Center for Embedded Systems
An NSF Industry/University Cooperative Research Center

Registration and Fusion of EVS and SVS Runway Images for Embedded Systems

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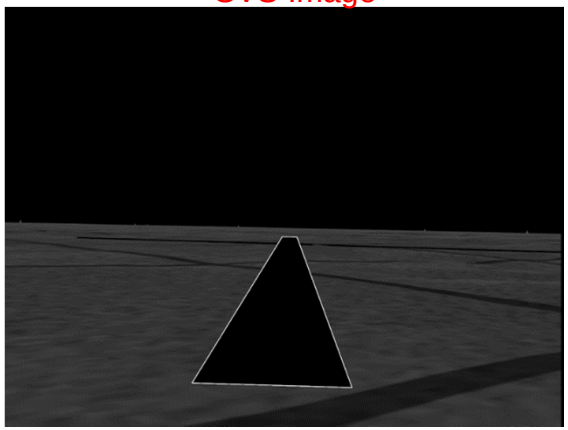
Project Overview and Description

Project Description

- The precise detection of runways is crucial for safely landing aircrafts because more than half of the accidents occur during the final approach and landing.
- The runway detection methodology being developed exploits information from enhanced vision system (EVS) and synthetic vision system (SVS) image frames of the runways.
- The goal is to generate image frames that contain enhanced runway and surrounding information by fusing the EVS and SVS frames.
- The resulting image frames can be incorporated into head-up displays (HUDs) to assist the pilot in landing the aircraft safely.

EVS Image

SVS Image



Approach

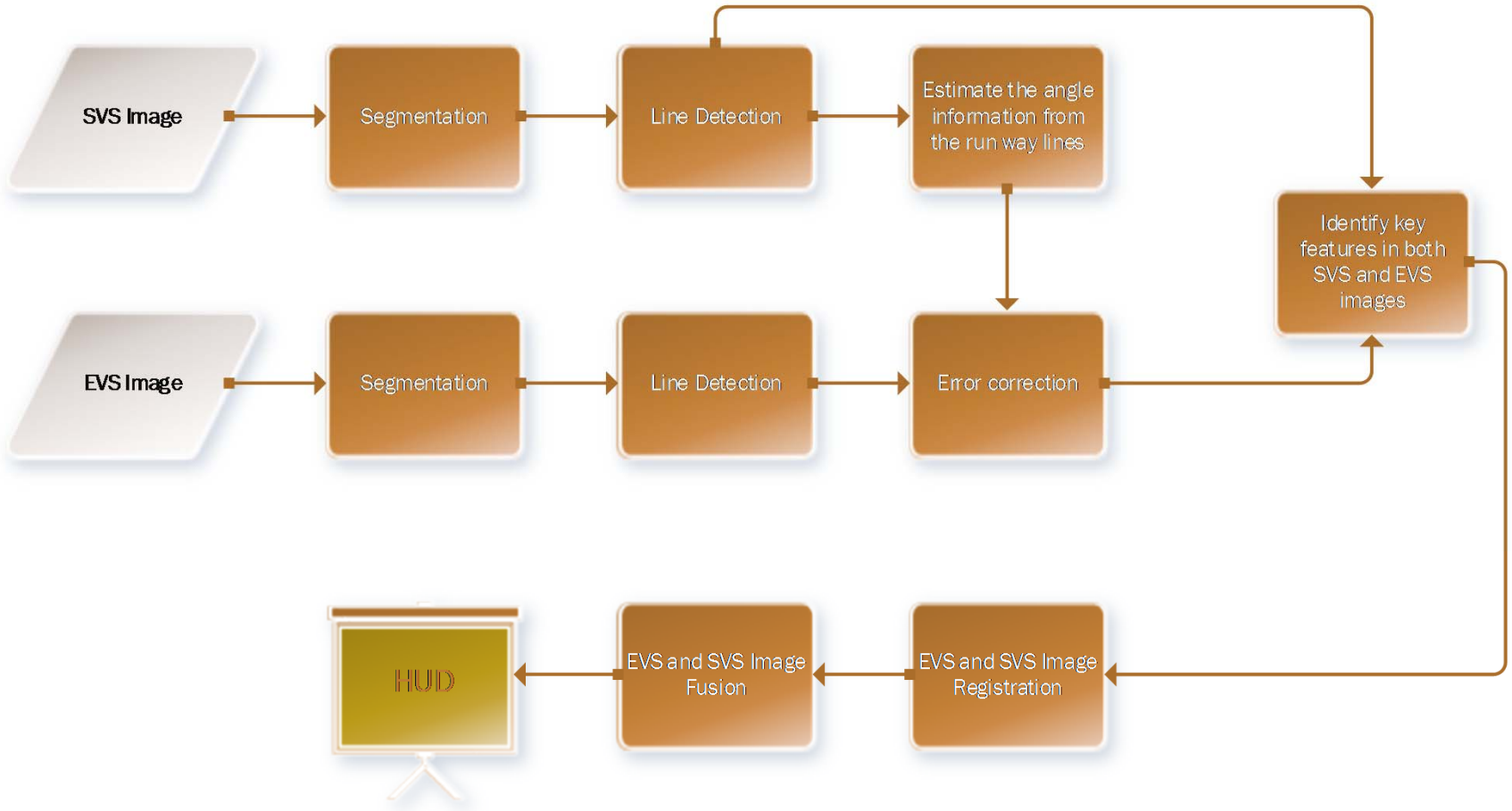
Novelty

1. Fusion of EVS and SVS images
2. Novel algorithms to:
   (a) Extract features from EVS and SVS images
   (b) Register EVS and SVS runway images
   (c) Fuse the registered images so that the information from both images can be displayed optimally
   (d) Simulate adverse weather condition images to objectively evaluate performance
3. Embed algorithms into multi-core processing environments for real-time applications

Benefits to member companies

1. Lead to the development of novel landing heads-up display systems
2. Will also be applicable to a vast range of other problems at Rockwell Collins involving image registration and image fusion.

Technical Detail



Technical Detail

Laplacian Line Detection Masks

-1	-1	-1
2	2	2
-1	-1	-1

2	-1	-1
-1	2	-1
-1	-1	2

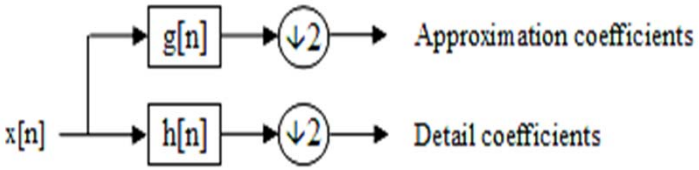
-1	2	-1
-1	2	-1
-1	2	-1

-1	-1	2
-1	2	-1
2	-1	-1

DWT

$$y_{low}[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k].g[n-k]$$

$$y_{high}[n] = (x * h)[n] = \sum_{k=-\infty}^{\infty} x[k].h[n-k]$$



Technical Detail

Fusion Objective

$$f_{ES}(x,y) = Fusion\ (f_E(x,y), f_S(x,y))$$

Such that the correlation

$$[f_{ES}(x,y) \otimes f_E(x,y)] + [f_{ES}(x,y) \otimes f_S(x,y)]$$

Is maximized

Rule 1: Maximum Selection Criterion

$$LL_{ES} = \max(LL_S, LL_E)$$
$$LH_{ES} = \max(LH_S, LH_E)$$
$$HL_{ES} = \max(HL_S, HL_E)$$
$$HH_{ES} = \max(HH_S, HH_E)$$

Technical Detail

Rule 2: Average Selection Criterion

$$LL_{ES} = \text{ave}(LL_S, LL_E)$$
$$LH_{ES} = \text{ave}(LH_S, LH_E)$$
$$HL_{ES} = \text{ave}(HL_S, HL_E)$$
$$HH_{ES} = \text{ave}(HH_S, HH_E)$$

Rule 3: Maximum Selection for high frequency sub-bands (HL, LH, HH) and average selection for low frequency sub-band (LL)

$$LL_{ES} = \max(LL_S, LL_E)$$
$$LH_{ES} = \max(LH_S, LH_E)$$
$$HL_{ES} = \max(HL_S, HL_E)$$
$$HH_{ES} = \max(HH_S, HH_E)$$

The fused image is obtained by taking the inverse wavelet transform after application of the selection rule.

Technical Detail

Turbulence Model

$$H(u,v) = e^{-k(u^2+v^2)^{5/6}}$$

Weiner Filter

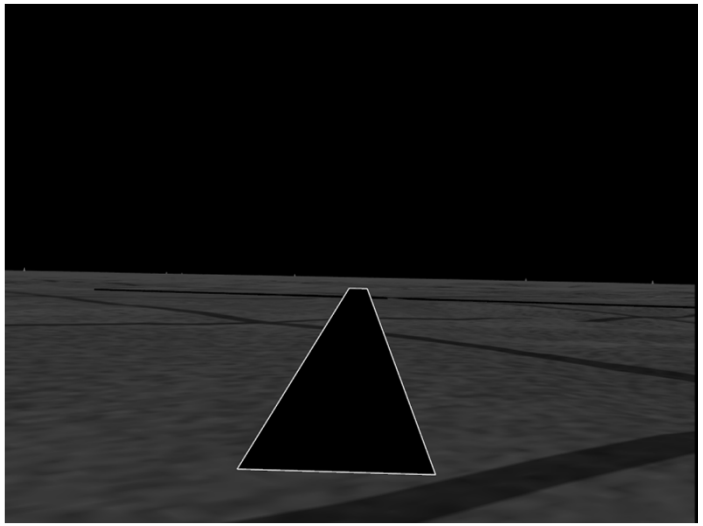
$$\widehat{F}(u,v) = \left[\frac{1}{H(u,v)}\frac{|H(u,v)|^2}{|H(u,v)|^2 + k}\right] G(u,v)$$

Objective evaluations

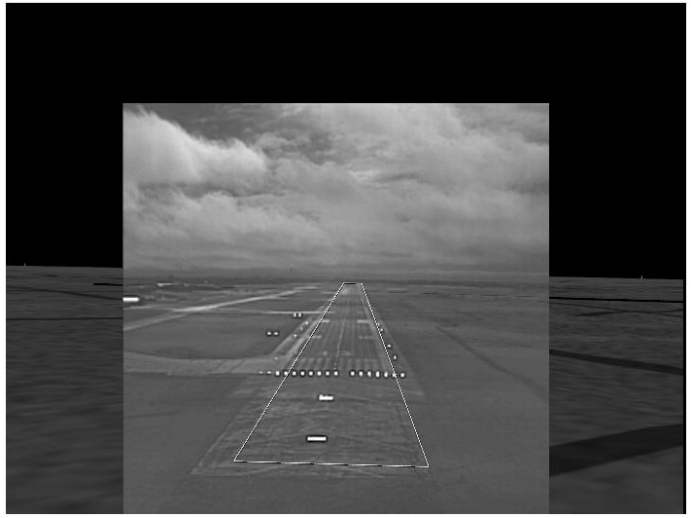
- Root Mean Square Error (RMSE) for registration
- Correlation Coefficient for fusion

Results

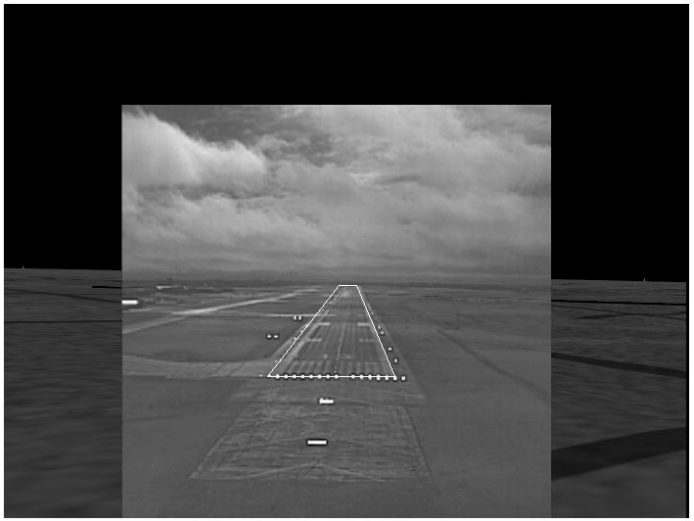
EVS Image



SVS Image



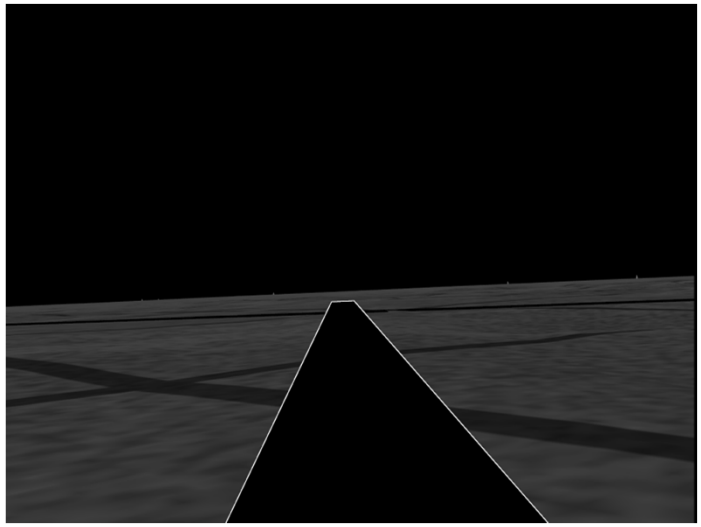
Fusion



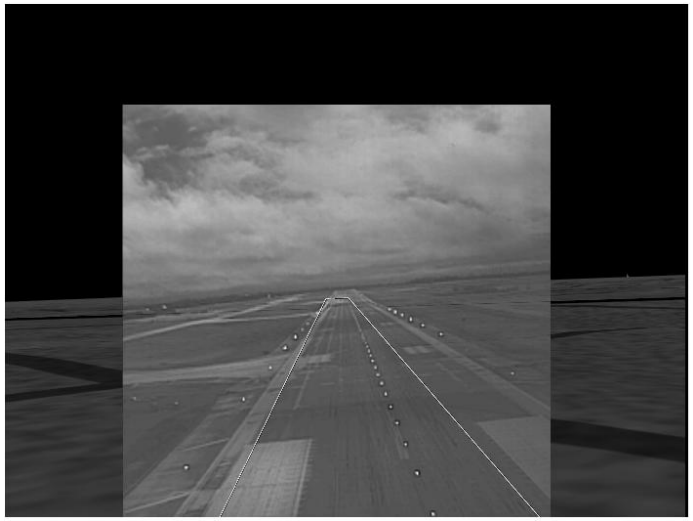
Registration and Fusion

Results

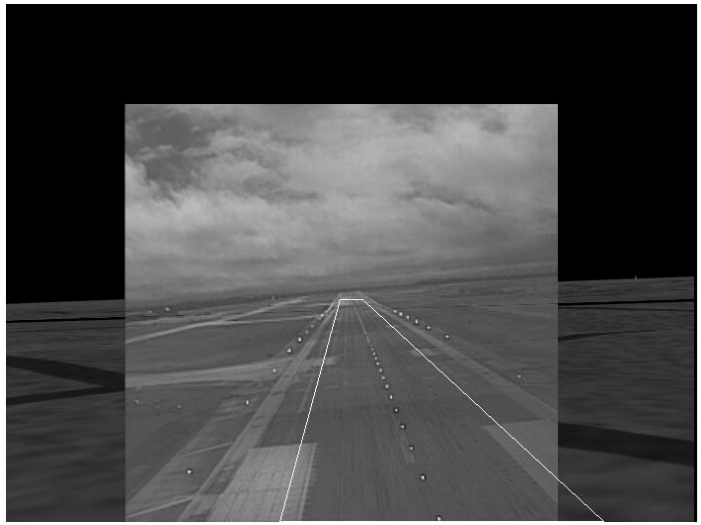
EVS Image



SVS Image

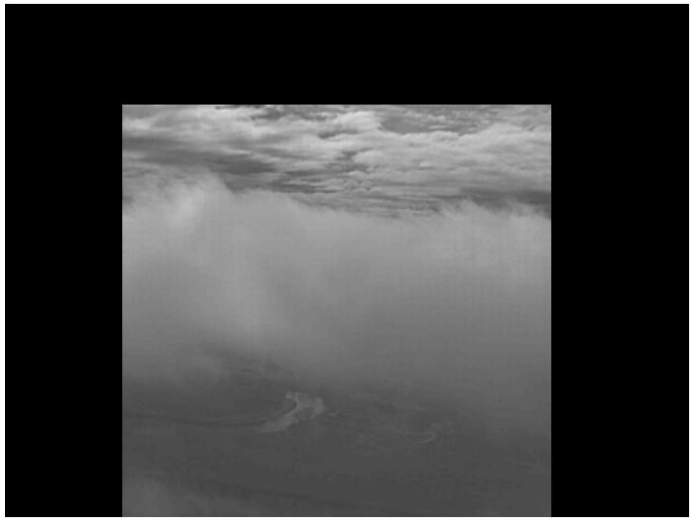


Fusion

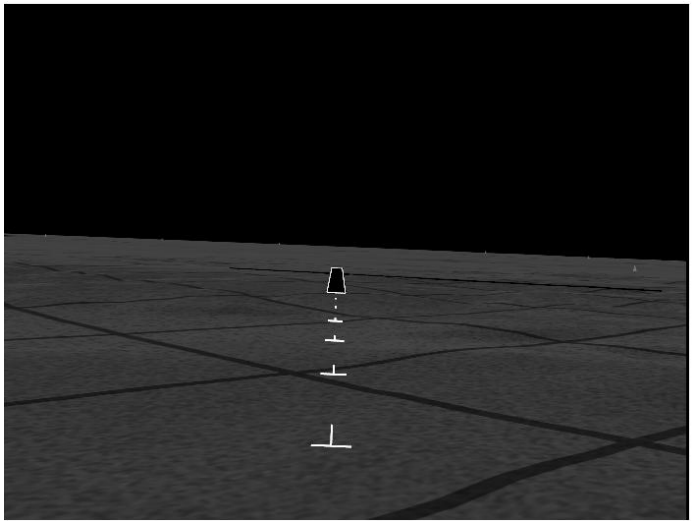


Registration and Fusion

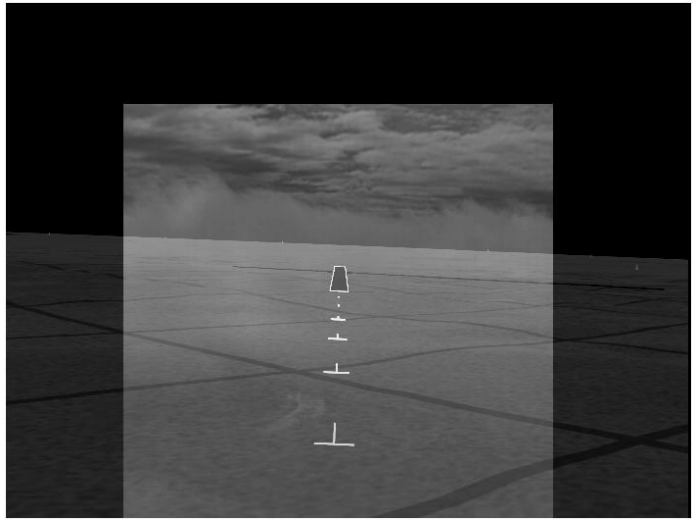
Fusion Results



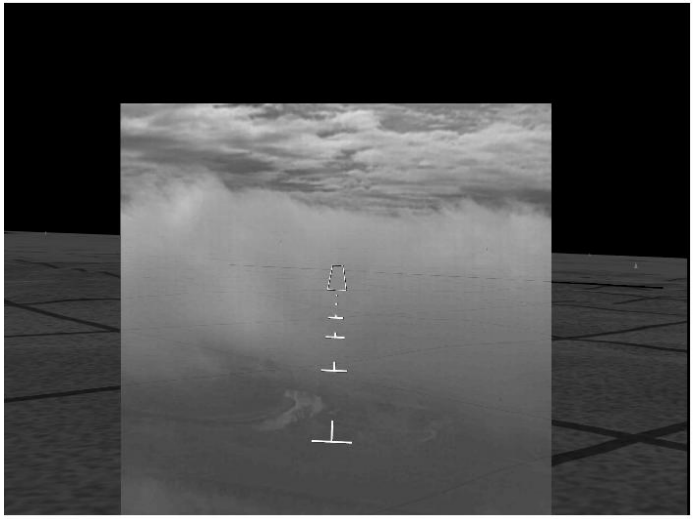
EVS Image



SVS Image



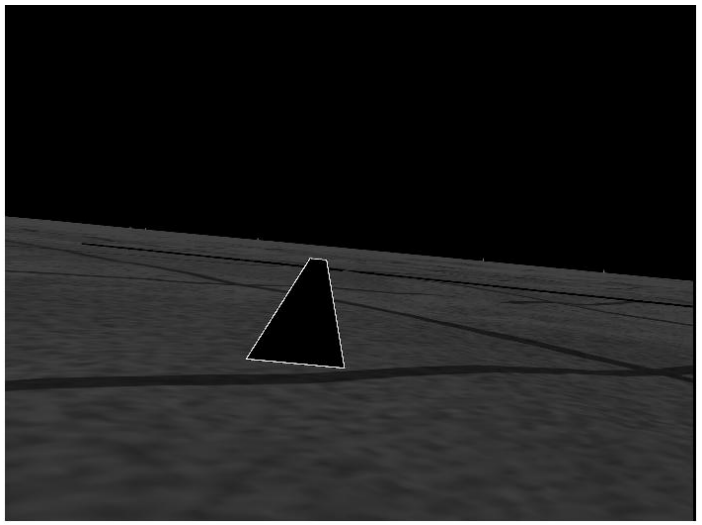
DWT Fusion (average)



DWT Fusion (maximum)

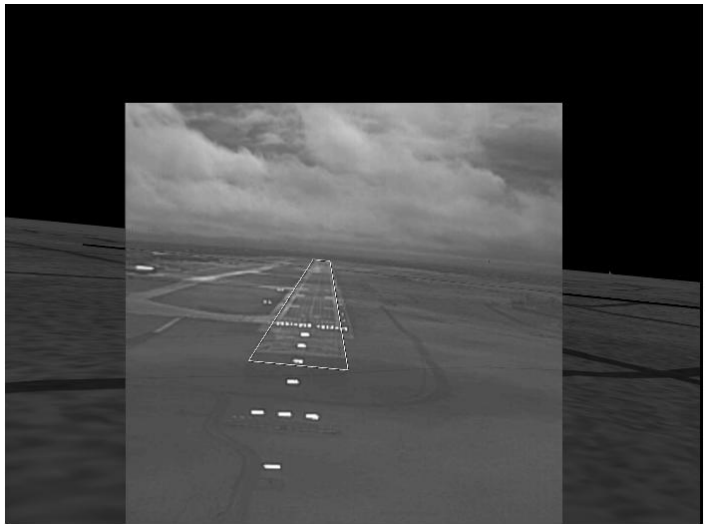
Fusion Results

EVS Image



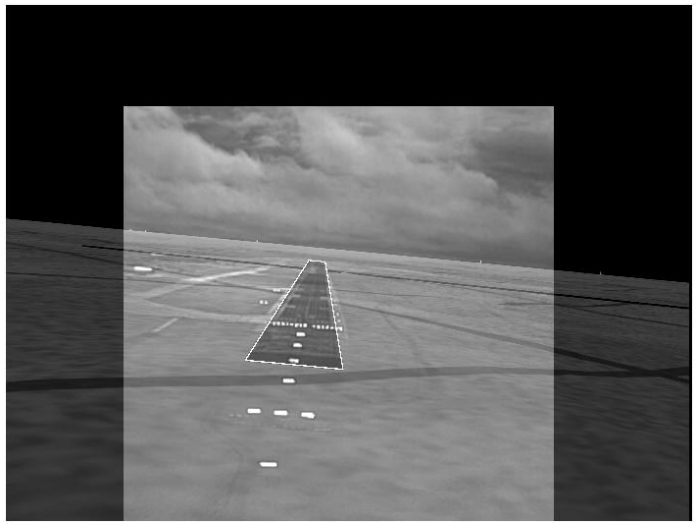
SVS Image

DWT Fusion (average)

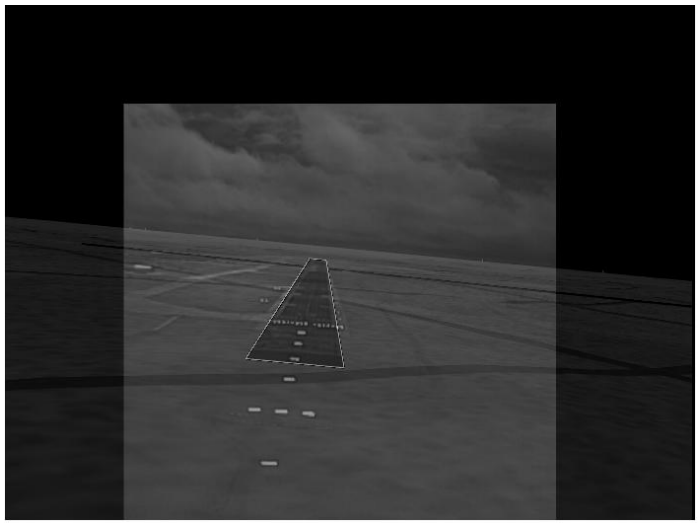


DWT Fusion (maximum)

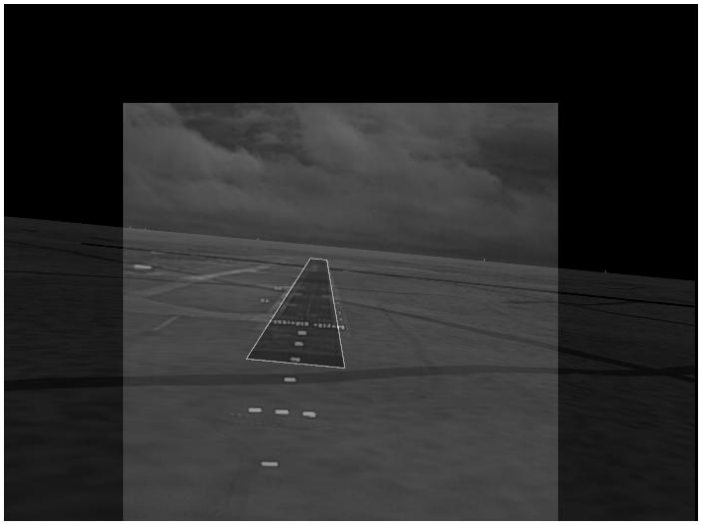
Fusion Results



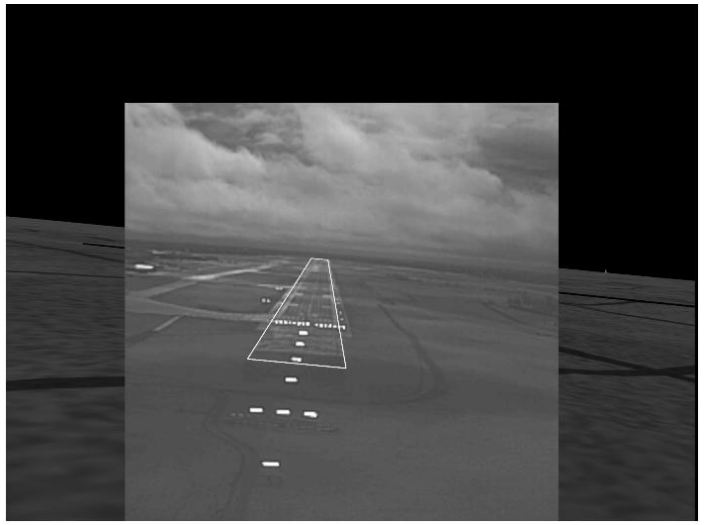
Averaging



DWT Fusion (Mixed)



GHM Fusion (average)



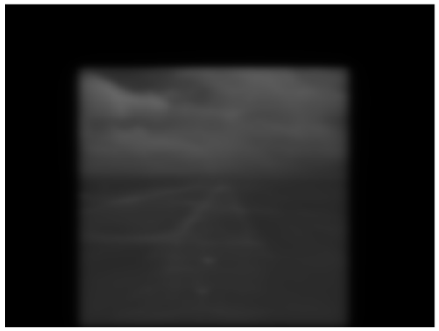
GHM Fusion (maximum)

Turbulence

Original

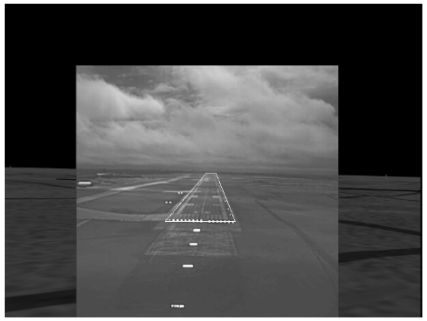
Low Turbulence

Mild Turbulence

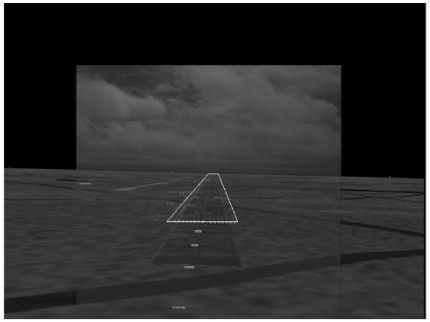


Severe Turbulence

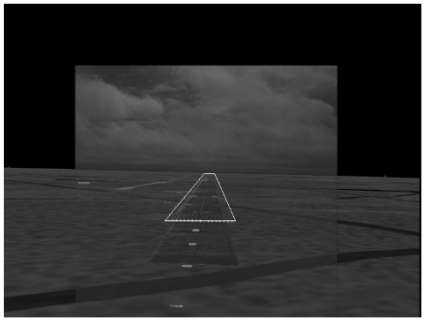
Registration & Fusion in Turbulence



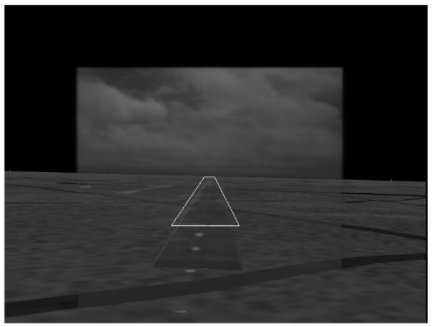
No Turbulence



Low Turbulence



Mild Turbulence



Severe Turbulence