Target Tracking at Gifu University

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Outline

- Summary and conclusion
- Conceptual design of tracking apparatus
- Direct imaging on CCD arrays
- Matched filter
Summery and conclusion

- Detectors have to provide noise reduction in tracking apparatus.

- The direct imaging on CCD arrays is constructed. In the preliminary evaluation, its accuracy is $< 10 \, \mu\text{m}$ for a stationary target.

- The matched filter will be one of candidates. By the simulation, it has improved performance on S/N and detect ability of target rotation angle.
Conceptual design of tracking apparatus

Aerosol will scatter and absorb probe light

\[
\begin{align*}
\phi, \tau, \ldots, \phi, \tau, \\
&x, y, z, \ldots, t, \phi \\
&\dot{x}, \dot{y}, \dot{z}, \\
&x, y, z
\end{align*}
\]

1. Direct imaging on CCD arrays
2. Matched filter
Direct imaging on two CCD arrays

The PMB image is sampled by 500ns pulse. Position $x$ is determined by:

$$x = \frac{w}{M} \left( \frac{\text{Count}_1 - \text{Count}_2}{2} \right)$$

$\text{Count}_1$: Cell number of CCD$_1$
$\text{Count}_2$: Cell number of CCD$_2$

CCD: TCD1023, 1024 cells

$w=14 \mu m$: Cell width

$M=3$: Magnification

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Preliminary evaluation of direct imaging

CCD$_2$ output vol. $v$ (V) vs. $x_{CCD}$ (mm)

CCD$_1$ output vol. $v$ (V) vs. $x_{CCD}$ (mm)

$Count_2 = 151$

$Count_1 = 84$

$x = -150 \mu m$

$r = 3.0 \text{ mm}$

Detected $x$ (µm) vs. Target position $x$ (µm)

$x = -500$ to $500$

$y = -500$ to $500$

$I = 100$ to $200$

$V = 8.0$ to $9.0$

$t$ (µs) = 0 to 200

$CCD$ output vol.

$CCD$ output vol.

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Matched Filter is well developed as a pattern reorganization method.

Matching a matched filter:

\[
g(x, y) \star \text{Filter}(X, Y) = g(x, y) \times \text{Filter}(X, Y)
\]
Original image and matched filter

Org. image

Matched Filter

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Input image and correlation output of a cone-target

Input image

Corr. output

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Correlation output can be obtained from noisy signal

Input image

Corr. output

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Position is detected from correlation output

Input image

Corr. output

$\Delta z = -2.0 \text{ mm}$  $\Delta z = 0 \text{ mm}$  $\Delta z = 2.0 \text{ mm}$
Correlation output is weakly sensitive to rotation

Input image

Corr. output

(0 deg.)  (-5 deg.)  (-10 deg.)  (-15 deg.)
Correlation output is a function of rotation angle $\phi$. The correlation $f \star g$ is plotted against rotation angle $\phi$ in degrees. The graph shows a peak at $\phi = 0$ and decreases as $\phi$ increases in either direction.
Rotation angle detection by two matched filters

Matched filter ($\phi=5$ deg)

Matched filter ($\phi=-5$ deg)

Photo sensor (PSD, CCD)

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Rotation angle is obtained from difference of two correlation outputs.

Rotation Angle $\phi$ [deg]

Corr$_+$, Corr$_-$, Corr$_+$ - Corr$_-$ [a.u.]