# IBMR 2010 Project Part-2

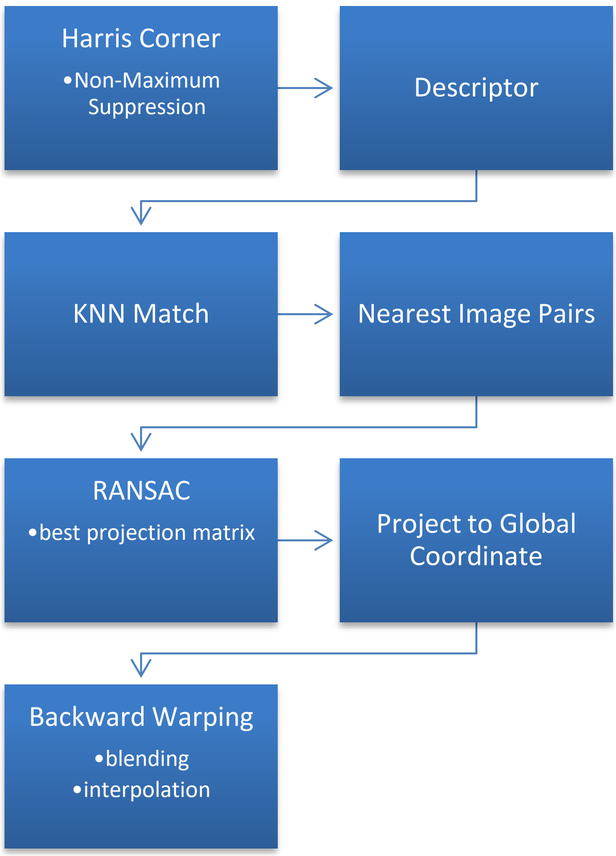
*Requirement*

- RANSAC
- Projection Mapping / Affine Mapping
- Image Warping

*Bonus*

- Non-Maximum Suppression
- Bilinear Interpolation
- Linear Blending
- Stitching your own photos

*Work flow*



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# *Classes*

欄位

方法

add() : Matrix (+ 1 多載)
at() : double& (+ 1 多載)

div() : Matrix (+ 1 多載)
get() : double (+ 1 多載)

Matrix() (+ 4 多載)

mul() : Matrix (+ 1 多載)
multiply() : Matrix (+ 1 多載)

operator-() : Matrix (+ 1 多載)
operator*() : Matrix (+ 1 多載)
operator/() : Matrix (+ 1 多載)
operator+() : Matrix (+ 1 多載)

sub() : Matrix (+ 1 多載)

欄位

方法

方法

printMatrix() : void (+ 1 多載)

方法

欄位

欄位

欄位

*Implement method*

# *Nearest Image Pairs*

**Step 1.** For image1, image2…imageN , get Descriptors from each image and put them into Descriptors container $\mathrm{D}$. Each Descriptor $\mathrm{D}_i$ contains the following attributes

欄位

- image: the image index of this descriptor
- col: the center position X in image
- row: the center position Y in image
- matrix: descriptor patch

**Step 2.** Using KNN search to find the most nearest Descriptor pair for each $\mathrm{D}_i$. Each matching pair contains the following attributes

欄位

- image1: Descriptor1 image index
- Image2: Descriptor2 image index
- X1: Descriptor1 center X
- Y1: Descriptor1 center Y
- X2: Descriptor2 center X
- Y2: Descriptor2 center Y

**Step 3.** Vote the nearest image using a counter matrix $\mathrm{C}_{\mathrm{N}\times\mathrm{N}}$. The value of $\mathrm{C}_{\mathrm{ij}}$ shows how many matching pairs from image i to image j (where $\mathrm{C}_{\mathrm{ii}}$ must be zero because image cannot match to itself).

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 10 | 3 | 49 |
| 1 | 1 | 0 | 15 | 21 | 2 |
| 2 | 7 | 15 | 0 | 10 | 26 |
| 3 | 3 | 19 | 8 | 0 | 3 |
| 4 | 40 | 3 | 23 | 3 | 0 |

**Step 4.** There are at least $N-1$ connects between two images, and two overlap possibilities for each connect. We could match the $2(N-1)$ top biggest connects by the following rules.

a、 Select the most biggest $C_{ij}$ and set $C_{ij} = C_{ji} = -1$ mark as checked

b、 Compute projection matrix $P_{ij}$ and $P_{ji}$ using RANSAC

c、 If checked connects $< 2(N-1)$, go to step a.

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 10 | 3 | -1 |
| 1 | 1 | 0 | 15 | 21 | 2 |
| 2 | 7 | 15 | 0 | 10 | 26 |
| 3 | 3 | 19 | 8 | 0 | 3 |
| 4 | -1 | 3 | 23 | 3 | 0 |

Find max value $C_{04} = 49$

Compute projection matrix $P_{04}$ and $P_{40}$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 10 | 3 | -1 |
| 1 | 1 | 0 | 15 | 21 | 2 |
| 2 | 7 | 15 | 0 | 10 | -1 |
| 3 | 3 | 19 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Find max value $C_{24} = 26$

Compute projection matrix $P_{24}$ and $P_{42}$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 10 | 3 | -1 |
| 1 | 1 | 0 | 15 | -1 | 2 |
| 2 | 7 | 15 | 0 | 10 | -1 |
| 3 | 3 | -1 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Find max value $C_{13} = 21$

Compute projection matrix $P_{13}$ and $P_{31}$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 10 | 3 | -1 |
| 1 | 1 | 0 | -1 | -1 | 2 |
| 2 | 7 | -1 | 0 | 10 | -1 |
| 3 | 3 | -1 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Find max value $C_{12} = 15$

Compute projection matrix $P_{12}$ and $P_{21}$

# *Project to Global Coordinate*

- Once we have the projection matrices connect the two nearest images, we can project all images into a global coordinate (in this example is the coordinate of image 0).

$$P_{gj} = P_{gk} * P_{kj}$$

- Let image 0 to be the global coordinate. If $P_{i0}$ and $P_{ij}$ exist, compute $P_{j0}$ and $P_{0j}$ by

$$P_{j0} = P_{ji} * P_{i0}$$
$$P_{0j} = P_{j0}^{-1}$$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 10 | 3 | -1 |
| 1 | 1 | 0 | -1 | -1 | 2 |
| 2 | 7 | -1 | 0 | 10 | -1 |
| 3 | 3 | -1 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Find $P_{40}$ and $P_{42}$ exist

Compute $P_{20}$ and $P_{02}$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 4 | -1 | 3 | -1 |
| 1 | 1 | 0 | -1 | -1 | 2 |
| 2 | -1 | -1 | 0 | 10 | -1 |
| 3 | 3 | -1 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Find $P_{20}$ and $P_{21}$ exist

Compute $P_{10}$ and $P_{01}$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | -1 | -1 | 3 | -1 |
| 1 | -1 | 0 | -1 | -1 | 2 |
| 2 | -1 | -1 | 0 | 10 | -1 |
| 3 | 3 | -1 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Find $P_{10}$ and $P_{13}$ exist

Compute $P_{30}$ and $P_{03}$

| Image | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | -1 | -1 | -1 | -1 |
| 1 | -1 | 0 | -1 | -1 | 2 |
| 2 | -1 | -1 | 0 | 10 | -1 |
| 3 | -1 | -1 | 8 | 0 | 3 |
| 4 | -1 | 3 | -1 | 3 | 0 |

Fill complete

## *Backward Warping*

**Step 1.** Let $\mathrm{W}_i$ and $\mathrm{H}_i$ as width and height of image i.

The boundary of image i $\mathrm{B}_i = \begin{bmatrix} 0 & \mathrm{W}_i & 0 & \mathrm{W}_i \\ 0 & 0 & \mathrm{H}_i & \mathrm{H}_i \\ 1 & 1 & 1 & 1 \end{bmatrix}$

**Step 2.** Project $\mathrm{B}_i$ to image 0 coordinate by $\mathrm{P}_{0i}$

$$\mathrm{B}_i' = \frac{\mathrm{P}_{0i} * \mathrm{B}_i}{s}, where\ s\ is\ the\ scaler of\ each\ point$$

**Step 3.** Since we have $\mathrm{B}_i' (where\ i = 1 \ldots N)$, select $\mathrm{maxX}, \mathrm{maxY}, \mathrm{minX}, \mathrm{minY}$.
The global boundary is $(\mathrm{minX}, \mathrm{minY})$ as left-top bound, and $(\mathrm{maxX}, \mathrm{maxY})$ as right-bottom bound.

**Step 4.** Create a result image $\mathrm{R}$ with

$$\mathrm{width} = \mathrm{maxX} - \mathrm{minX} + 1$$

$$\mathrm{height} = \mathrm{maxY} - \mathrm{minY} + 1$$

**Step 5.** For each point in result image, project to every image coordinate by $\mathrm{P}_{i0}$.

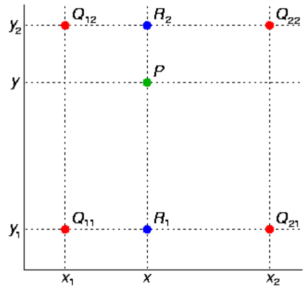
$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \mathrm{P}_{i0} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

**Step 6.** If $u$ and $v$ is in the boundary of $\mathrm{I}_i$, set $\mathrm{R}(x, y) = \mathrm{I}_i(u, v)$

# Bilinear Interpolation

$\mathrm{R}(x, y) = \mathrm{I}_i(u, v)$. When $u$ and $v$ are floating numbers, we can use Bilinear Interpolation instead of nearest method to avoid aliasing.

Let $\mathrm{P} = \mathrm{I}_i(u, v)$




$$\mathrm{R}(x, y) = \mathrm{Q}_{11}(x_2 - x)(y - y_2) +$$
$$\mathrm{Q}_{12}(x_2 - x)(y_1 - y) +$$
$$Q_{21}(x - x_1)(y - y_2) +$$
$$Q_{22}(x - x_1)(y_1 - y)$$

# Linear Blending

In Backward Warping step 5 and step 6, $\mathrm{R}(x, y)$ could map to multiple images $(u_i, v_i)$ which means $\mathrm{R}(x, y)$ is in the overlapped area.

**Step 1.** Compute each distance $\mathrm{D}_i$ from $(u_i, v_i)$ to image i center $(X_i, Y_i)$.

$$\mathrm{D}_i = \sqrt{(u_i - X_i)^2 (v_i - Y_i)^2}$$

**Step 2.** The value of $\mathrm{R}(x, y)$

$$\mathrm{R}(x, y) = \frac{\sum \frac{1}{\mathrm{D}_i}(u_i, v_i)}{\sum \frac{1}{\mathrm{D}_i}}$$

# *Projection Mapping*

Project image i $(x_i, y_i)$ to image j $(u_i, v_i)$

$$\begin{bmatrix} su_i \\ sv_i \\ s \end{bmatrix} = P_{ji} \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix}$$

$$\begin{cases} su_i = ax_i + by_i + c \\ sv_i = dx_i + ey_i + f \\ s = gx_i + hy_i + i \end{cases}$$

$$solve \begin{cases} ax_i + by_i + c - (gx_i + hy_i + i)u_i = 0 \\ dx_i + ey_i + f - (gx_i + hy_i + i)v_i = 0 \end{cases}$$

$$Let\ i = 1, 2, 3 \dots k, where\ k \geq 4\ because\ of\ the\ \text{DOF} = 8$$

$$\text{solve A}[a \quad b \quad c \quad d \quad e \quad f \quad g \quad h \quad i]^T = 0$$

$$\begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -u_1x_1 & -u_1y_1 & -u_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -v_1x_1 & -v_1y_1 & -v_1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 & -u_2x_2 & -u_2y_2 & -u_2 \\ 0 & 0 & 0 & x_2 & y_2 & 1 & -v_2x_2 & -v_2y_2 & -v_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_k & y_k & 1 & 0 & 0 & 0 & -u_kx_k & -u_ky_k & -u_k \\ 0 & 0 & 0 & x_k & y_k & 1 & -v_kx_k & -v_ky_k & -v_k \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \end{bmatrix} = 0$$

Using SVD get $\text{A} = \text{USV}^T$, where V is a 9-by-9 matrix

$$P_{ji} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} = \text{scale} * \begin{bmatrix} V_{19} & V_{29} & V_{39} \\ V_{49} & V_{59} & V_{69} \\ V_{79} & V_{89} & V_{99} \end{bmatrix}$$

# *RANSAC*

**Step 1.** Get $n$ matching pairs from two nearest image i and j

| pair | image i | | image j | |
|---|---|---|---|---|
| 1 | $x_1$ | $y_1$ | $u_1$ | $v_1$ |
| 2 | $x_2$ | $y_2$ | $u_2$ | $v_2$ |
| 3 | $x_3$ | $y_3$ | $u_3$ | $v_3$ |
| 4 | $x_4$ | $y_4$ | $u_4$ | $v_4$ |
| ⋮ | | | | |
| n | $x_n$ | $y_n$ | $u_n$ | $v_n$ |

**Step 2.** Set the best projection matrix $\mathrm{BP} = \mathrm{NULL}$,
best supported counter $\mathrm{BS} = 0$, loop $\mathrm{L} = 0$.

**Step 3.** Random select $k$ matching pairs to solve projection matrix $P_{ji}$

**Step 4.** Project all image i points $(\mathrm{x}_i, \mathrm{y}_i)$ to image j coordinate $(\mathrm{x}_i', \mathrm{y}_i')$

**Step 5.** Set supported counter $\mathrm{S} = 0$, and check all projected points$(\mathrm{x}_i', \mathrm{y}_i')$.
If$|\mathrm{x}_i' - u_i| < threshold\ and\ |\mathrm{y}_i' - v_i| < threshold,\ \mathrm{S{+}{+}}$.

**Step 6.** If $\mathrm{S} > \mathrm{BS}$, set $\mathrm{BP} = P_{ji}\ and\ BS = S$

**Step 7.** If $\mathrm{L} < \mathrm{maxLoop},\ \mathrm{L{+}{+}}$ and go to **Step3**

**Step 8.** Return the best projection matrix $\mathrm{BP}$

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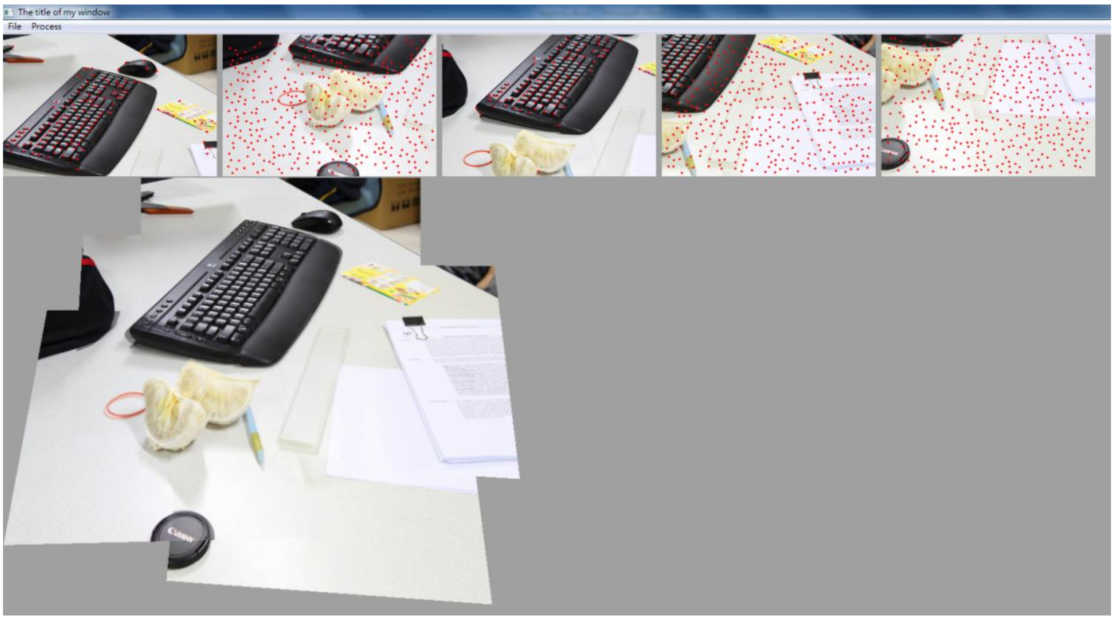
# *Result*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