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# Umbrella curvature: a new curvature estimation method for point clouds

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**Abstract**

This paper presents a novel method for surface curvature estimation. By using the k-nearest neighbors algorithm, an 8 neighbors ring is selected from point cloud for each point. Surface normal vector is estimated by neighbors coordinates. Local surfaces are classified using the point of interest and its 8 neighbors ring coordinates. In this paper surface curvature is calculated based on normal vector and neighbors ring coordinate. Surface curvature calculated using the novel method is called umbrella curvature. To evaluate how this method performs, the curvature of a sample surface was estimated by the umbrella curvature and surface variance method. The results show that the umbrella curvature performs well and is superior in terms of accuracy. However the method in computation is more expensive than variance method.



*Keywords*: point cloud; registration; surface curvature; k- nearest neighbours; surface normal vector.

## 1. Introduction

Modern coordinate measuring machines with continuous contact scanning probes and high-speed 3D laser scanners are increasingly being used to collect coordinate data points on a physical model surface. The data points, due to their high density, are often referred to as point cloud data. It is a fundamental task to be able to accurately

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and reliably estimate the relevant geometric features such as normal vector and curvature of these discrete data points in common CAD/CAM applications, as the theoretical CAD model may not be available [1]. Typical applications of these geometric features include segmentation of the point cloud data [2], geometric shape inference, surface reconstruction [3] and registration [4].

Lack of analytical formulas makes curvature computation a complex step in surfaces obtained from point cloud data. The curvature estimation techniques are usually classified in two categories: the surface fitting method and the discrete method. In surface fitting method a function is chosen to model the local surface shape. It has been one of the more popular and stable techniques for curvature estimation. The discrete method employs either a direct approximation formula for the curvature, or an approximation of the curvature tensor, from which curvature and other differential properties can be estimated. One of the main motivations for developing this method is to avoid the computational costs associated with the surface fitting method. Generally, the discrete method leads to some gain in computation time at the cost of attainable accuracy [5].

The present work focuses on the reliable estimation of the curvature estimation for point cloud data. A new method for point cloud curvature estimation is proposed that can used in point clouds registration withreduced computational costs. The method called umbrella curvature.

The estimation procedure would involve the following three main steps:

1. Identify the homogenous neighboring points for estimating the normal vector;
2. Estimate the normal vector based on points in the local neighborhood; and
3. Calculate umbrella curvature for each point in point cloud data.

## 2. Neighbors determination and normal vector estimation

Though distance-based neighbors are popularly used in the literature mainly because of their simplicity; however the results are not very satisfactory, especially when the point distribution is uneven [6]. This paper uses a new method called homogeneous neighborhood for determining neighbors in point clouds. This method, in addition to the distance takes into consideration the directional balance. The directional balance describes whether the neighbors are well spread around the point of concern. For the points with uneven distribution as shown in Fig. 1, using k-nearest neighbors algorithm is not desirable for normal vector estimation. The homogeneous neighbors are shown in Fig. 1(b). This algorithm is desirable for the normal vector estimation and detail of which is to be published later.

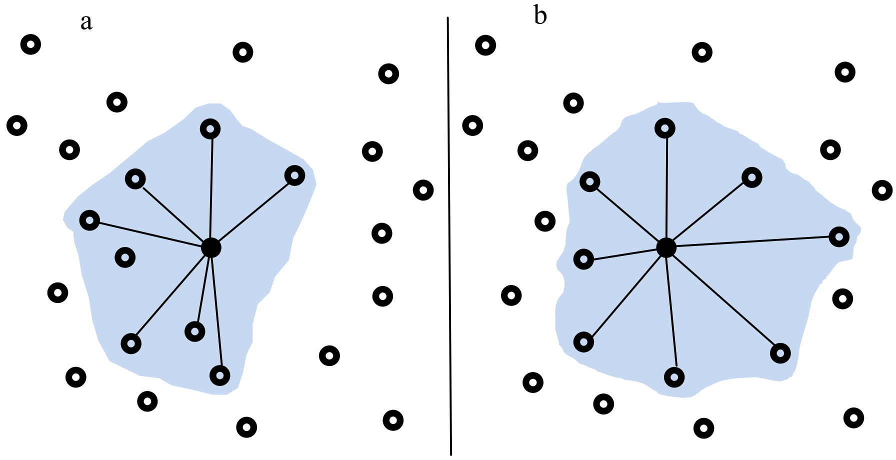


Fig. 1. (a) k-nearest neighbors; (b) homogeneous neighbors.

For the estimation of the surface normal vector in a point clouds, the covariance matrix, will be applied since the first order plane fitting is equivalent to the eigenvalue problem of the covariance matrix [3]. The set of neighbors is denoted by $N(p_i)$. To calculate a normal vector, the centroid $o_i$ of $N(p_i)$ is computed first. The normal $n_i$ is