Eclipse: Practicability Beyond 1-NN and Skyline

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ABSTRACT

In this paper, we propose a novel Eclipse query which is more practical than the existing 1-NN query and skyline query. In addition, we present a few properties of Eclipse query and the general idea for computing Eclipse.

1. INTRODUCTION

The skyline computation, aiming at identifying a set of skyline points that are not dominated by any other point, is very important for multi-criteria data analysis and decision making.

Definition 1. (Skyline). Given a dataset $P$ of $n$ points in $d$-dimensional space. Let $p = (p[1], p[2], ..., p[d])$ and $p' = (p'[1], p'[2], ..., p'[d])$ be two different points in $P$, we say $p$ dominates $p'$, denoted by $p \prec p'$, if for all $i$, $p[i] \leq p'[i]$, and for at least one $i$, $p[i] < p'[i]$, where $p[i]$ is the $i$-th dimension of $p$ and $1 \leq i \leq d$. The skyline points are those points that are not dominated by any other point in $P$.

The essence of dominance definition in skyline is that for any given attribute weight vector $w = \langle w[1], w[2], ..., w[d] \rangle$, we have $S(p) < S(p')$, where $S(p)$ ($S(p')$) is the attribute sum of $p$ ($p'$). That is, we say $p$ dominates $p'$ if $S(p) < S(p')$ for all $w[j]/w[1] = (0, +\infty)$, where $j = 2, 3, ..., d$. Therefore, we have another skyline definition as follows.

Definition 2. (Skyline). Given a dataset $P$ of $n$ points in $d$-dimensional space and an attribute weight vector $w = \langle w[1], w[2], ..., w[d] \rangle$. Let $p = (p[1], p[2], ..., p[d])$ and $p' = (p'[1], p'[2], ..., p'[d])$ be two different points in $P$, we say $p$ dominates $p'$, denoted by $p \prec p'$, if $S(p) < S(p')$ for all $w[j]/w[1] = (0, +\infty)$, where $S(p)$ ($S(p')$) is the attribute sum of $p$ ($p'$) and $j = 2, 3, ..., d$. The skyline points are those points that are not dominated by any other point in $P$.

Similarly, for the classic 1-NN query, we can also use the domination definition to define 1-NN query.

Definition 3. (1-NN). Given a dataset $P$ of $n$ points in $d$-dimensional space and an attribute weight vector $w = \langle w[1], w[2], ..., w[d] \rangle$. Let $p = (p[1], p[2], ..., p[d])$ and $p' = (p'[1], p'[2], ..., p'[d])$ be two different points in $P$, we say $p$ dominates $p'$, denoted by $p \prec p'$, if $S(p) < S(p')$ for all $w[j]/w[1] = t_j$, where $S(p)$ ($S(p')$) is the attribute sum of $p$ ($p'$), $t_j \in (0, +\infty)$, and $j = 2, 3, ..., d$. The 1-NN point is the point that is not dominated by any other point in $P$.

Motivation. Recall our hotel example in [3] again. Figure 1(a) shows a dataset $P = \{p_1, p_2, ..., p_6\}$, each representing a hotel with two attributes: distance to the destination and price. Figure 1(b) shows the corresponding points in the two dimensional space. Here $x$ and $y$ coordinates correspond to the value of attributes for distance to the destination and price, respectively. For a user who wants to reserve a hotel, i) the output of skyline is too much, and ii) it is difficult to set the exact attribute weights, e.g., $w[1] = 2$ and $w[2] = 5$. However, it is easy for the user to set the range of attribute weight ratio. For example, the user may not care the price, so he/she may set $w[2]/w[1] = [2, 5]$, i.e., distance is more important for him/her. Please note here we use the smaller the better in dominance definition, so we give the lower weight if this attribute is more important.

Figure 1: A skyline example of hotels.
If \( w[1], w[2], ..., w[d] \), let \( p = (p[1], p[2], ..., p[d]) \) and \( p' = (p'[1], p'[2], ..., p'[d]) \) be two different points in \( P \), we say \( p \) dominates \( p' \), denoted by \( p \preceq p' \), if \( S(p) < S(p') \) for all \( w[j]/w[1] = [t_j1, t_j2] \), where \( S(p) \) (\( S(p') \)) is the attribute sum of \( p \) (\( p' \)), \( 0 < t_j1 < t_j2 \) and \( j = 2, 3, ..., d \). The Eclipse points are those points that are not dominated by any other point in \( P \).

| Property 2. (Transitivity) | Given three points \( p_1, p_2, \) and \( p_3 \). If \( p_1 \preceq p_2 \) and \( p_2 \preceq p_3 \), then \( p_1 \preceq p_3 \). |

We show a new idea to compute 1-NN and skyline, furthermore, we can compute our Eclipse by adapting the same idea. We only focus on two dimensional case, it is straightforward to extend to the higher dimensional space. The idea is shown in Figure 2. We have three points \( a, b, c \) in primal plane (Figure 2(a)) and their corresponding lines in dual plane (Figure 2(b)).

For 1-NN query, if the weight ratio is \( t = \frac{1}{r} \) and \( r_{ab} < r < 0 \), where \( r_{ab} \) is the slope of line \( ab \). The 1-NN query result (W.l.o.g., the query point is the origin point in this paper) is point \( a \). Correspondingly, in the dual space, line \( a \) is the nearest line to \( x \)-axis in interval \((ab,0)\) of \( x \)-axis. Similarly, if \( r_{ac} < r < r_{bc} \), the 1-NN query result is point \( b \). Correspondingly, in the dual space, line \( b \) is the nearest line to \( x \)-axis in interval \((bc,ac)\) of \( x \)-axis.

For skyline query, the weight ratio is \((0,\infty)\). Correspondingly, in the dual space, we need to search the entire interval \((-\infty,0)\) of \( x \)-axis. In interval \((-\infty,bc)\) of \( x \)-axis, the result is line \( c \), in interval \((bc,ab)\) of \( x \)-axis, the result is line \( b \), and in interval \((ab,0)\) of \( x \)-axis, the result is line \( a \). Totally, the skyline query result is \( a, b, c \).

For our Eclipse query, if the weight ratio is \((t_1 = \frac{1}{r_1}, t_2 = \frac{1}{r_2})\), we have corresponding interval \((r_2,r_1)\) of \( x \)-axis in dual space. For example, if \( r(bc) < r_2 < r(ac) \) and \( r(ab) < r_1 < 0 \), the query result is \( a, b \).

4. CONCLUSION AND FUTURE WORK

In this paper, we described the general idea of Eclipse query which is more practical than 1-NN query and skyline query. For the future work, we will give the detailed algorithms for computing Eclipse in multi-dimensional space. Furthermore, we would like to estimate the average number \([1]\) of Eclipse points with the assumption of the independent and identically distributed dataset.

5. REFERENCES

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