**When the SKY meets the CROWD:   
A probabilistic approach to cost reduction**

# Problem Statement

Attempt to reduce the cost of crowdsourcing using skyline points.

# Notations and Definitions

1. A skyline tuple is not dominated by any other tuple.
2. Tuple A is said to dominate tuple B iff the following holds:
3. A={a1,a2,a3} B={b1,b2,b3}
4. a1>=b1 and a2>=b2 and a3>=b3 and (a1>b1 or a2>b2 or a3>b3)
5. Tuple A is said to ignore B if any of the above condition fails. In that case A and B cannot be compared and relatively are skylines if not dominated by any other point.
6. A>B: A dominates B.
7. A<b: B dominates A.
8. Tuple⬄record.
9. Dimension⬄ attribute
10. Ranges will be denoted as R(a-b) denoting ‘range from a to b’.
11. D-score and R-score: Dominance and Recessive score respectively.
12. Recessive refers to ‘being dominated’. A point that is too recessive (probabilistic case under ranged dimensions) has a lower probability of being a skyline.
13. D-score = (probability A dominates B based on unknown dimensions)/ (no. of unknown dimensions in A).
14. R-score = (probability A is dominated by B based on unknown dimensions)/ (no. of unknown dimensions in B).

# Intuition

The intuition behind using skyline points is that because such points are not dominated by any other point, they are more likely to appear as top search results depending on the scenario. Moreover, skyline are not only the points that are not dominated by any other point, but also the points that dominate others. Hence using them we can eliminate the points that need not be crowdsourced thereby reducing the overall cost of the process.

# Methods so far

Using probabilistic approach to skyline queries:

1. For the S-known set, where we know all the dimensions, we can use the brute force approach for calculating skyline queries.
2. We first judge two points on the known dimensions. If for the known dimensions, partial skyline condition holds, then we explore the unknown dimensions. Else we term them as ‘incomparable’.
3. Suppose out of 5 known dimensions of A and B, A dominates B (A>=B) on 3 of those. A is unknown on the 4th dimension while B is unknown on the 5th (assumption). Since A is dominating on 3 dimensions, the only chance is that A can dominate B entirely. So, let us try and give a higher weightage to A of being a dominating over B, i.e., let us provide a weightage to the probability of A>=B by dividing its probability with the number of unknown dimensions as the more the number of unknown dimensions, the lesser will be its probability to acquire values such that A>=B for all values. Note that this will only be done for conflicting dimensions. E.g. If dim4 (A) = R10-15 (range 10 to 15) and dim4 (B) =5, then A>=B on dim 4 irrespective of the value it takes. Such dimensions won’t count to the weightage reduction. Such an assumption is based on the fact that for an actual database, the known dimensions are of a higher value and shall contribute more towards deciding the skyline points. Infrequent will be the cases where in a database the unknown values are of more importance than the known values.
4. We are increasing the probability of a potential skyline point because initially our attempt is to cover as many skyline points as we can irrespective of the non-skyline points that will be included in the set so that we can perform maximum reductions. We’ll also sort the points based on the maximum known dimensions, in an attempt to reduce the number of comparisons.
5. Now, for points A={10,15,20,R5-10,14} and B={4,4,8,7,R6-16}, the method for probability calculation will be (notice that A already dominates B on all the known dimensions.)
   * 1. dim4 (A>=B) = ((10-7)/15 )\* 1(no. of unknown dimensions in A)
     2. dim4(B>=A) = (7-5)/(15\*1(no. of unknown dimensions in B) ) (we are reducing the probability of B being able to dominate A as we would like A to be a potential skyline as it already dominates B on the known dimensions.)
     3. dim5(A>=B) = (14-7)\*1/10
     4. dim5(B>=A) = (16-14)/10\*1
     5. Prob (A>=B) = Prob(dim4(A>=B)) \* Prob(dim5(A>=B))

   6.    We simply cannot ignore the probability of B>=A as skyline points themselves are incomparable. But in cases where the values of a tuple are low, if we provide equal probability to the unknown values of the dominating as well as the dominated tuple, then chances are that we might be bringing all the tuples to stage where most of them will be incomparable. E.g. if there are 4 unknown dimensions for each point, having an equally likely probability on each of the dimensions can cause either to be not comparable on any of the 4 dimensions with a probability of 25%. So instead of bringing all the points into the potential skyline set, we would like to incur some loss and reduce the set size for the initial stage, considering the fact that a point that is initially low(low on dimension values) will stay low even after crowdsourcing. We would like to minimize such points in the initial set. In graph directed G= (V, E) the set of vertices are all the points in the dataset that haven’t been eliminated in the preprocessing stage. A directed edge exists from a point u to a point v if denoting the weighted probability that A dominated B. If no such edge is there then A ignores B (A and B are not comparable). In such a case there won’t be a back edge from B to A if there’s an edge from A to B. Bidirectional edges will occur only in cases when two points have all dimensions unknown. We have a faint idea of how good this approach of being not comparable would be. However, absence of edges denoting non-comparability is still information.

 7. Let's assume we have all the probabilities of A>=B and B>=A for all the points.  Now, one thing is that the graph showing the dominance-recessive relation among points will be a dense one (depends on the diversity of the dimensions having ranged values), with edges from every vertex to every vertex, and bidirectional. A dense graph saves us the need to traverse the graph in order to inculcate the effect of neighbors on the vertex. This was to counter the ripple effect. Though we haven’t been able to come up with anything less than brute force in case of graphs. A brute force approach will give us a relation for every point with every other point. So the graph will be dense and removing a point will have direct impact on all the other points. So there’s no need to consider a ripple of depth 2 or 3. All the effects will directly take place. This is still a brute force idea.

 8. A point will be a potential ‘good point’ for outsourcing if it has a high D-score and a low R-score, with max difference between the D-score and R-score.  Define formula for D-score and R-score

D-score = (probability A dominates B based on unknown dimensions)/ (no. of unknown dimensions in A).

As of now I don’t think R-score will be playing a significant role as we are not considering it. Still, in case we might want to use it in future:  
R-score

 9. To reduce the number of comparisons, one approach is to perform a piecewise brute force, i.e., to first compare all the points that have d unknown dimensions. Make the graph for them and, compute the D-score and the R-score, then using this, perform crowdsourcing. After the obtained results, perform eliminations with all other points. The remaining points from the d unknown dimension set can be merged with the points with d-1 unknown dimensions and the process can be repeated.

# Discussions

Q. ) What is partial skyline condition?   
  
Partial skyline condition states that the skyline conditions for two points should hold for all the known dimensions of the two points. E.g. if dimensions 1, 2, and 4 are known for points A and B, then either A>=B or A<=B should hold for these three dimensions. If not, there’s no point comparing them on ranged dimensions.

Q.) What does “weightage reduction” mean? What would have happened if in the first three dimensions A did not completely dominate B?   
  
We ignore it. There won’t be a case (or very rare) where there’s a point that is not comparable to lots of points that are getting eliminated by skyline points as well as not comparable to a skyline point as well. At least that’s what we thought when Shivam and I were discussing about it. Always there’s a possibility of outliers where such a point could exist, but we were thinking of getting some results first, then trying to improve them by making changes to the methods that led us to the results. We are prioritizing the probability of a point dominating other. We thought that a major role will be played by the ability of a point dominating others rather than being dominated or being not comparable. So we decided to boost the probability of dominance. So, if a point is dominating 5-6 points, even if there is a fair chance, we are increasing its probability of being amongst the initial points that will be crowdsourced. Again, this is one way of dealing with the problem. We discussed that it would help reduce the size of the initial crowdsourced set by having maximum eliminations so that even though some point that may actually be a skyline might get missed, some point that should not be crowdsourced will have a very low chance of being a part of this set unless it’s an outlier kind of a point or very close to skylines.

Q.)Not clear. What is the 7, 15? Can we formalize this to make it easy to understand? Let’s say A={a1,a2,a3,R(x-y), a5} and B={b1,b2,b3,b4,b(x’-y’)} then ......  
  
Other points follow calculations based on weightage. Dim5 (A>=B) refers to A and B compared on dimension no. 5, representing the probability of A dominating B over that particular dimension. It’s based on the same approach that you were using when you dealt with ranges initially. We blurred the overlapping region instead of being so discrete about it, which was causing us a lot of computation problems like we previously discussed. Unlike your approach, we are not ignoring it completely. So we have considered it in a range but in such a way that it gives value to both but differently based on the difference in ranges. I hope the remaining points are a bit clear. We’ll still try to come up with a concrete idea of how to write all this more formally so that the same can be carried forward and need not be changed from time to time.

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