動画像を用いた高度道路交通システム

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Virtual View Generating Using Image-based Rendering (IBR)

Objective

- Generating image stream of a virtual view point using images from multiple static cameras

- Applications
  - ITS (safe driving assistance)
  - Security surveillance
  - Entertainment

Related work（1/3）

- Feature detection
  - Detect features using SIFT [Lowe, IJCV 2004]

Related work（2/3）

- Pairwise feature matching
  - match features between each pair of images

Related work（3/3）

- Refine matching using RANSAC [Fischler & Bolles 1987]

Approach

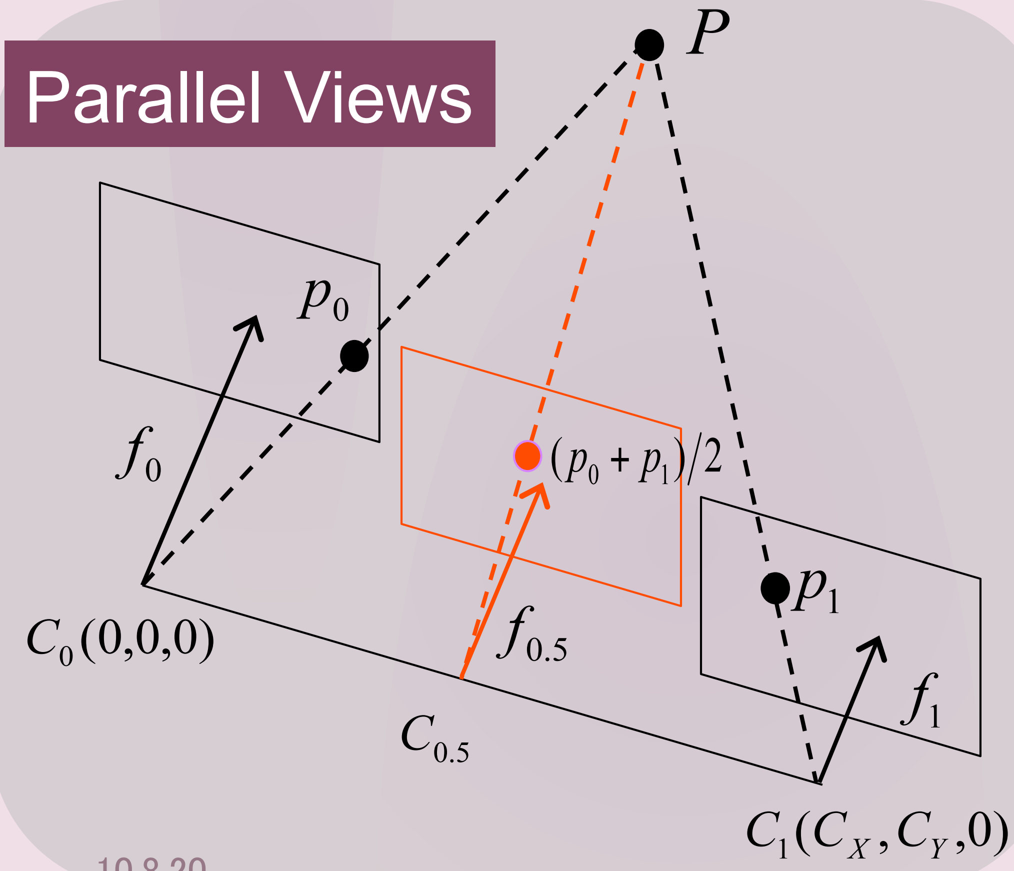
- Our approach extends view morphing (a IBR method based on implicit geometry) by integrating
  - Robust fundamental matrix estimation
  - Feature matching

- View morphing has not been wildly used in real application
  - Shape preserved
  - Disadvantage
    - Excess needs of manual operations
    - Need of a prior knowledge of scene geometry

Shape-preserving

Parallel view: situation where linear interpolation of images is *shape-preserving*

Parallel Views



Perspective projection

$$\Pi_1 = \begin{bmatrix} f_1 & 0 & 0 & -f_1 C_X \\ 0 & f_1 & 0 & -f_1 C_Y \\ 0 & 0 & f_1 & 0 \end{bmatrix}$$

$$\Pi_0 = \begin{bmatrix} f_0 & 0 & 0 & 0 \\ 0 & f_0 & 0 & 0 \\ 0 & 0 & f_0 & 0 \end{bmatrix}$$

Linear interpolation

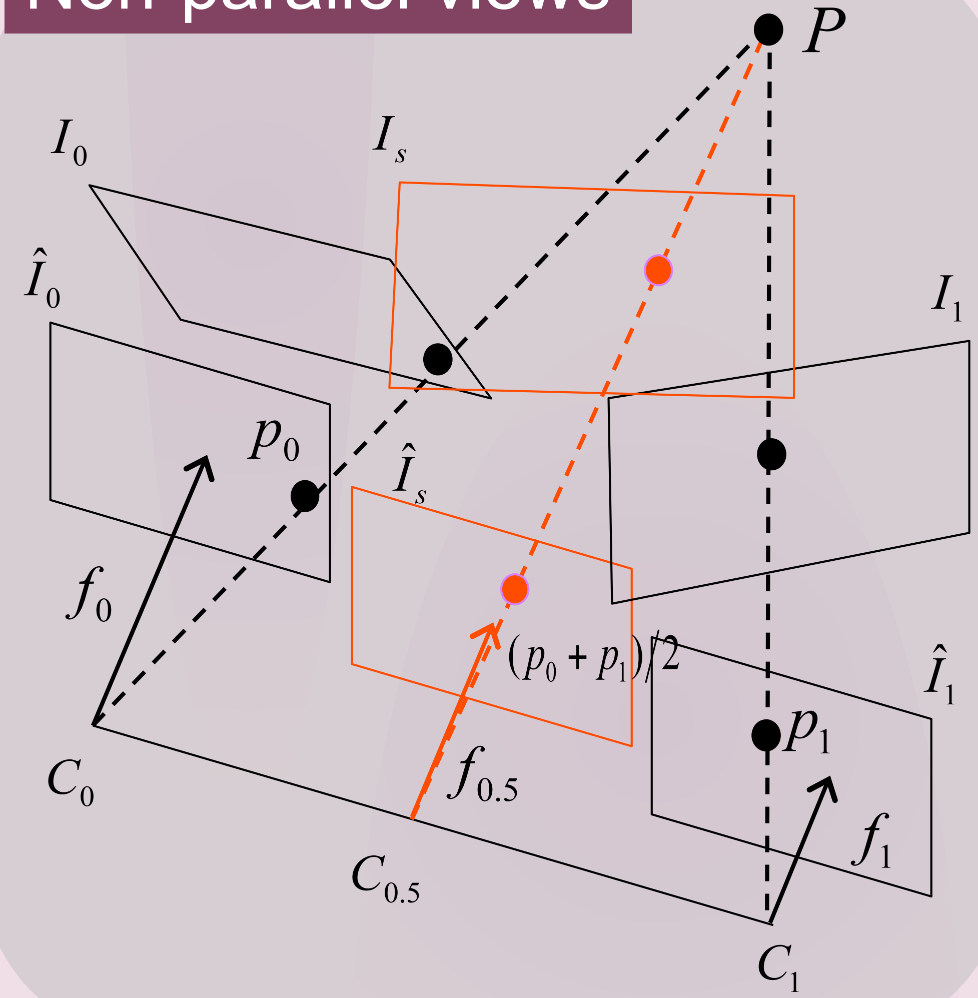
$$(1-s)p_0 + sp_1$$
$$= (1-s)\frac{1}{Z}\Pi_0 P + s\frac{1}{Z}\Pi_1 P$$
$$= \frac{1}{Z}\Pi_s P$$

New perspective view

$$\Pi_s = (1-s)\Pi_0 + s\Pi_1$$
$$C_s = (sC_X, sC_Y, 0)$$
$$f_s = (1-s)f_0 + sf_1$$

View morphing

Non-parallel views



Three steps

(1) Prewarping

original images I_0, I_1 are prewarped to form parallel views $\hat{I}_0, \hat{I}_1$

(2) Morph

$\hat{I}_s$ is produced by interpolating the prewarped images

(3) Postwarping

$\hat{I}_s$ is postwarped to form I_s

Prewarping（1/4）

- Projective transforms: H_0, H_1
  - Each consisting of rotations

- $R_{\theta_i}^{d_i}$: rotation of angle θ_i about axis d_i in depth which makes the image plane become parallel
- R_{ϕ_i} : Affine warping to align the scanlines

Prewarping（2/4）

- How we do prewarping ?

①Estimate fundamental matrix: F

- Using 8-point algorithm
  - Select a set of key points from I_0, I_1 by SIFT
  - Match key points between image pair
    - Finding the nearest neighbor of their descriptors in Euclidean distance
  - Estimate F via RANSAC iterations
    - Linear estimation from 8 points correspondence

Prewarping（3/4）

②Factorize F with singular value decom-position

- Obatin two unit eigenvectors

$$e_0 = \left[e_0^x, e_0^y, e_0^z\right]^T,\ e_1 = \left[e_1^x, e_1^y, e_1^z\right]^T$$

- Select rotation axes as

$$d_0 = \left[-e_0^y, e_0^x, 0\right]^T,\ \left[x, y, z\right]^T = F d_0,\ d_1 = \left[-y, x, 0\right]^T$$

- Calculate angles

$$\theta_i = -\frac{\pi}{2} - \tan^{-1}\left(\frac{d_i^y e_i^x - d_i^x e_i^y}{e_i^z}\right)$$

$$\phi_i = -\tan^{-1}\left(\tilde{e}_i^y / \tilde{e}_i^x\right)$$

Prewarping (4/4)

③Do projective transform

- After image been rotated twice,

$$\widetilde{F} = R_{\phi_1} R_{\theta_1}^{d_1} F R_{-\theta_0}^{d_0} R_{-\phi_0} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & a \\ 0 & b & c \end{bmatrix}$$

- F should be in the form

$$(H_1^{-1})^T F H_0^{-1} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

- Introduce a translation T on I_1
- Calculate projective transform

$$T = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -a & -c \\ 0 & 0 & b \end{bmatrix}$$

$$H_0 = R_{\phi_0} R_{\theta_0}^{d_0}, H_1 = T R_{\phi_1} R_{\theta_1}^{d_1}$$

Image Interpolation（1/2）

- Feature correspondence
  - Need a sufficient number of matches between source images and they should be equally distributed.
    - Difficult in case of images with wild baseline
- How we do interpolating

①Jointly use SIFT and Harris detectors

②Corner point: normalized cross-correlation

SIFT point: nearest neighbor in descriptor

Image Interpolation（2/2）

- How we do interpolating

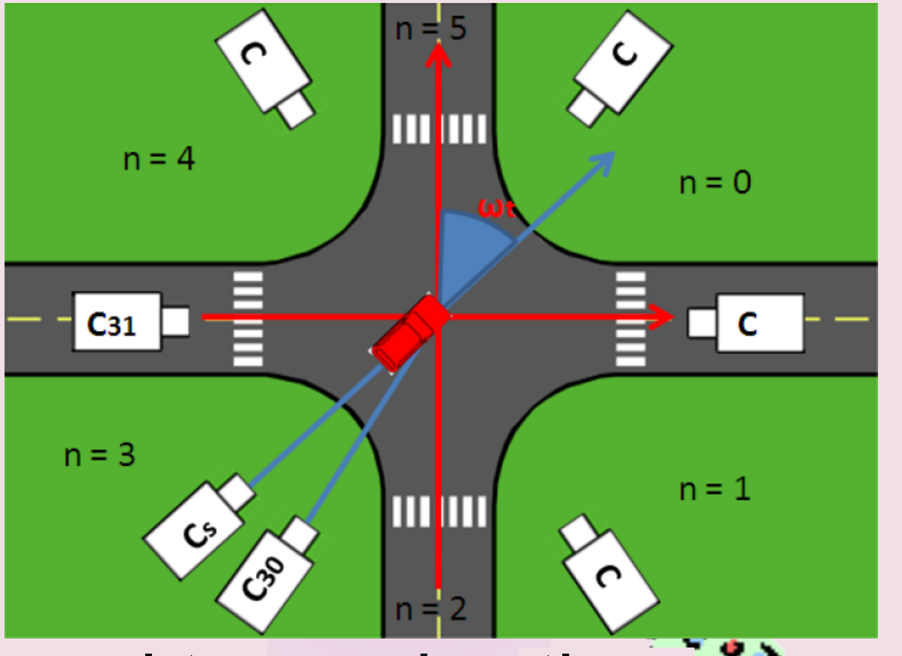
③Eliminate the false outliers

- Use the precomputed fundamental matrix to remove outliers by enforcing Epipolar constrain $\tilde{m}'^{T} F \tilde{m} = 0$
  - Obtain a set of sufficient correspondence with high confidence
- If necessary, improve the results by hand.

④Do image warp and cross-dissolve

Experiments（1/6）

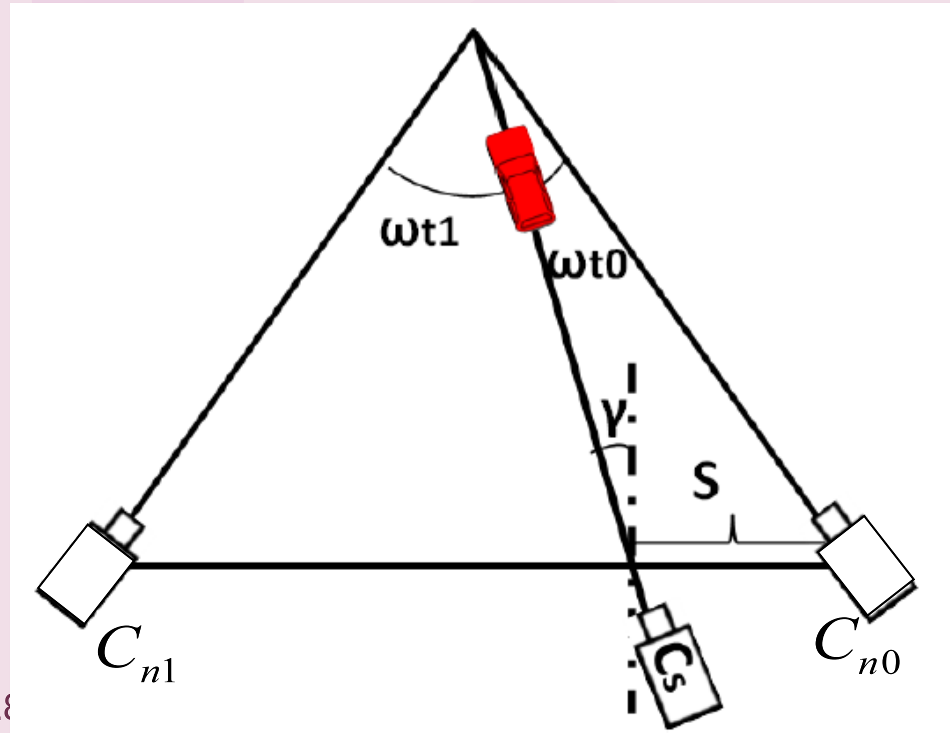
- Apply our method to intersection images
  - Generate a reference view that dynamically follows host vehicle at high position
- Camera setting
  - Six cameras, not calibrated in advance
  - Each one and clockwise neighbor form a pair C_{n_0}, C_{n_1}



  - Onboard system is supposed to receive the image stream while approaching intersection

Experiments（2/6）

- Assume online direction of host vehicle is known as ω_t
- Choose camera pair n which has the closest direction with ω_t

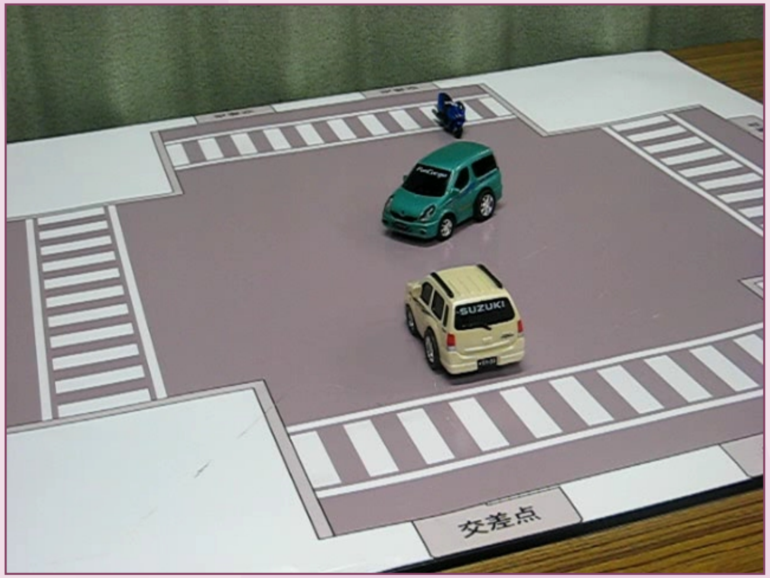


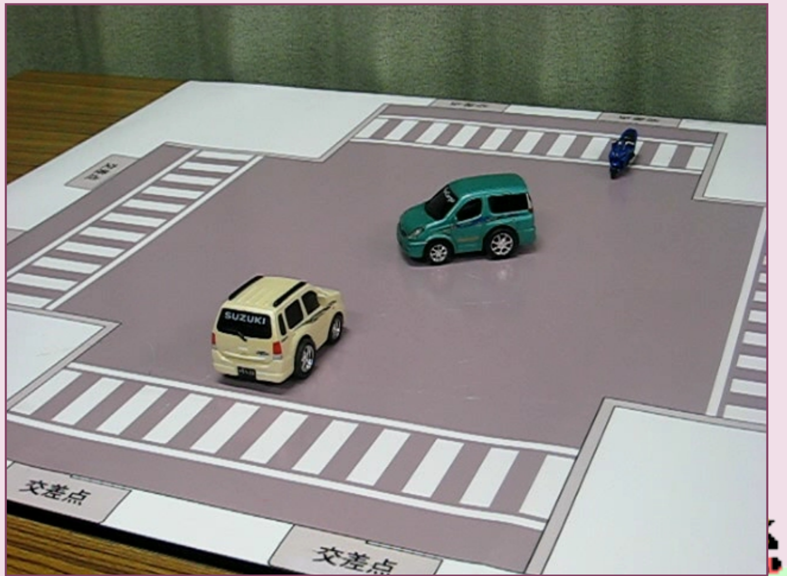
Approximate morphing rate s by

$$s_t = \omega_{t0} / (\omega_{t0} + \omega_{t1})$$
$$\gamma = (\omega_{t1} - \omega_{t0})$$

Experiments（3/6）

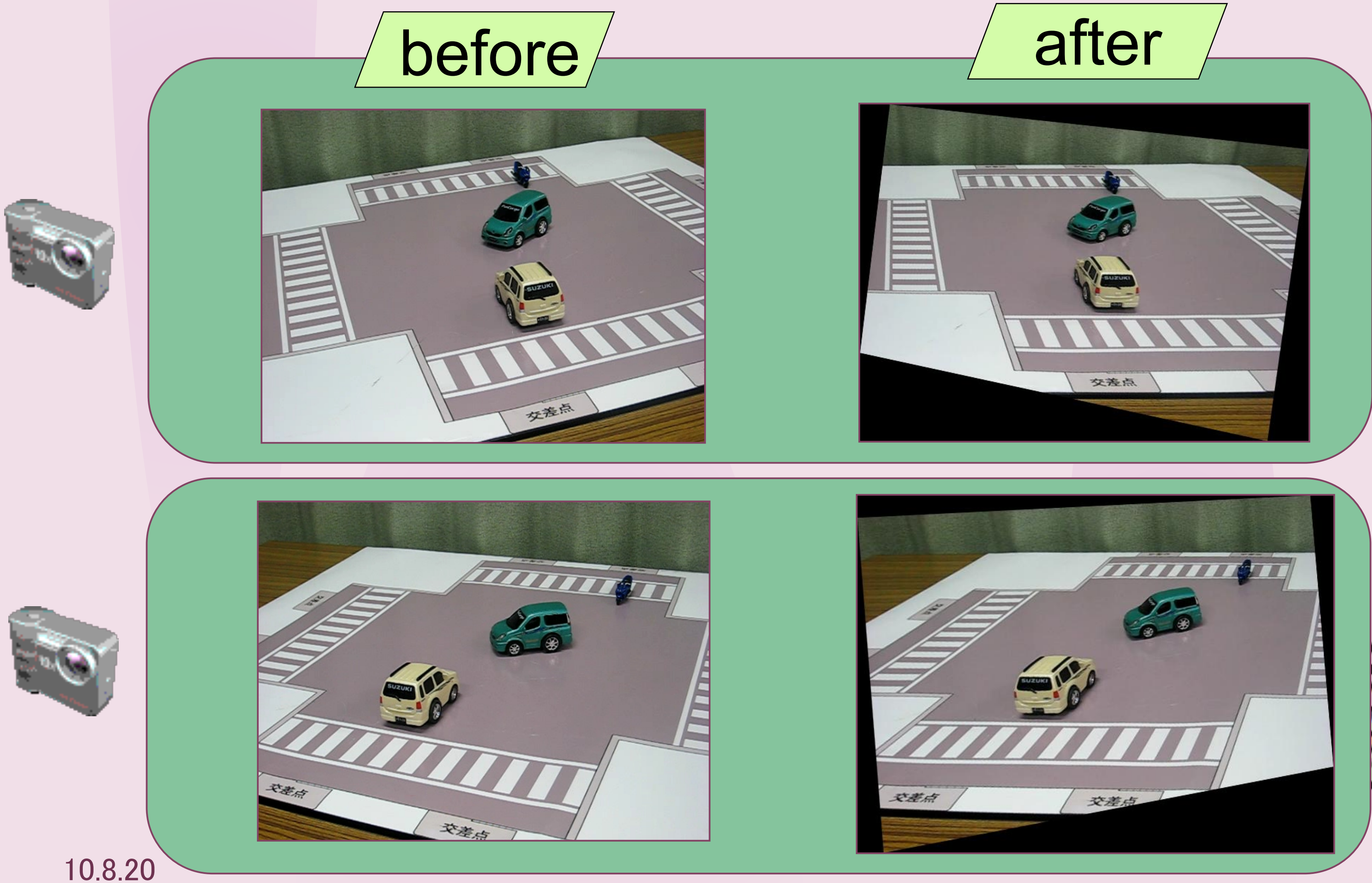
- Source image streams
  - Distance of viewpoints is around 60^o





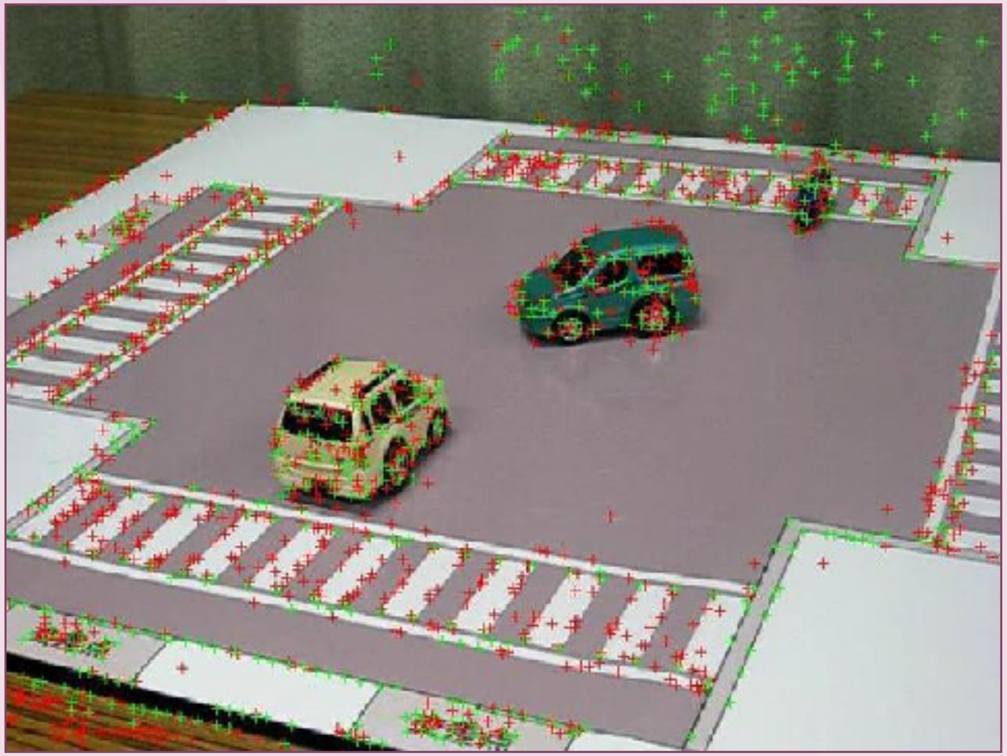
Experiments（4/6）

- Prewarping



Experiments（5/6）

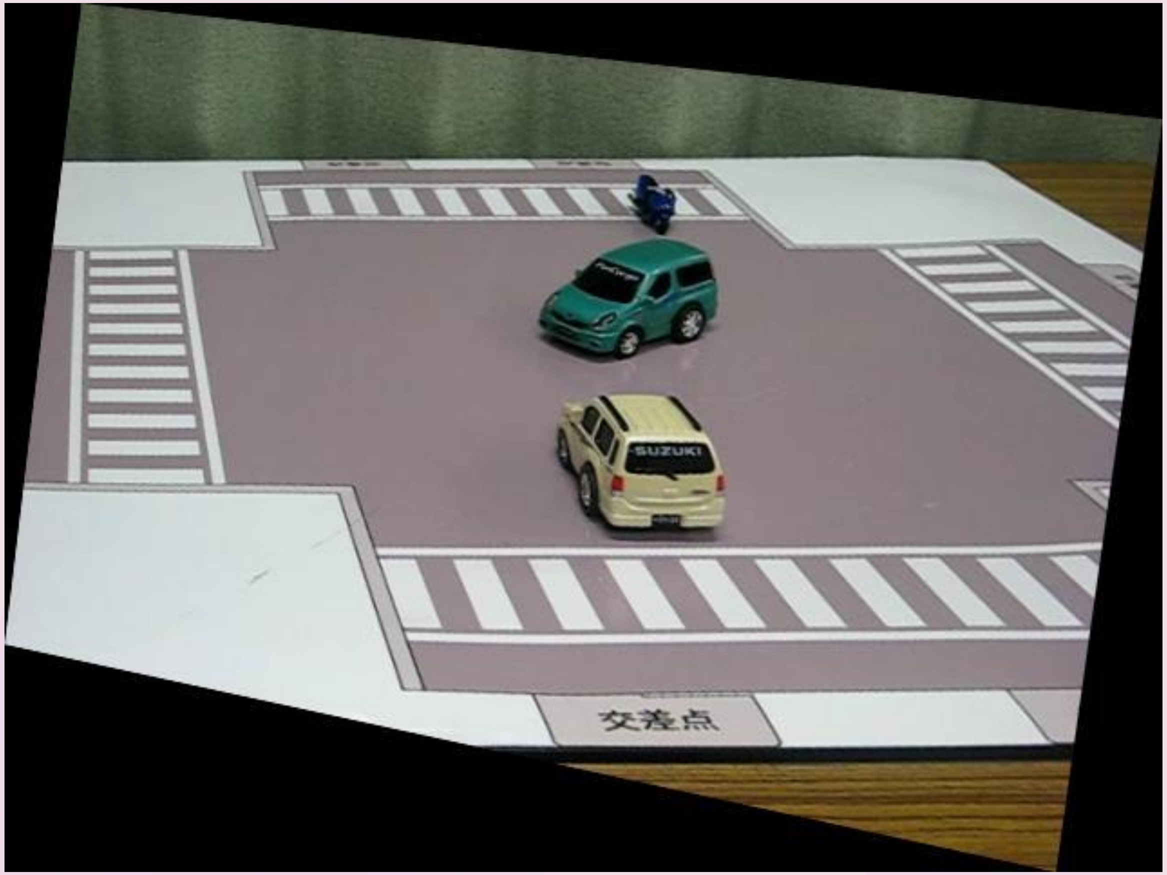
- Results of SIFT & Harris-Corner detectors



+ : SIFT
+ : Harrs

Experiments（6/6）

- An image stream from a virtual viewpoint



Conclusion

- To put view morphing into practice use, it is necessary to reduce manual operations
- Our approach has shown a solution
  - It is capable to work on images even taken from disparate view points
    - Without any prior knowledge of scene geometry
    - Without excess manual operation
  - Results are good.
- Need more tests.