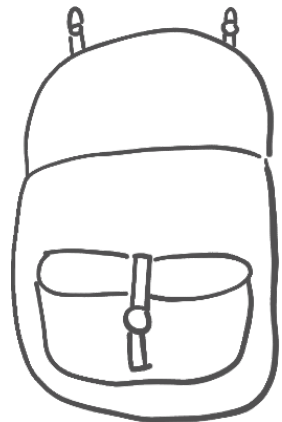


5 ❤️ - 5 🍀

15 ⚖️ - 10 🧊

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20 ⚖️ - 30 🧊



8 ❤️ - 3 🍀

10 ⚖️ - 9 🧊



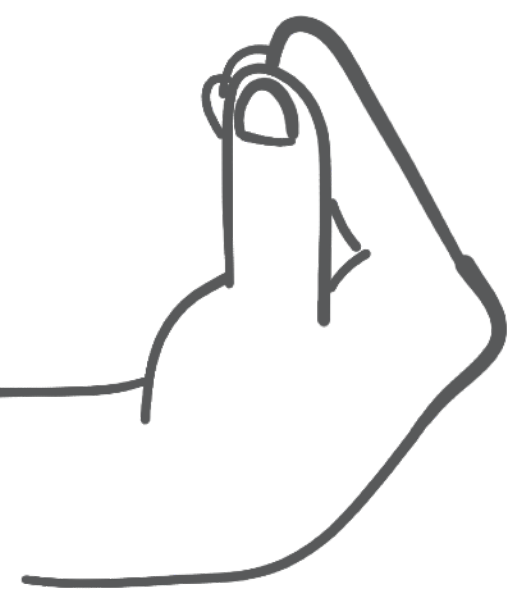
15 ❤️ - 5 🍀

5 ⚖️ - 10 🧊



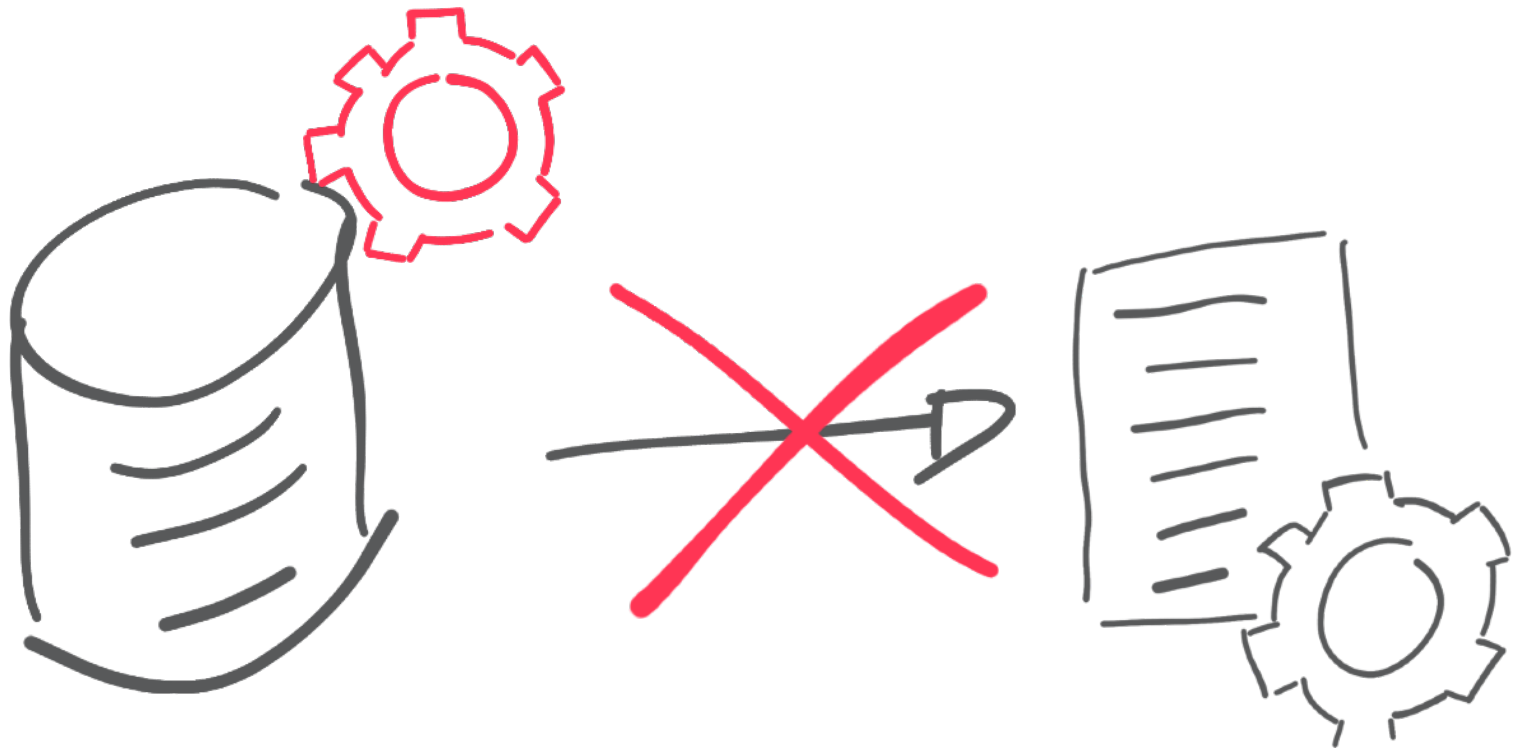
7 ❤️ - 15 🍀

10 ⚖️ - 5 🧊

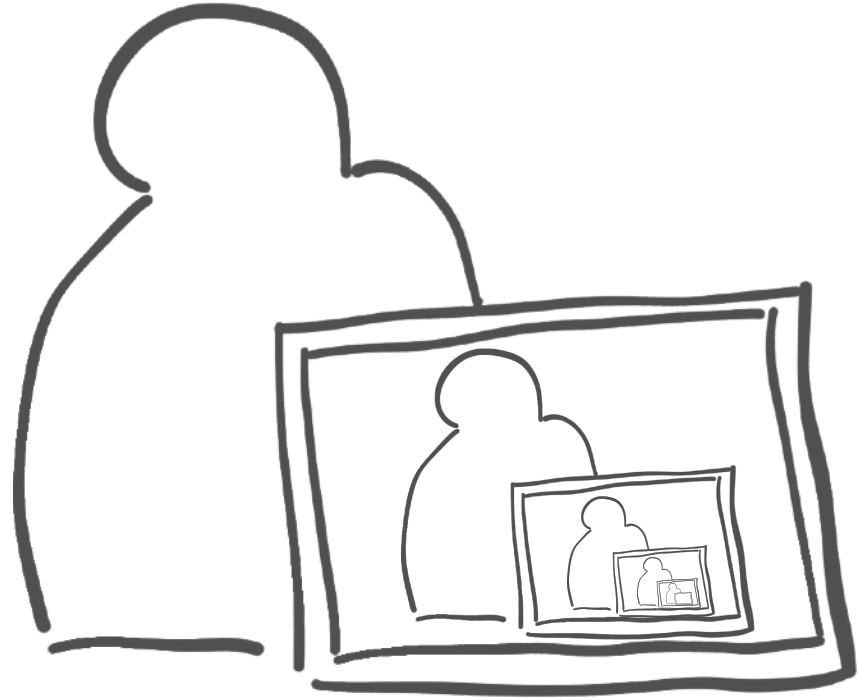


Why
in

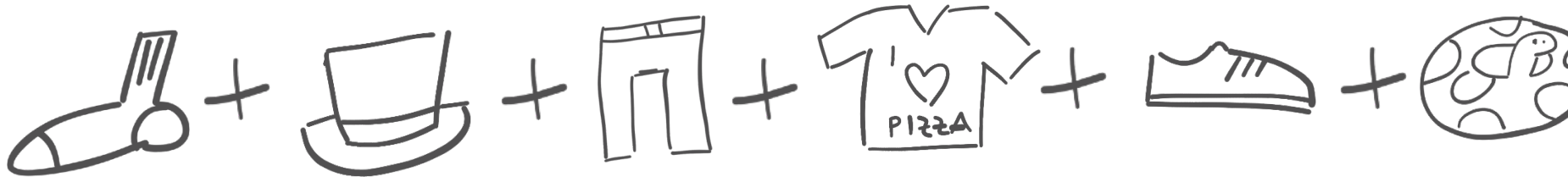
PostgreSQL?








Recursive Queries



Variable number of iterations



```
create table inventory (  
  item_id integer,  
  item_name varchar,  
  value int,  
  weight int);  
  
insert into inventory values  
(1, 'Socks'      , 10, 3),  
(2, 'Hat'        , 15, 5),  
(3, 'Trousers'   , 5, 15),  
(4, 'Shoes'      , 8, 10),  
(5, 'T-Shirt'    , 7, 10);
```

Item	Value	Weight
 Socks	10	3
 Hat	15	5
 Trousers	5	15
 Shoes	8	10
 T-Shirt	7	10

Recursive Queries

-

How To

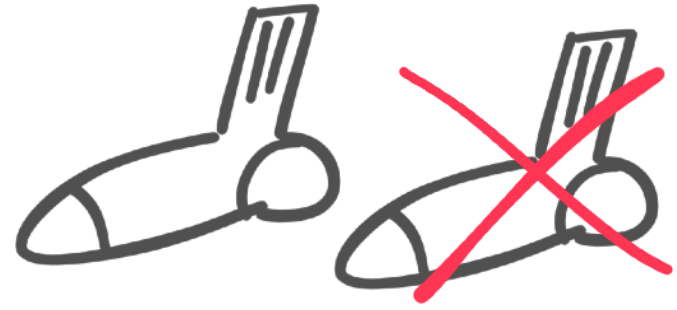


```
WITH RECURSIVE items(picked_items, nr_items) as (  
  SELECT ARRAY[item_name] as picked_items,  
         1 nr_items  
  from inventory where item_name = 'Socks'  
  UNION ALL  
    select picked_items || item_name,  
         nr_items + 1  
  from inventory  
  cross join items  
  where nr_items+1 <= 3  
)  
select * from items where nr_items=3;
```

name	nr_items
{Socks, Socks, Socks}	3
{Socks, Socks, Hat}	3
{Socks, Socks, Trousers}	3
{Socks, Socks, Shoes}	3
{Socks, Socks, T-Shirt}	3
...	
{Socks, T-Shirt, Hat}	3
{Socks, T-Shirt, Trousers}	3
{Socks, T-Shirt, Shoes}	3
{Socks, T-Shirt, T-Shirt}	3

(25 rows)

Knapsack Constraints



```
WITH RECURSIVE items(item_id, picked_items, nr_items, total_weight, total_value) as (  
  SELECT  
    item_id,  
    ARRAY[item_name] as picked_items,  
    1 nr_items,  
    weight total_weight,  
    value total_value  
  from inventory  
  UNION ALL  
  select  
    inventory.item_id,  
    picked_items || item_name,  
    nr_items + 1,  
    weight + total_weight,  
    value + total_value  
  from inventory cross join items  
  where  
    picked_items::varchar[] @> ARRAY[item_name] = false  
    and weight + total_weight <= 20  
)  
select * from items order by total_value;
```

item_id	picked_items	nr_items	tot_weight	tot_value
3	{Trousers}	1	15	5
5	{T-Shirt}	1	10	7
4	{Shoes}	1	10	8
1	{Socks}	1	3	10
5	{Shoes,T-Shirt}	2	20	15
4	{T-Shirt,Shoes}	2	20	15
. . .				
2	{Socks,T-Shirt,Hat}	3	18	32
5	{Hat,Socks,T-Shirt}	3	18	32
1	{Hat,T-Shirt,Socks}	3	18	32
2	{T-Shirt,Socks,Hat}	3	18	32
1	{Hat,Shoes,Socks}	3	18	33
4	{Socks,Hat,Shoes}	3	18	33
2	{Socks,Shoes,Hat}	3	18	33
2	{Shoes,Socks,Hat}	3	18	33
4	{Hat,Socks,Shoes}	3	18	33
1	{Shoes,Hat,Socks}	3	18	33

(33 rows)

~~{Socks, Shoes, Hat}~~

~~{Socks, Hat, Shoes}~~

~~{Shoes, Socks, Hat}~~

~~{Shoes, Hat, Socks}~~

~~{Hat, Shoes, Socks}~~

{Hat, Socks, Shoes}

```
UNION ALL
```

```
select
```

```
    inventory.item_id,  
    picked_items || item_name,  
    nr_items + 1,  
    weight + total_weight,  
    value + total_value
```

```
from inventory cross join items
```

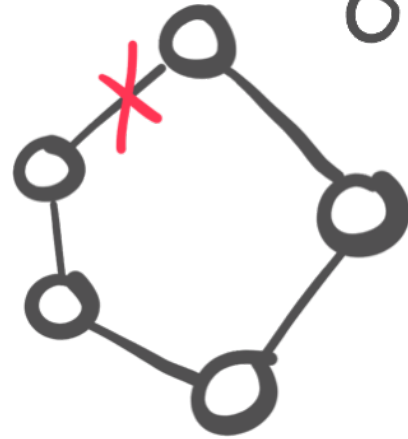
```
where
```

```
picked_items::varchar[] @> ARRAY[item_name] = false  
and weight + total_weight <= 20  
and inventory.item_id > items.item_id
```

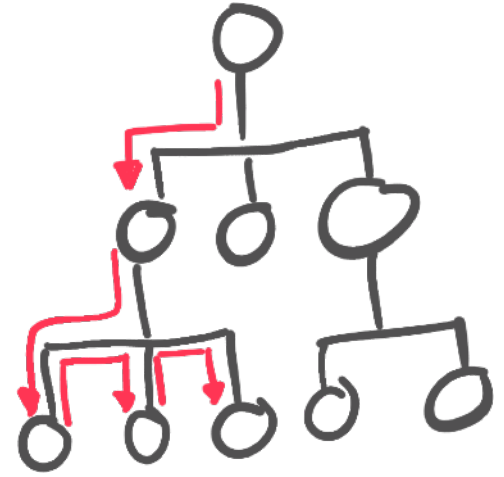
item_id	picked_items	nr_items	tot_weight	tot_value
3	{Trousers}	1	15	5
5	{T-Shirt}	1	10	7
4	{Shoes}	1	10	8
1	{Socks}	1	3	10
2	{Hat}	1	5	15
5	{Shoes,T-Shirt}	2	20	15
3	{Socks,Trousers}	2	18	15
5	{Socks,T-Shirt}	2	13	17
4	{Socks,Shoes}	2	13	18
3	{Hat,Trousers}	2	20	20
5	{Hat,T-Shirt}	2	15	22
4	{Hat,Shoes}	2	15	23
2	{Socks,Hat}	2	8	25
5	{Socks,Hat,T-Shirt}	3	18	32
4	{Socks,Hat,Shoes}	3	18	33

(15 rows)

New in Pg 14

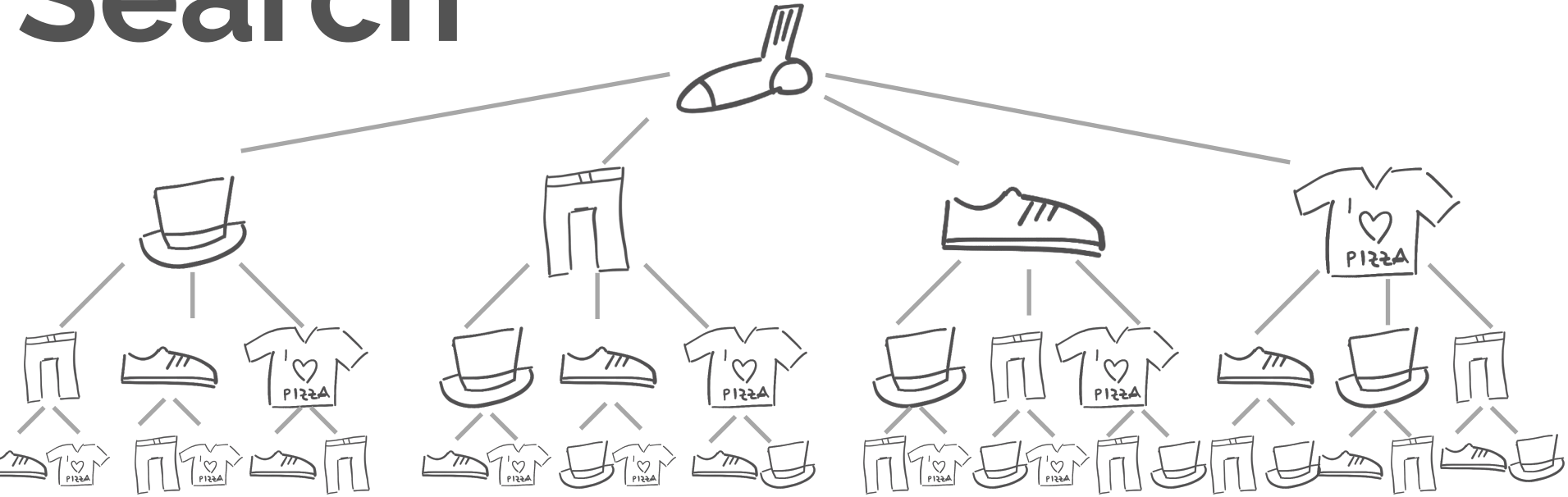


CYCLE

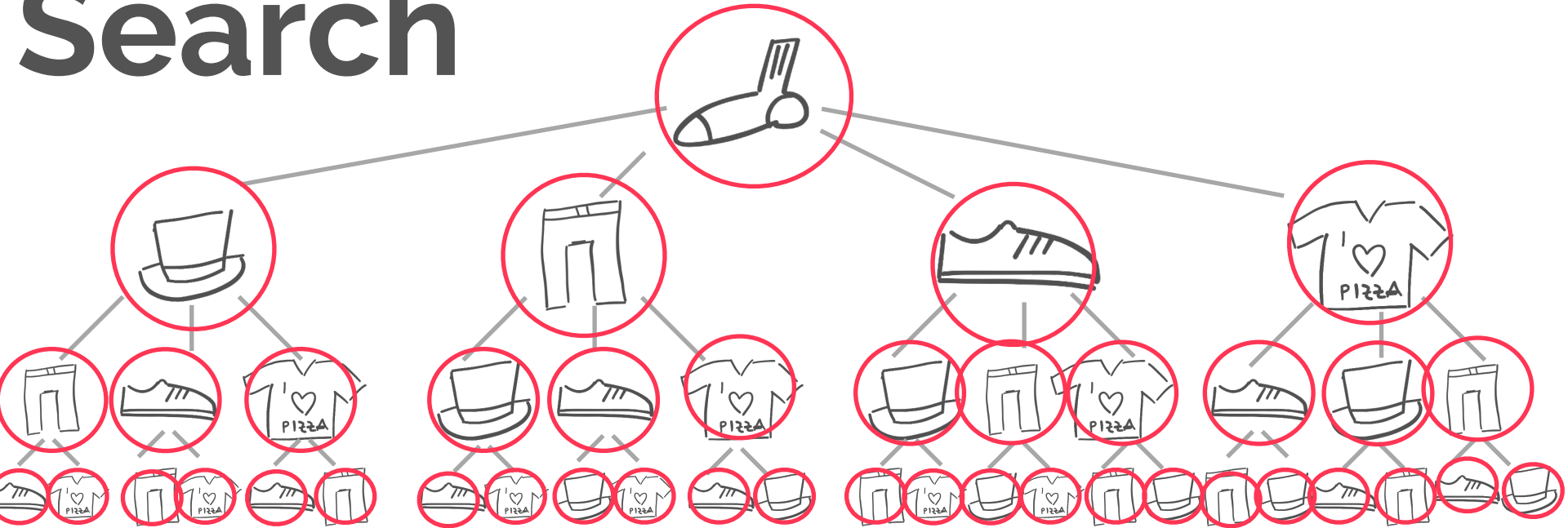


SEARCH

Search



Search



BREADTH

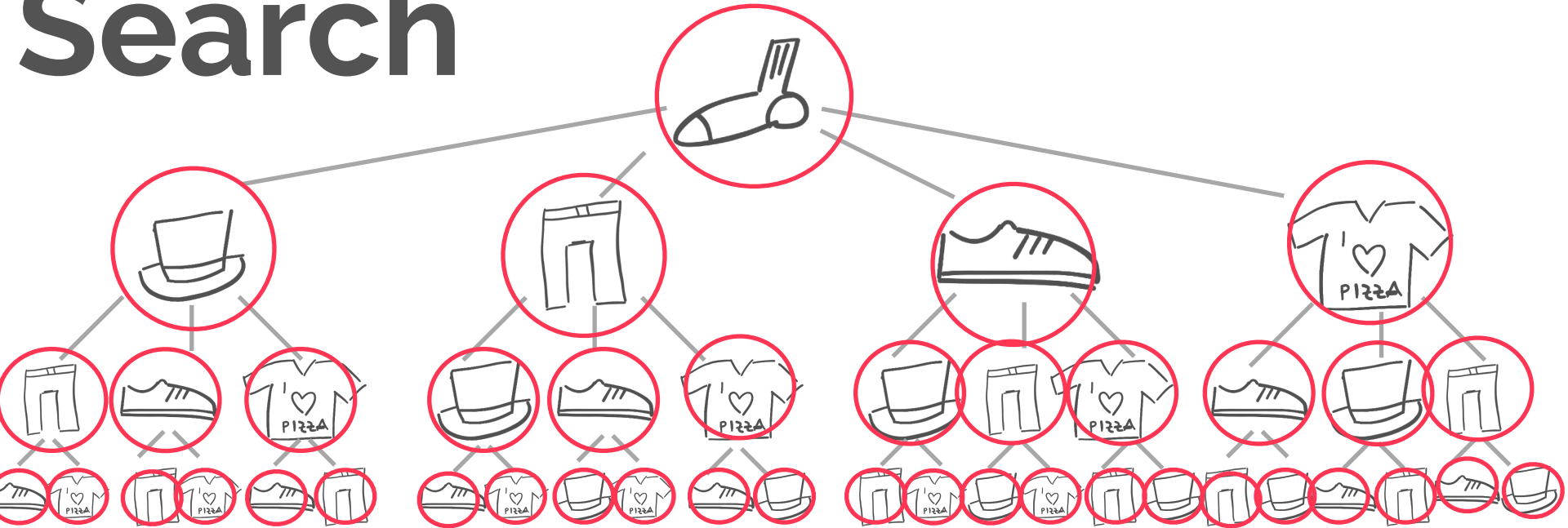
```
WITH RECURSIVE items(item_id, picked_items, nr_items, total_weight, total_value) as (  
    SELECT  
        item_id,  
        ARRAY[item_name] as picked_items,  
        1 nr_items,  
        weight total_weight,  
        value total_value  
    from inventory  
    UNION ALL  
    select  
        inventory.item_id,  
        picked_items || item_name,  
        nr_items + 1,  
        weight + total_weight,  
        value + total_value  
    from inventory cross join items  
    where  
        picked_items::varchar[] @> ARRAY[item_name] = false  
        and weight + total_weight <= 20  
  
    ) SEARCH BREADTH FIRST BY item_id SET ordercol  
select * from items order by ordercol;
```

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item_id	picked_items	nr_items	tot_weight	tot_value	ordercol
1	{Socks}	1	3	10	(0,1)
2	{Socks,Hat}	2	8	25	(1,2)
3	{Socks,Trousers}	2	18	15	(1,3)
4	{Socks,Shoes}	2	13	18	(1,4)
5	{Socks,T-Shirt}	2	13	17	(1,5)
2	{Socks,Trousers,Hat}	3	23	30	(2,2)
2	{Socks,Shoes,Hat}	3	18	33	(2,2)
2	{Socks,T-Shirt,Hat}	3	18	32	(2,2)
3	{Socks,Hat,Trousers}	3	23	30	(2,3)
3	{Socks,T-Shirt,Trousers}	3	28	22	(2,3)
3	{Socks,Shoes,Trousers}	3	28	23	(2,3)
4	{Socks,Hat,Shoes}	3	18	33	(2,4)
4	{Socks,T-Shirt,Shoes}	3	23	25	(2,4)
4	{Socks,Trousers,Shoes}	3	28	23	(2,4)
5	{Socks,Hat,T-Shirt}	3	18	32	(2,5)
5	{Socks,Shoes,T-Shirt}	3	23	25	(2,5)
5	{Socks,Trousers,T-Shirt}	3	28	22	(2,5)

(17 rows)

Search



DEPTH

item_id	picked_items	nr_items	tot_weight	tot_value	ordercol
1	{Socks}	1	3	10	{(1)}
2	{Socks,Hat}	2	8	25	{(1),(2)}
3	{Socks,Hat,Trousers}	3	23	30	{(1),(2),(3)}
4	{Socks,Hat,Shoes}	3	18	33	{(1),(2),(4)}
5	{Socks,Hat,T-Shirt}	3	18	32	{(1),(2),(5)}
3	{Socks,Trousers}	2	18	15	{(1),(3)}
2	{Socks,Trousers,Hat}	3	23	30	{(1),(3),(2)}
4	{Socks,Trousers,Shoes}	3	28	23	{(1),(3),(4)}
5	{Socks,Trousers,T-Shirt}	3	28	22	{(1),(3),(5)}
4	{Socks,Shoes}	2	13	18	{(1),(4)}
2	{Socks,Shoes,Hat}	3	18	33	{(1),(4),(2)}
3	{Socks,Shoes,Trousers}	3	28	23	{(1),(4),(3)}
5	{Socks,Shoes,T-Shirt}	3	23	25	{(1),(4),(5)}
5	{Socks,T-Shirt}	2	13	17	{(1),(5)}
2	{Socks,T-Shirt,Hat}	3	18	32	{(1),(5),(2)}
3	{Socks,T-Shirt,Trousers}	3	28	22	{(1),(5),(3)}
4	{Socks,T-Shirt,Shoes}	3	23	25	{(1),(5),(4)}

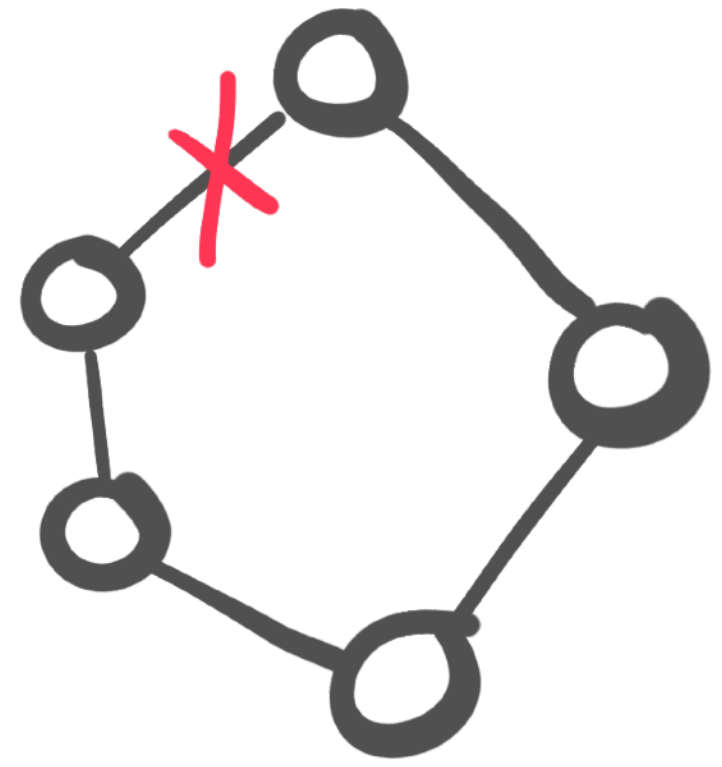
(17 rows)

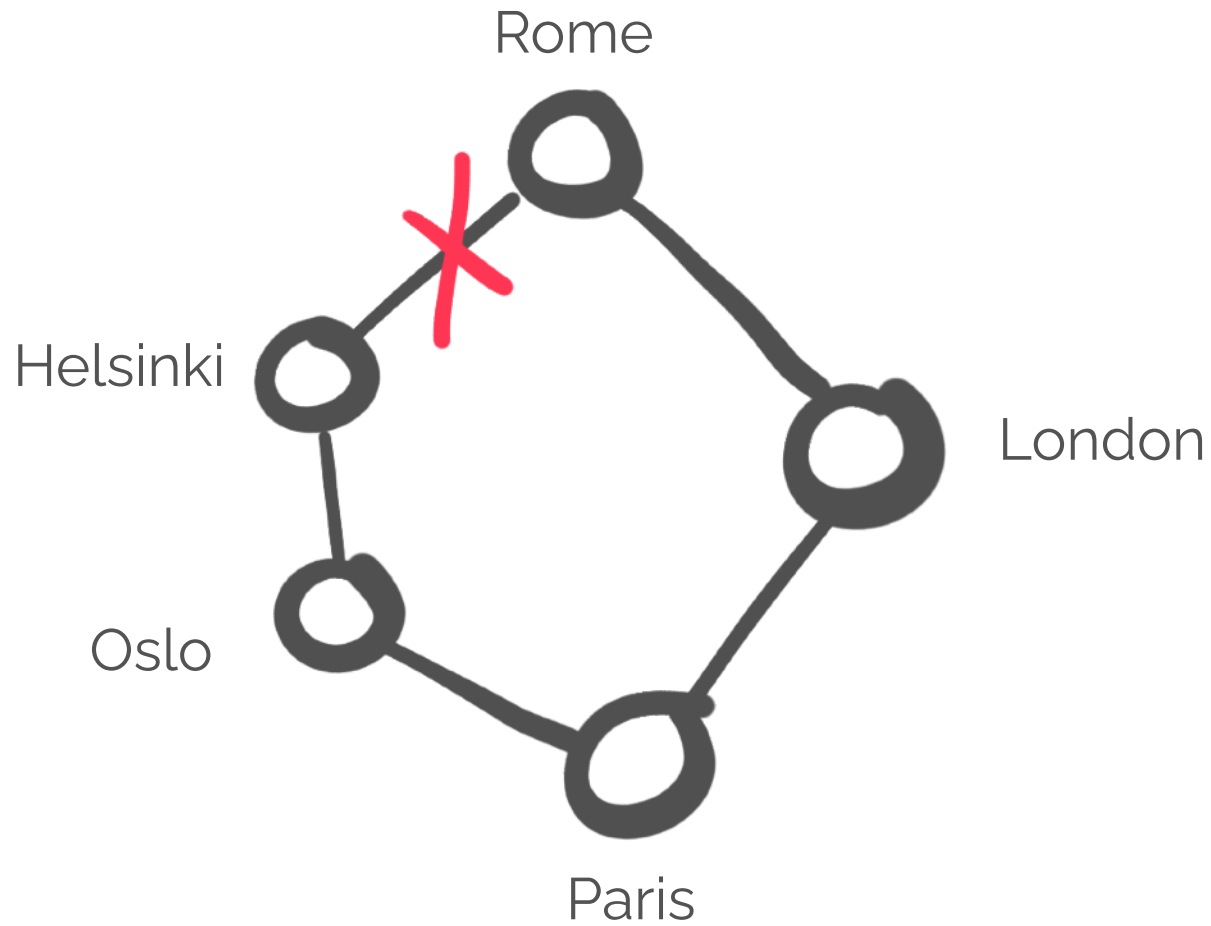
```
WITH RECURSIVE items(item_id, picked_items, nr_items, total_weight, total_value) as (  
    SELECT  
        item_id,  
        ARRAY[item_name] as picked_items,  
        1 nr_items,  
        weight total_weight,  
        value total_value  
    from inventory  
    UNION ALL  
    select  
        inventory.item_id,  
        picked_items || item_name,  
        nr_items + 1,  
        weight + total_weight,  
        value + total_value  
    from inventory cross join items  
    where  
        picked_items::varchar[] @> ARRAY[item_name] = false  
        and weight + total_weight <= 20  
  
    ) SEARCH DEPTH FIRST BY item_id SET ordercol  
select * from items order by ordercol;
```

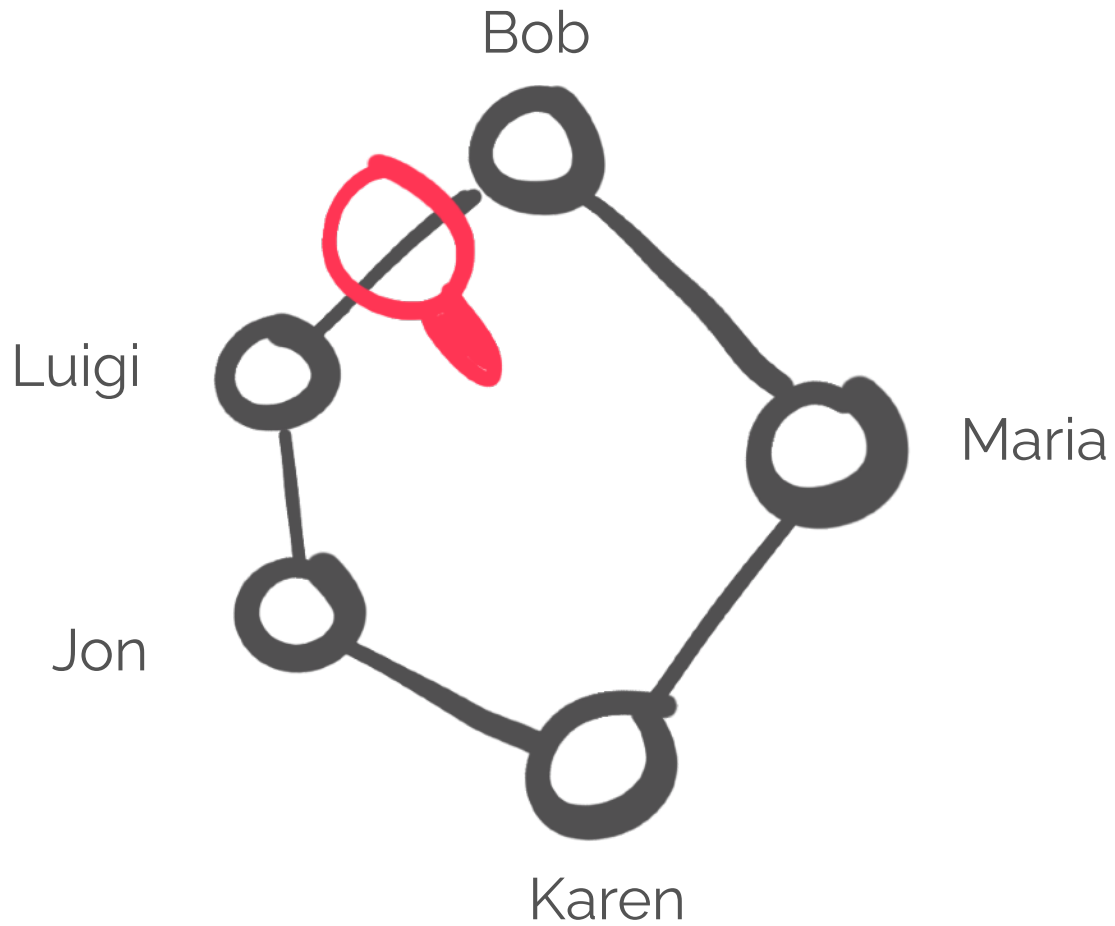
item_id	picked_items	nr_items	tot_weight	tot_value	ordercol
1	{Socks}	1	3	10	(0,1)
2	{Socks,Hat}	2	8	25	(1,2)
3	{Socks,Trousers}	2	18	15	(1,3)
4	{Socks,Shoes}	2	13	18	(1,4)
5	{Socks,T-Shirt}	2	13	17	(1,5)
2	{Socks,Trousers,Hat}	3	23	30	(2,2)
2	{Socks,Shoes,Hat}	3	18	33	(2,2)
2	{Socks,T-Shirt,Hat}	3	18	32	(2,2)
3	{Socks,Hat,Trousers}	3	23	30	(2,3)
3	{Socks,T-Shirt,Trousers}	3	28	22	(2,3)

item_id	picked_items	nr_items	tot_weight	tot_value	ordercol
1	{Socks}	1	3	10	{{(1)}
2	{Socks,Hat}	2	8	25	{{(1),(2)}
3	{Socks,Hat,Trousers}	3	23	30	{{(1),(2),(3)}
4	{Socks,Hat,Shoes}	3	18	33	{{(1),(2),(4)}
5	{Socks,Hat,T-Shirt}	3	18	32	{{(1),(2),(5)}
3	{Socks,Trousers}	2	18	15	{{(1),(3)}
2	{Socks,Trousers,Hat}	3	23	30	{{(1),(3),(2)}
4	{Socks,Trousers,Shoes}	3	28	23	{{(1),(3),(4)}
5	{Socks,Trousers,T-Shirt}	3	28	22	{{(1),(3),(5)}
4	{Socks,Shoes}	2	13	18	{{(1),(4)}
2	{Socks,Shoes,Hat}	3	18	33	{{(1),(4),(2)}

Cycle







```
picked_items::varchar[] @> ARRAY[item_name] = false
```

```
inventory.item_id > items.item_id
```

```
CYCLE item_id SET is_cycle USING items_ids
```

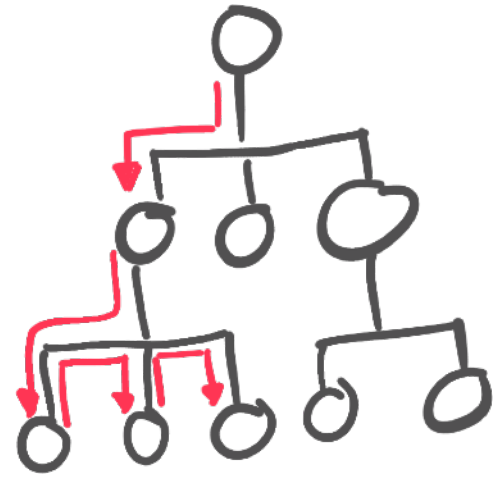
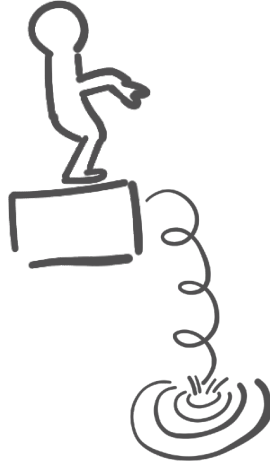
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item_id	picked_items	is_cycle	items_ids
1	{Socks}	f	{(1)}
1	{Socks,Socks}	t	{(1),(1)}
2	{Socks,Hat}	f	{(1),(2)}
3	{Socks,Trousers}	f	{(1),(3)}
4	{Socks,Shoes}	f	{(1),(4)}
5	{Socks,T-Shirt}	f	{(1),(5)}
1	{Socks,Hat,Socks}	t	{(1),(2),(1)}
2	{Socks,Hat,Hat}	t	{(1),(2),(2)}
3	{Socks,Hat,Trousers}	f	{(1),(2),(3)}
4	{Socks,Hat,Shoes}	f	{(1),(2),(4)}
5	{Socks,Hat,T-Shirt}	f	{(1),(2),(5)}
1	{Socks,Trousers,Socks}	t	{(1),(3),(1)}
.	.	.	.

Knapsack Problem



Base + Recursion

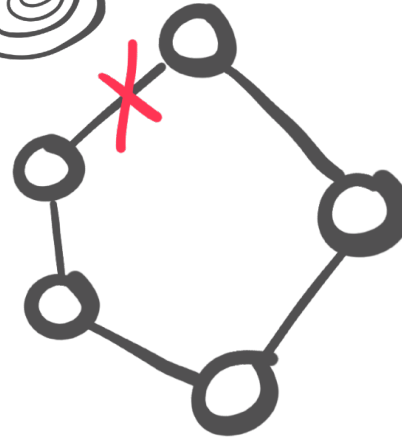


SEARCH

PostgreSQL



Recursive Queries



CYCLE

References

Knapsack Problem

https://en.wikipedia.org/wiki/Knapsack_problem

Knapsack in PostgreSQL

<https://aiven.io/blog/solving-the-knapsack-problem-in-postgresql>

PostgreSQL 14 Search and Cycle Features

<https://aiven.io/blog/explore-the-new-search-and-cycle-features-in-postgresql-14>

Aiven 

<https://aiven.io/>