A JOINT CLASSIFICATION METHOD FOR TLS POINT CLOUD BY INTENSITY AND COLOR INFORMATION

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NSFC No. 41671449 support this work
Outline

Problem

Method

Experiment

Summary
Problem

The TLS (Terrestrial laser scanner) is *widely* used in 3D modeling

TLS point cloud is *massive, dispersed and unordered*

We need a *fast and accurate* classification method
Problem

Previous Studies

Based on strongly varying density \cite{Hackel2016}.
Based on neighborhood dimensionality \cite{Yang2013}.
Based on the geometry and color information \cite{Ramiya2014}.
Based on combining structure and context \cite{Kumari2015}.
Based on neighborhood selection & selecting feature \cite{Weinmann2015}.
Based on feature similarity & semantic dependency \cite{Zhang2015}.

These methods are based on the **spatial features** of point cloud:

- The logic and computation are complicated.
- The difficulty increases with the complexity of the target shape.

Spatial features is difficulty, but **physical properties**?
Problem

Previous Studies

based on intensity information  
(Song et al., 2002)

Based on intensity information and elevation information  
(Charaniya et al., 2004)

Based on pseudo reflection image  
(Coren and Sterzai, 2006)

Based on color information  
(Strom et al., 2010; Knopf, 2011; Matti & Nebiker, 2014; Luo et al., 2016)

TLS original intensity data are inapplicable in directly retrieving
TLS intensity correction is not applicable and accurate
TLS can obtain the intensity and color information of the target surface

We want a classification method by INTENSITY and COLOR
Method

TLS Point Cloud

Intensity Correction → Joint Classification → Classified Result

Color Correction
Method

Intensity Correction

radar range equation:  \[ P_R = \frac{P_E D_R^2 \rho \cos \alpha}{4\pi R^2} \eta_{sys} \eta_{atm} \]

\( P_E \), \( D_R \), \( \eta_{atm} \), and \( \eta_{sys} \) can be assumed as constant, in TLS

So, we can get:

\[ P_R = \frac{C \rho \cos \alpha}{R^2} \]
\[ C = \frac{P_E D_R^2}{4\pi} \eta_{sys} \eta_{atm} \]

Distance and incidence angle are important factors in intensity correction
Method

Incidence Angle Correction

\[ f(\cos \alpha) = a \cos \alpha^b + c \]

The incidence angle correction \( I_c = I - f(\cos \alpha) + f(\cos \alpha_c) \)
Method

Distance Correction

\[ f(R) = \begin{cases} aR^3 + bR^2 + cR + d, & 1 \leq x < 5 \\ eR^2 + fR + g, & 5 \leq x < 14 \\ hR^3 + iR^2 + jR + k, & x \geq 14 \end{cases} \]

The incidence angle correction

\[ I_c = I - f(R) + f(R_c) \]
Method

Original Intensity Image

Corrected Intensity Image

Original Intensity Histogram

Corrected Intensity Histogram
Method

Color Correction

\[
\begin{bmatrix}
  R' \\
  G' \\
  B'
\end{bmatrix} =
\begin{bmatrix}
  k_R & n_G & m_B \\
  m_R & k_G & n_B \\
  n_R & m_G & k_B
\end{bmatrix}
\begin{bmatrix}
  R \\
  G \\
  B
\end{bmatrix}
\]

\[
\Rightarrow 
\begin{bmatrix}
  R' \\
  G' \\
  B'
\end{bmatrix} =
\begin{bmatrix}
  k_1 & \omega_G & -\omega_B \\
  -\omega_B & k_2 & \omega_R \\
  \omega_G & -\omega_R & k_3
\end{bmatrix}
\begin{bmatrix}
  R'' \\
  G'' \\
  B''
\end{bmatrix}
\]

\[
\Rightarrow 
\begin{bmatrix}
  R' \\
  G' \\
  B'
\end{bmatrix} =
\begin{bmatrix}
  k & \omega_G & -\omega_B \\
  -\omega_B & k & \omega_R \\
  \omega_G & -\omega_R & k
\end{bmatrix}
\begin{bmatrix}
  R'' \\
  G'' \\
  B''
\end{bmatrix} +
\begin{bmatrix}
  \Delta R \\
  \Delta G \\
  \Delta B
\end{bmatrix}
\]
Method

Scanning A RGB

Scanning B RGB

Corrected Scanning B RGB
Method

The $I_i$ (intensity), and $I_c$ (color) were used as vectors in coordinate system of classification

$$E = 10^2 \sqrt{( \log_{10} I_i )^2 + ( \log_{10} I_c )^2} + C$$

$C$ is a variable based on distance

$$C = \frac{R}{R_s} \times (I_s - I)$$

$R$ is distance of per point, $R_s$ is standard distance, $I$ is corrected intensity of per point and $I_s$ is standard intensity
Experiment

Used the instrument Faro Focus3D 120. A façade of building was scanned three times at different distances and incidence angles.

<table>
<thead>
<tr>
<th>Scanning</th>
<th>Distance Range</th>
<th>Incidence Angle Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning A</td>
<td>6-19 m</td>
<td>0-89 degree</td>
</tr>
<tr>
<td>Scanning B</td>
<td>19-34 m</td>
<td>0-89 degree</td>
</tr>
<tr>
<td>Scanning C</td>
<td>1.5-19 m</td>
<td>0-89 degree</td>
</tr>
</tbody>
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Experiment

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<td></td>
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<td>Scanning C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experiment

Classification Image

Scanning A | Scanning B | Scanning C

Intensity Only

Intensity & Color
Experiment

**Scanning A**

- Scalar field (879991 values) [256 classes]

**Scanning B**

- Scalar field (462456 values) [256 classes]

**Scanning C**

- Scalar field (674016 values) [256 classes]

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**Intensity Only**

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**Intensity & Color**

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Summary

This method has higher accuracy and universality

TLS of the Faro focus series has its specific characteristics

If the intensity of other TLS parameters are known, this method can be extended to other TLS intensity data correction as well.
Thank You