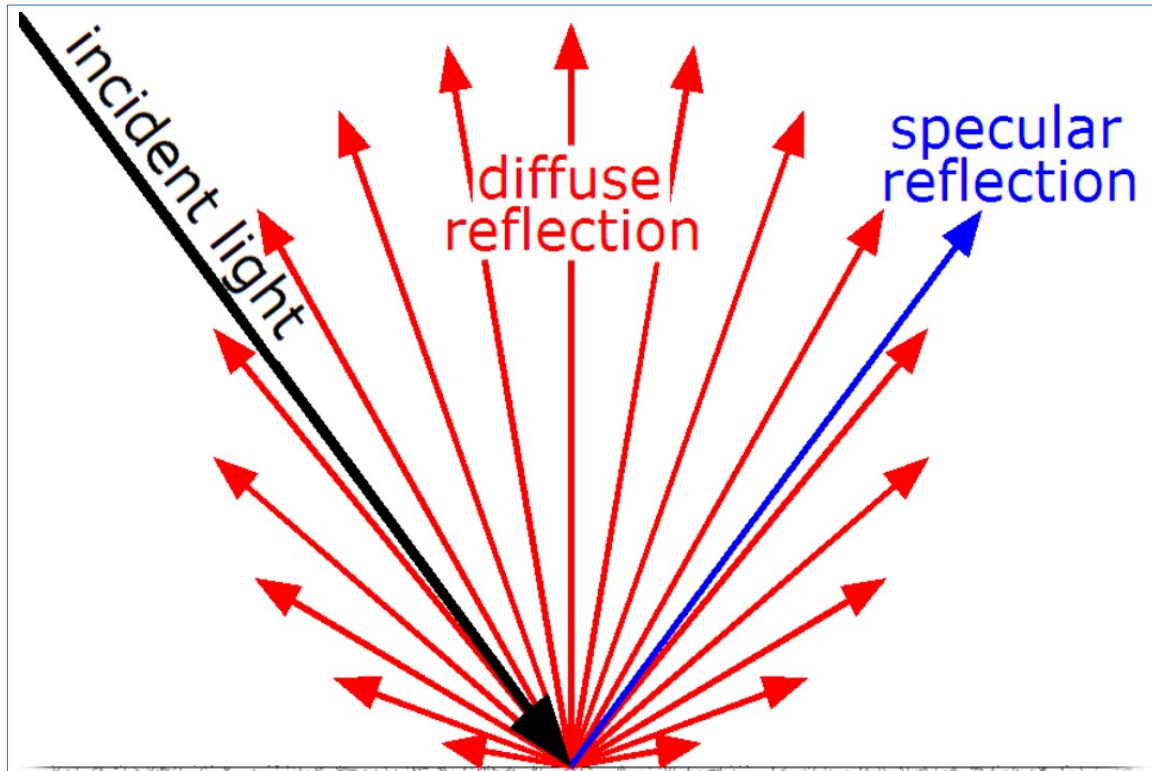


Diffuse Reflection



Two Key Characteristics:

1. The surface with reflectivity as $K_d = (k_r, k_g, k_b)$, e.g., diffuse coefficients;

2. The decay of incident light is inverse proportional to its distance from the source to the surface point. e.g., $1/(r^2)$, where r is being the distance from the light source to the surface.

Specular vs. diffuse reflection

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

Diffuse Reflection: the reflection of light uniformly in all different directions, the surface of this reflection exhibits Lambert reflection, e.g., equal luminance when viewed from all directions.

Diffuse Reflection Formulation

Light source $I_s(x,y)$ consists of r, g, b 3 primitive colors as follows, but let's simplify it as white color, so r, g, b all equal and have the highest value (if in graphics, they are 255)

$$\vec{I}_s(x,y,z) = (I_r(x,y,z), I_g(x,y,z), I_b(x,y,z)) \quad \dots (1)$$

Object surface consists of reflectivity, e.g., coefficient of reflection

$$\vec{K}_d = (K_r, K_g, K_b) \quad \dots (2)$$

\vec{r}_d vector in Equation (1) is a ray equation, just like $I_s(x,y,z)$ but has no r, g, b primitive color defined in it for the matter of simplicity.

Diffuse Reflection Equation

Let's consider white color of the point light source, then each primitive color r , g , b of the object surface $I(x,y,z)$ can be computed as follows:

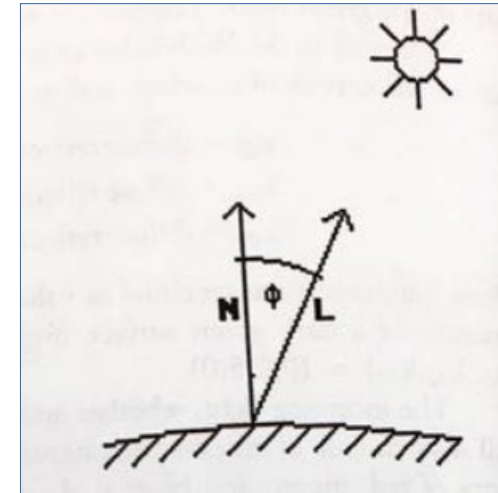
$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \frac{1}{\|\vec{r}\|_2} \quad \dots (1.1)$$

where

$$\|\vec{r}\|_2^2 = x_r^2 + y_r^2 + z_r^2$$

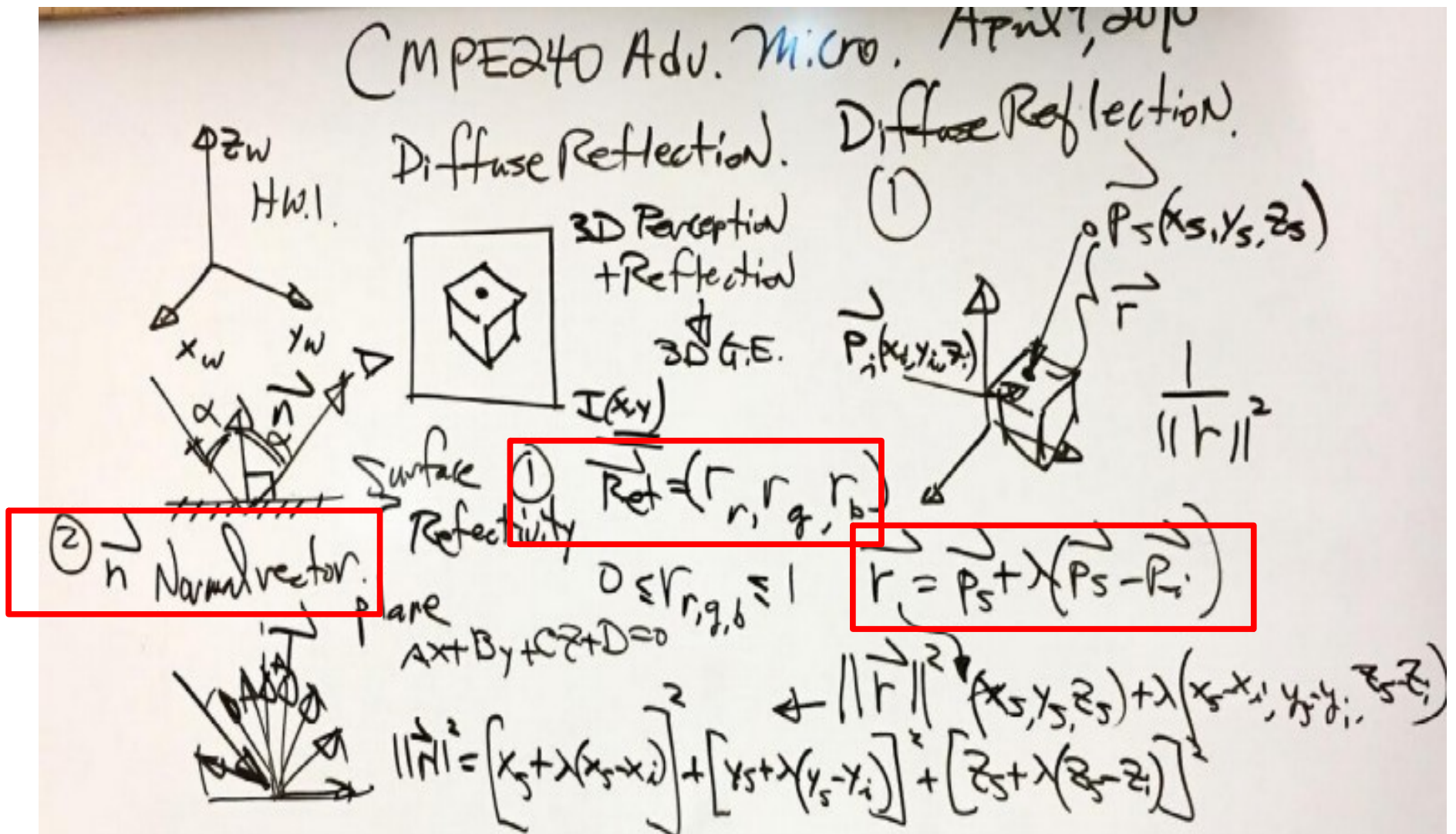
$$I_g = K_{dg} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.2)$$

$$I_b = K_{db} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.3)$$



Reference: Computer Graphics, C. K. Pokorny, C. F. Gerald, pp. 514

Formulation Of Diffuse Reflection Equation



Point Light Source And Incident Angle

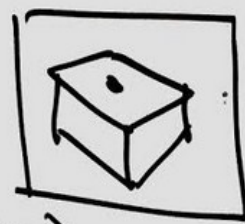
Point light source

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② $\vec{P}_S(x_s, y_s, z_s) = (r_{P_S}, g_{P_S}, b_{P_S})$

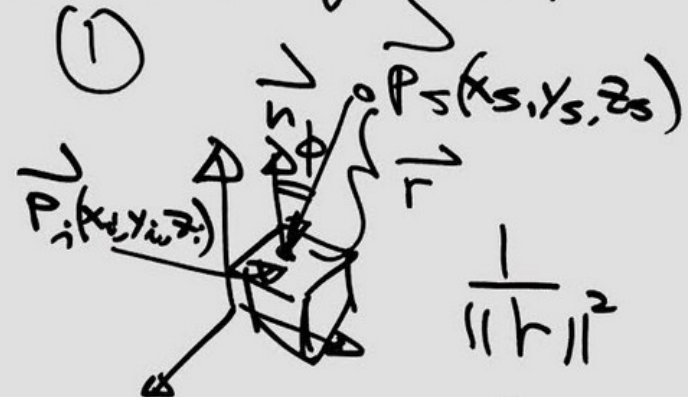


$0 \leq r, g, b \leq 1$
16 bits / 24 bits.
"The Sun"



Diffuse Reflection.

①



$$\frac{1}{\|r\|^2}$$

③

$$\vec{n} \cdot \vec{r} = \|\vec{n}\| \|\vec{r}\| \cos \phi$$

$$\cos \phi = \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|}$$

$$I_{diff}(x, y, z) = k \frac{1}{\|r\|^2} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} (r, g, b)$$

① ②

$$\vec{r} = \vec{P}_S + \lambda (\vec{P}_S - \vec{P}_i)$$

$$\|\vec{r}\|^2 = [x_s + \lambda(x_s - x_i)]^2 + [y_s + \lambda(y_s - y_i)]^2 + [z_s + \lambda(z_s - z_i)]^2$$

Angle of incident light

Step 1-5 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection

ONLY

Step 1. $\{ \vec{P}_i(x_i, y_i, z_i) | i \in I \}$

Step 2. \vec{P}_S white, Step 3.

$\vec{R} = (r, g, b) = (1.0, 0.0, 0.0)$ "Red"

Step 4. Eq (1)

$$I_{\text{diff}}(x, y, z) = k \frac{1}{\|\vec{r}\|^2} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} (r, g, b)$$

Compute Diff. Reflection ON Each Face (1) (2) ... (1)

"Visible" $\vec{P}_i(x_i, y_i, z_i)$ (world)

Step 5. Transformation Pipeline (World-2-Viewer + Perspective projection)

$P_1 \rightarrow P_2 \rightarrow P_3 \rightarrow P_4$
Counter Clockwise

Arrange vertex in contour clock wise direction when viewing from outside

The image contains handwritten notes and diagrams. The notes are organized into steps: Step 1 defines a set of points $\vec{P}_i(x_i, y_i, z_i)$. Step 2 and 3 specify material properties like white surface and a red reflection vector $\vec{R} = (1.0, 0.0, 0.0)$. Step 4 provides a formula for diffuse intensity $I_{\text{diff}}(x, y, z)$. Step 5 describes a transformation pipeline from world space to viewer space. Diagrams include a square face with a point $P(x, y)$, a 3D cube with a point $P_S(x_S, y_S, z_S)$ and vectors \vec{n} and \vec{r} , and a vertex ordering diagram showing vertices S_1, S_2, \dots arranged counter-clockwise.

Step 6 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection Diffuse Reflection.

ON LCD

Step 6. Compute Colour On Each Line (Linked by $\vec{P}_i \neq \vec{P}_j$)

Interpolation (B_i for $x \neq y$)

$I_{diff}(x,y,z) = k \frac{1}{\|r\|^2} \frac{n \cdot r}{\|n\| \|r\|} (r, g, b)$

Given \vec{P}_i, \vec{P}_j , Draw a line Linking $\vec{P}_i \neq \vec{P}_j$ "GAP'S"

D.D.A. $y = ax + b$

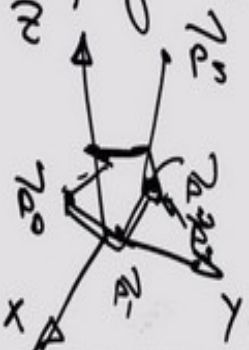
Step 5. Transformation Pipeline

Example On Diffuse Reflection Computation (1)

April 16, 2018 CMPE240 Adv. Micro HL 1/

- 1) Homework Submission via E-mail (Project w/ Source Code). the 2nd ONE ON SPI-Slave Due ^{Exported.} this Week;
- 2) Roadmap: Objective - 3D G.E. < 3D Diffuse Reflection
- 2D G.E. S.P.I. (master/slave) I/P
- 3) INTER for Summer (2 pos). (Hardware I/P)
ARM/CPU (Linux Device Driver.) LCD Driver*
Vision/Machine Learning

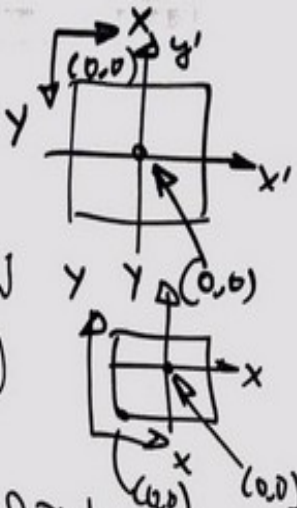
Example: Ray Equation. Continued from the Last Lecture.



$I_{diff, P_2}(x_2, y_2, z_2)$ in x_w, y_w, z_w World
 $E(200, 200, 200)$, Perspective Projection
 Input (2D LCD)

Viewer Coordinate System
 $\dots (1)$

Input (x_i, y_i, z_i)
 $X_i'' = \frac{D}{z_i} \cdot x_i$
 $Y_i'' = \frac{D}{z_i} \cdot y_i$
 focal Distance $D = 100$



Example On Diffuse Reflection Computation (2)

$\{\vec{P}_i(x_i, y_i, z_i) | i=0, 1, \dots, 6\}$
 Hence, from P.P. (Eqn-1), we have
 Suppose $D=10$, find
 $\{\vec{P}_i(x_i, y_i) | i=0, 1, \dots, 6\}$

Example: Given $(x_0, y_0) = (1, 1), (x_1, y_1) = (3, 5)$
D.D.A. to Draw a Line
 $Slope = a = \frac{y_1 - y_0}{x_1 - x_0} = \frac{5-1}{3-1} = 2$
 (Note: if $|a| < 1$, then No GAP,
 $y_{k+1} = a x_{k+1} + b, x_{k+1} = x_k$
 Switch x and y.
 $\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}$
 $y = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$
 $= \frac{y_2 - y_1}{x_2 - x_1}x + y_1 - \frac{y_2 - y_1}{x_2 - x_1}x_1$
 $y = ax + b, \frac{1}{a}y = x + \frac{b}{a} (1,1)$
 $\therefore x = \frac{1}{a}y - \frac{b}{a} \dots (2)$
 $x = \frac{1}{2}y + \frac{1}{2} \begin{cases} x_{k+1} = x+1 \\ x_{k+1} = \frac{1}{2}y_{k+1} + \frac{1}{2} \end{cases}$

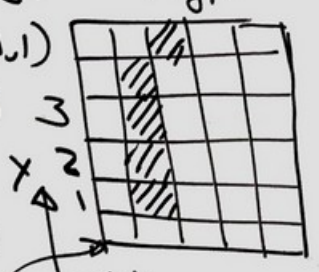
(Location + Color)
Interpolation to find Color
Find Boundaries?
 Find Boundary: $y = ax + b$
 $y_{k+1} = ax_{k+1} + b, x_{k+1} = x_{k+1}$
D.D.A. (Digital Differential Algorithm)

Diagrams showing a square grid with points and a line segment drawn through it, illustrating the DDA algorithm.

A 7x7 grid with columns labeled 0 to 6. The grid shows the path of a line segment drawn using the DDA algorithm, starting at (1,1) and ending at (3,5). The path is marked by blue squares at (1,1), (2,2), (3,3), (3,4), (3,5), (2,6), and (1,7).

Use DDA Algorithm To Find Boundary Points

Algorithm: 1° Given (x_0, y_0) Starting pt, (x_{N-1}, y_{N-1}) Ending pt.
 Find Slope a ;
 2° if $|a| < 1$, then $\begin{cases} x_{k+1} = x_k + 1 \\ y_{k+1} = ax_{k+1} + b \end{cases}$
 3° Finish all pts till Reaching (x_{N-1}, y_{N-1}) or $x = \frac{1}{a}y - \frac{b}{a}$, then $\begin{cases} y_{k+1} = y_k + 1 \\ x_{k+1} = \frac{1}{a}y_{k+1} - \frac{b}{a} \end{cases}$
 DDA Algorithm

Harry LI CMPE240 Adv. Micro April 18, 2018. y.
 Diffuse Reflection Computation.
 D.D.A (github/rualili)
 Example: Fig. 1
 Starting pt. (1,1)
 Ending (2,5)
 Slope: $\frac{y_2 - y_1}{x_2 - x_1} = \frac{5-1}{2-1} = 4$ (0,0)

 $y = ax + b \rightarrow x = \frac{1}{a}y + \left(-\frac{b}{a}\right)$
 For $y_3 = y_2 + 1 = 2 + 1 = 3$
 $x_3 = \frac{1}{a}y_3 + \left(-\frac{b}{a}\right) = \frac{1}{4} \cdot 3 + \frac{1}{4} = \frac{4}{4} = 1$ $b = -1$
 For $y_4 = y_3 + 1 = 3 + 1 = 4$
 $x_4 = \frac{1}{a}y_4 + \left(-\frac{b}{a}\right) = \frac{1}{4} \cdot 4 + \frac{1}{4} = \frac{5}{4}$ $b = -1$
 Next. Diffuse Reflection ON Boundaries.
 Index: $y_{k+1} = y_k + 1$
 $x_{k+1} = \frac{1}{a}y_{k+1} + \left(-\frac{b}{a}\right)$
 $= \frac{1}{4} \cdot 2 + \left(-\frac{1}{4}\right) = \frac{3}{4}$ $y_k = 1$

① DDA: Where pixels locations are.

② Interpolation to find color (Diffuse Reflection)

From 3D illustration in Fig 2 → 2D

Note:

1. Derive linear interpolation technique, equation (1) and (2), to find the boundary color along x-dimension and y-dimension respectively;
2. Then calculate average of the color from x-dimension and y-dimension as in Equation (3).

Develop Interpolation Technique:

$$I_{diff}(x) = \frac{I_{diff}(x_i) - I_{diff}(x_j)}{x_i - x_j} x - \frac{x_j}{x_i - x_j} (I_{diff}(x_i) - I_{diff}(x_j)) + I_{diff}(x_j) \quad (1)$$

$$I_{diff}(y) = \frac{I_{diff}(y_i) - I_{diff}(y_j)}{y_i - y_j} y - \frac{y_j}{y_i - y_j} (I_{diff}(y_i) - I_{diff}(y_j)) + I_{diff}(y_j) \quad (2)$$

$$I_{diff}(x,y) = \frac{1}{2} (I_{diff}(x) + I_{diff}(y)) \quad (3)$$

where $(x,y) \in \Omega_{DDA}$

1. Derive linear interpolation technique, equation (1) and (2), to find the boundary color along x-dimension and y-dimension respectively;
2. Then calculate average of the color from x-dimension and y-dimension as in Equation (3).

$$I_{diff}(y) = \frac{I_{diff}(y_i) - I_{diff}(y_j)}{y_i - y_j} y - \frac{y_j (I_{diff}(y_i) - I_{diff}(y_j))}{y_i - y_j} + I_{diff}(y_j) \quad (2)$$

$$I_{\text{DDA}}(x, y) = \frac{1}{2} (I_{\text{DA}}(x) + I_{\text{DA}}(y)) \quad \dots (3)$$

where $(x, y) \in \Omega_{\text{DDA}}(\text{DDApts})$