# Automatic Target Recognition in Cluttered Visible Imagery

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## ABSTRACT

Detection of a target from among similar/dissimilar targets in a cluttered image is vital in automatic target recognition. A MACH filter is used for the target detection in cluttered imagery. The cluttered images are correlated using the filter formulated from training images. The target is expected to be detected in the first highest peak. MACH was assumed as an optimum filter for target detection, but results proved that the accuracy is low. So, a new approach is identified for design of an optimum filter. The top ten peaks are identified as Regions of Interest (ROI's) and these regions are correlated with all the training images using matched filter in the second stage. To further increase the accuracy, edge enhancement of the training set and input images using Sobel operator is done. Results proved that these new approaches greatly improved the accuracy. Using matched filter in the second stage after MACH gives us an advantage of identifying the orientation of the target as well.

**Keywords:** MACH Filter, ROI, Sobel Operator

## 1. INTRODUCTION

Automatic Target Recognition (ATR) (Kerekes and Kumar, 2008; Priyadarsini *et al*., 2012) in cluttered imagery faces a large number of problems as there could be targets with varied sizes and presentations, the targets can be in low contrast and varied illumination locations. The images can have varied brightness and different gray level variations in real time scenarios, which forces us to design a very effective filter for detection of the target which can overcome all the obstacles. The filter must be effective enough to detect the target in various varieties of clutters in different environments.

Target recognition (Priyadarsini *et al*., 2012; Mahalanobis *et al*., 1996) in an image is being done through 2 dimensional correlations with all the training templates or designing a Composite Correlation Filter (CCF) using all the training templates. Matched filter detects the target accurately in most of the cases but use of matched filter for the detection in (Meenalosini *et al*.,

2012) involves large number of computational complexities. SDF, MACE and MACH are few CCFs identified for use in ATR. They are good solution to reduce the number of computations. SDF and MACE are constrained CCFs that use hard constraints on the output, so MACH has been identified as the optimum filter for target detection over the past years. Though MACH has been able to rightly detect the target in few cases in the indoor environment, it is not accurate enough in majority of the outdoor test cases, where there is varied brightness and gray level variations.

As the main objective of the study is to develop an optimum filter (Mahalanobis and Kumar, 1997) for ATR in all environments, a 3 stage approach is developed. The main idea in the study is the assumption that the target lies in the highest correlation peak. However, the MACH correlation peaks for the failed cases showed that the target (Mahalanobis *et al*., 1996) majorly is in one of the top 10 peaks. These 10 peaks are identified as the Regions of Interest (ROIs) and they are matched with the

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training templates for detecting the target. Further, to make the system highly effective even for the outdoor environment, edge enhancement using SOBEL operator is implemented as the third stage.

## 1.1. Template-Based Matching

One important problem in image analysis is to find the exact location of a given pattern (Alkanhal and Kumar, 2003) (template) in a digital image that we refer to as search/input image. As the name suggests, here we have a rectangular template and the algorithms explicitly deal with the gray levels. The solution to image matching consists of computing a similarity measure. More precisely, for each pixel position 'x' in the search image domain for which there exists a sub-image (of the search image) centered at x and having same size as the template, we compute a similarity measure or normalized correlation between the test image and sub-image. Then we select among all the previous pixel positions the ones having the greatest similarity. We call matching region the set of these selected positions.

## 1.2. Conversion
## 1.2.1. Image Resolution

The original test images which are shown in **Fig. 1 and 2** reduced to 128×128 from 1200×900 so as to reduce the no. of computations. The images are reduced using the Matlab function imresize.

Syntax:

B = imresize(A, [mrows ncols])

B = imresize(A, [mrows ncols]) returns image B that has the number of rows and columns specified by [mrows ncols]. Either NUMROWS or NUMCOLS may be NaN, in which case imresize computes the number of rows or columns automatically to preserve the image aspect ratio.

## 1.3. Gray Scale Conversion

Template-based matching algorithms explicitly deal with the gray levels. The solution to image matching consists of computing a similarity measure. This matching is easy when implemented to gray scale images. The color photographs are converted to gray scale using the Matlab function.

Syntax Equation 1:

I=rgb2gray(RGB)                (1)



(a)



(b)



(c)



(d)

**Fig. 1.** Original images: (a) and (b)-training images, (c) and (d)-outdoor images
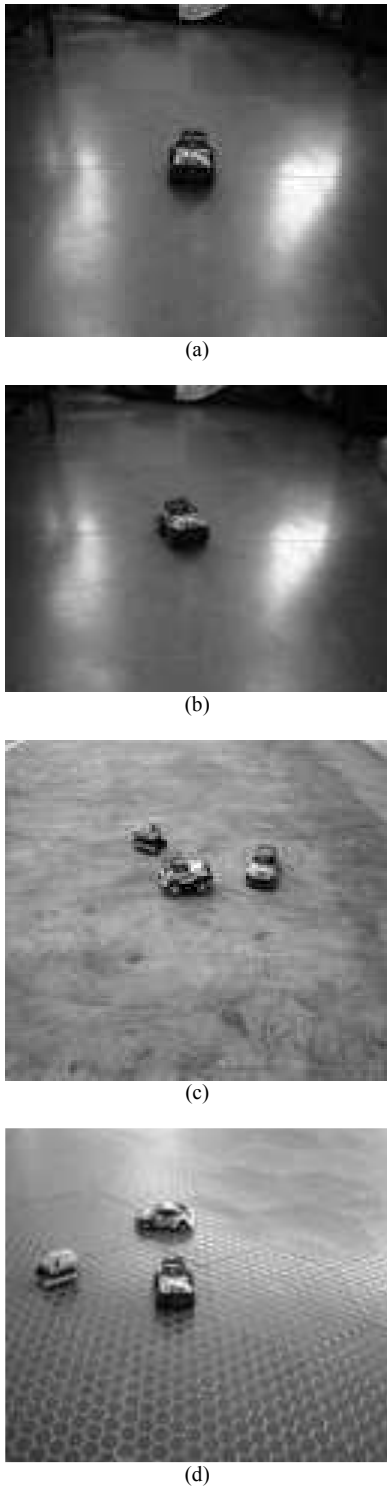
(a)



(b)



(c)



(d)

**Fig. 2.** Reduced size and Gray scale images (a) and (b) training images, (c) and (d) outdoor images
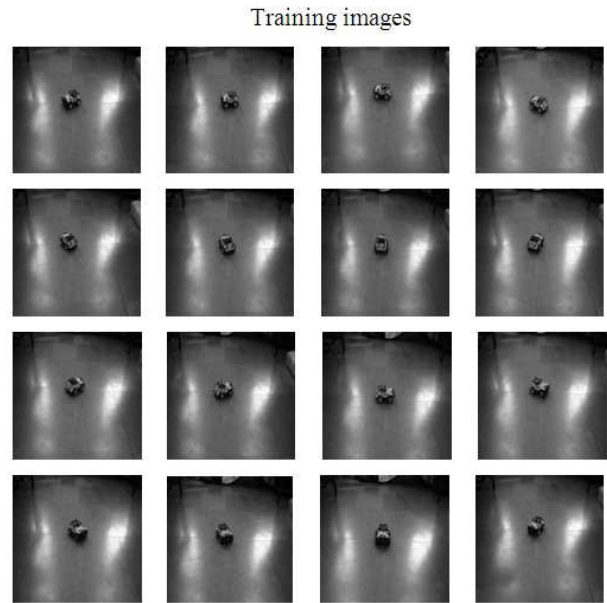
Training images



**Fig. 3.** Training images-16 different orientations



**Fig. 4.** Training templates

I = rgb2gray(RGB) converts the true color image RGB to the grayscale intensity image I. rgb2gray converts RGB images to grayscale by eliminating the hue and saturation information while retaining the luminance.

## Algorithm

rgb2gray converts RGB values to grayscale values by forming a weighted sum of the R, G and B components:

$$0.2989 * R + 0.5870 * G + 0.1140 * B$$

### 1.4. Image Database
### 1.4.1. Extracted Training Templates

From the training images which are shown in **Fig. 3-5**, templates of size 20 are extracted and stored in a binary file so that they can be accessed directly from the Matlab any time without each time extracting from the main image.
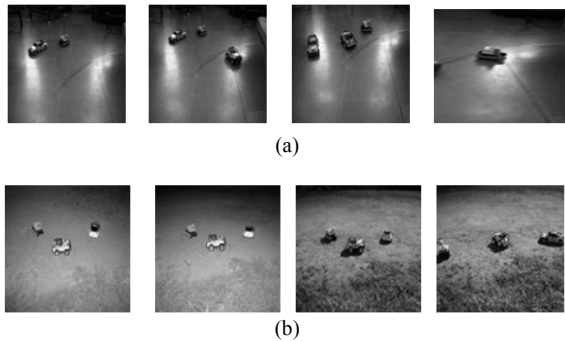
(a)



(b)

**Fig. 5.** (a) Indoor Images (b) Outdoor Images

## 2. MATERIALS AND METHODS

In matched filter which a training template is accessed from the database and normalized (Yoo and Han, 2009) is performed for the training template and the input image. Correlation peak (Alkanhal and Kumar, 2003; Mahalanobis *et al.*, 1996) is plotted. But due to difference in the orientation of the target in the training template and the input image, makes it necessary to correlate the input image with all the training templates and the highest peak among all the correlation (Yoo and Han, 2009) planes is identified as the target.

The matched filter which is shown in **Fig. 6** gives a perfect output in almost every case, but the disadvantage lies in the time taken for the complete process as the every template (here 16) needs to perform template based matching for the image of size 128×128.

### 2.1. Analysis

Matched filter which is shown in **Fig. 6** detects the right target in the test image when the orientation of the target in the image and training template matches perfectly. This method gives very accurate results, but involves lot of computations as each image of size 128×128 should be correlated with 16 templates of size 20×20 and the correlation peaks should be analysed. The complete process takes about 20 seconds to detect the target which is large and unsuitable to implement in real time scenarios.

### 2.2. Composite Correlation Filters

The field of correlation-filter-based pattern recognition (Kerekes and Kumar, 2008; Priyadarsini *et al.*, 2012) has been researched extensively over the past three decades and successfully used in various applications. This success is largely due to attractive properties such as shift invariance, graceful degradation and closed-form

solutions. The simplest correlation filter is the matched filter, in which the filter template is matched to a single training image. It is well known that the matched filter is optimal for detection (Meenalosini *et al.*, 2012; Mahalanobis and Kumar, 1997) of a known object in additive white noise; however, the use of matched filters is not attractive for Automatic Target Recognition (ATR) (Priyadarsini *et al.*, 2012), since the number of matched filters needed is very large when a wide range of target distortions must be handled.

In contrast to simple matched filters, composite CF (Kerekes and Kumar, 2008) designs allow the use of multiple training images and can produce a filter template that tolerates different types of noise and distortion. Many such designs also optimize performance criteria such as peak sharpness, output similarity and low output noise variance for improved performance in various conditions. Thus, when using CFs for a (Meenalosini *et al.*, 2012) detection/recognition task in the presence of distortion, we will likely need fewer composite CFs than matched filters.

The filter designs may be divided into several classes. We refer to the first class as constrained linear CFs, it includes such designs as OTSDF, MACE and MINACE filters. Designs in this class have the property that the designer specifies (constrains) the correlation output value for every training image. This property is commonly used to achieve a distortion-tolerant filter by specifying a constant output value over a representative set of distorted training images. Removing these hard constraints enlarges the filter solution space and leads to another class of filter designs that are commonly referred to as unconstrained linear filters. This class includes such designs as MACH, EMACH and UOTSDF filters.

### 2.3. Mach Filter

The basic filter equation for the MACH filter is Equation 2:

$$h = S^{-1}m$$
$$S = (1/N)\sum (Xi - M) * (Xi - M) \tag{2}$$

Where:
'h'  =  The filter
'm'  =  The vector representation of the mean of all templates
'S'  =  The diagonal matrix
'N'  =  The number of templates
'$X_i$'  =  A diagonal matrix with the ith template elements
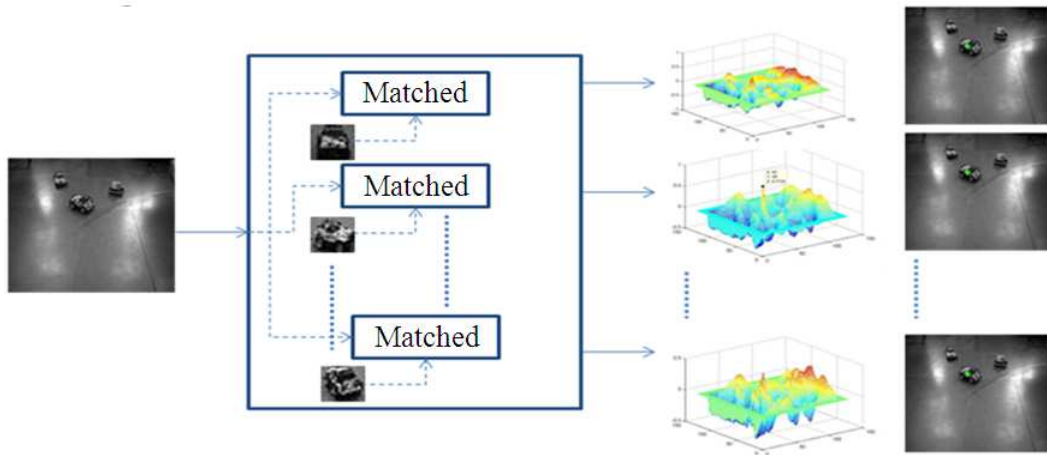'M'  =  The diagonal matrix with mean elements

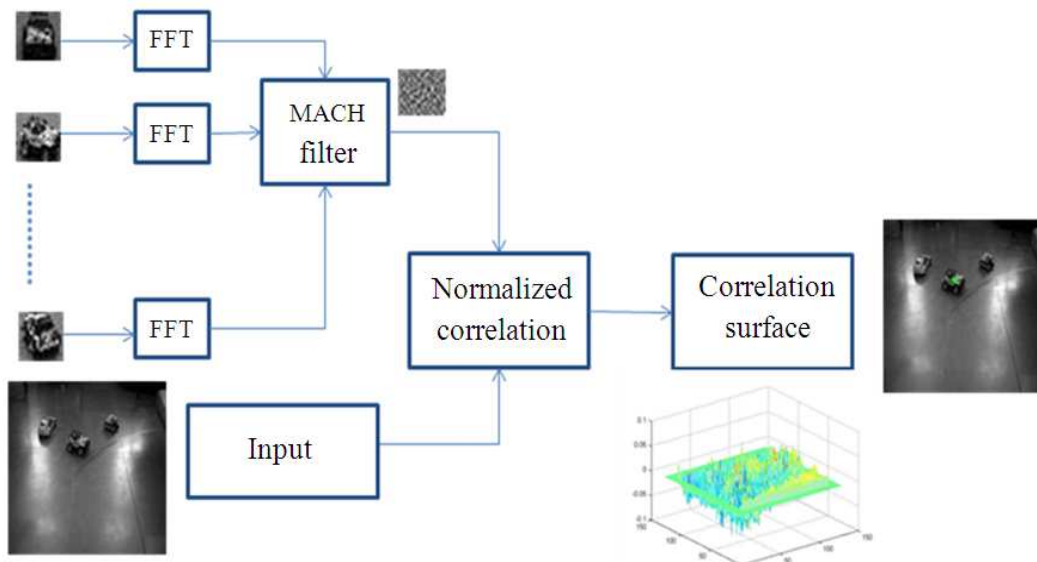**Fig. 6.** Matched filter block diagram



**Fig. 7.** MACH filter block diagram

## 2.4. Methodology
### 2.4.1. Filter Design Algorithm

- Initially access the binary files containing the templates and the test images, store them in some variables respectively
- MACH filter which is shown in **Fig. 7** is designed with all the training templates
- A matrix is created with the training image column vectors
- The mean of all the templates is found and is arranged as a column vector

- 'S' matrix is formed and finally filter is designed

## 3. RESULTS

### 3.1. Indoor
### 3.1.1. Outdoor

MACH filter which is shown in **Fig. 7** did not produce impressive results with the outdoor images which is shown in **Fig. 8** due to varied brightness, contrast and different gray level variations. The performance was very poor.
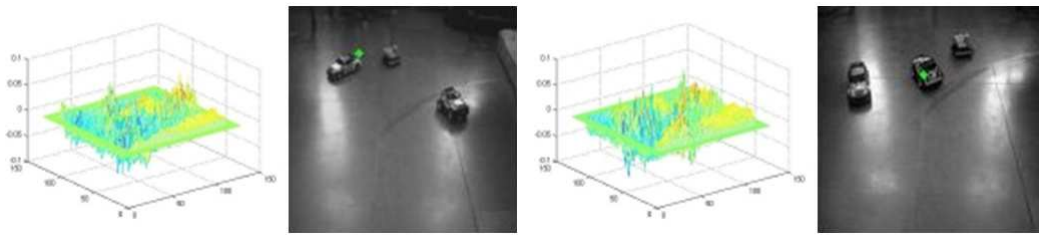
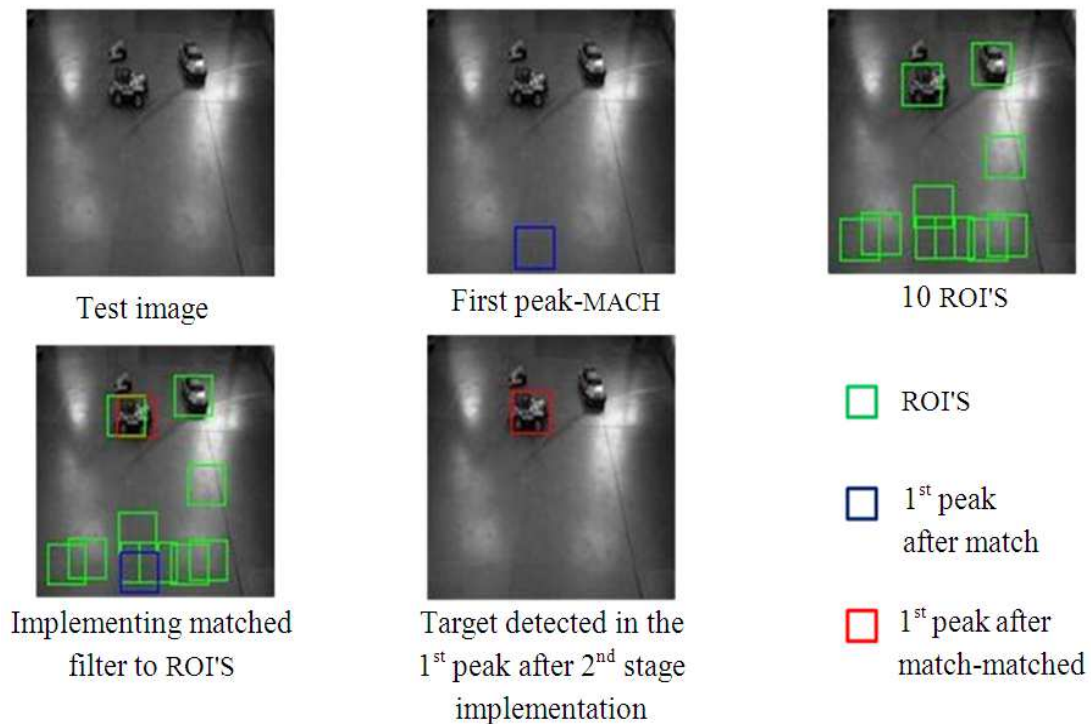**Fig. 8.** Indoor image result



**Fig. 9.** Step by step procedure of MACH-matched filter

However, in majority of the images, the target lied in the top 10 peaks. This encouraged us to add a second stage matched correlation (Bhuiyan *et al*., 2006; Mahalanobis and Kumar, 1997) filter to the MACH output.

### 3.2. Mach Upgrade

This is a two stage filter with the first stage MACH followed by the Matched filter which are shown in **Fig. 9-11**. Initially the MACH filter is applied to the test image. Now instead of concentrating solely on the first peak, ten Region of Interests (ROIs) is considered. These ten ROIs are those areas surrounding the top ten peaks. The size of the ROIs taken is a little larger than that of the template size so as to eliminate the possibility of non detection (Meenalosini *et al*., 2012) if a peak is at the edge of the target rather than the center. Now the matched filter is applied to these areas of interests and the highest peak is detected as the most probable target.

### Algorithm

- Initially access the binary files containing the templates and the test images, store them in some variables respectively
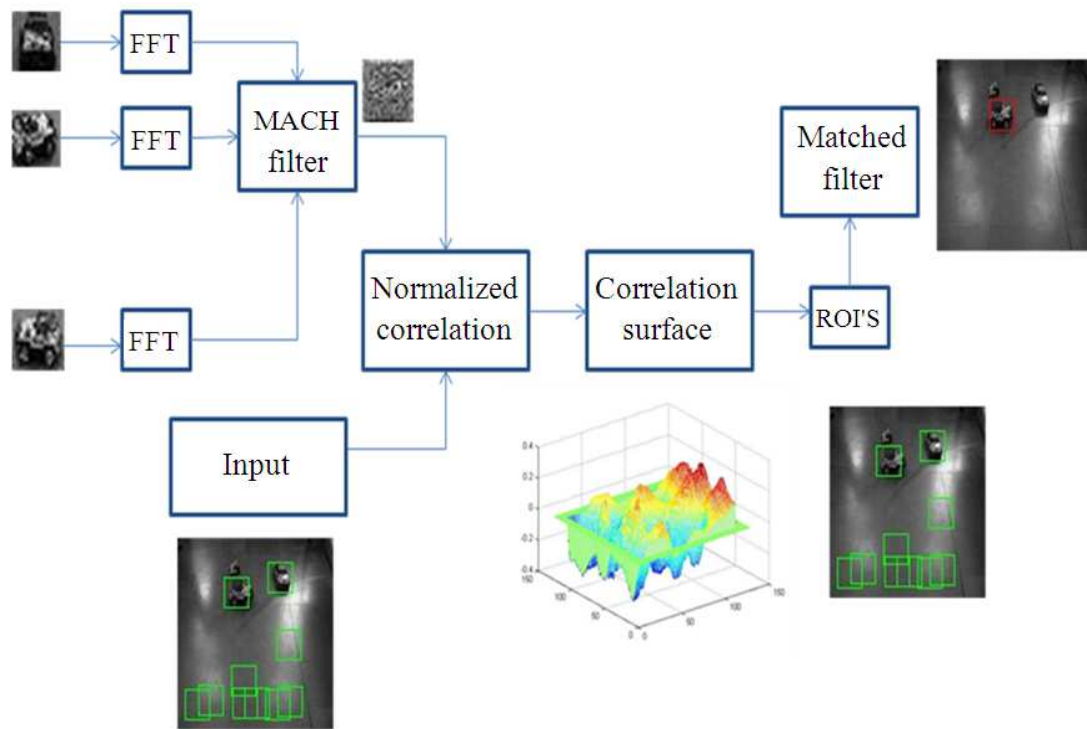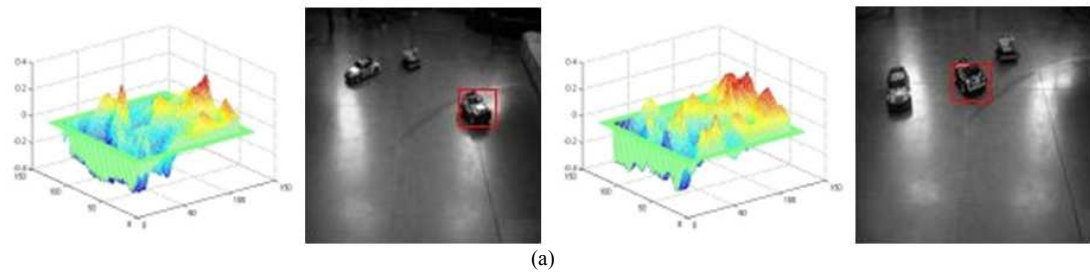- MACH filter is designed with all the training templates

**Fig. 10.** MACH-matched filter block diagram

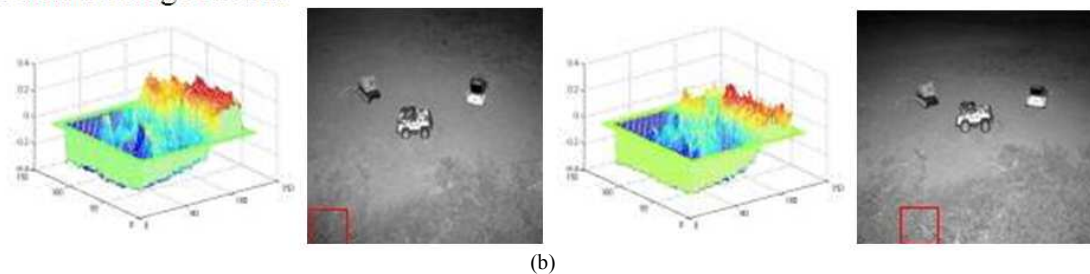## Indoor image results



(a)

## Outdoor image results



(b)

**Fig. 11.** MACH-matched filter output for indoor and outdoor images along with the correlation planes

- A matrix is created with the training image column vectors
- The mean of all the templates is found and is arranged as a column vector
- 'S' matrix is formed and finally MACH filter is designed
- The first highest peak is taken and the region around it of size of the template is nullified and this region is taken as the first Region of Interest (ROI)
- Similarly, now the next highest peak is identified and ROI is formed
- In this way, the top 10 ROIs are identified and located on the image
- The 10 ROIs are matched with the training templates in all orientations
- The highest correlation peak of all the matched planes is considered as the most probable target

### 3.3. Sobel-Mach-Matched

The Sobel operator (Vincent and Folorunso, 2009) is used in image processing, particularly within edge detection algorithms. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function.

### 3.4. Formulation

Mathematically, the operator (Vincent and Folorunso, 2009) uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives-one for horizontal changes and one for vertical. If we define A as the source image and $G_x$ and $G_y$ are two images which at each point contain the horizontal and vertical derivative approximations, the computations are as follows:

$$G_y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{pmatrix} * A$$

And:

$$G_x = \begin{pmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{pmatrix} * A$$

where, * here denotes the 2D-dimensional convolution operation.

The x-coordinate is here defined as increasing in the "right"-direction and the y-coordinate is defined as increasing in the "down"-direction. At each point in the image, the resulting gradient approximations can be combined to give the gradient magnitude, using:

$$G = \sqrt{G_x^2 + G_y^2}$$

### 3.5. Sobel Operator

The Sobel operator (**Fig. 12**) is applied for the input images and the edge enhancement is performed. Similarly, the designed MACH filter template is also Sobel operated and edge enhancement is performed. Now correlation is performed for the Sobel operated MACH template and the input image. The correlation plane is plotted and the ROIs are identified same as the MACH-Matched method (**Fig. 13**). After identifying ROIs, the similar process of matching the ROIs with all the templates is performed and the target is detected.

### Algorithm

- Initially access the binary files containing the templates and the test images, store them in some variables respectively
- MACH filter is designed with all the training templates
- A matrix is created with the training image column vectors
- The mean of all the templates is found and is arranged as a column vector
- 'S' matrix is formed and finally MACH filter is designed
- Apply the SOBEL operator which is shown in **Fig. 14** to MACH filter and the test image, correlate
- The first highest peak is taken and the region around it of size of the template is nullified and this region is taken as the first Region of Interest (ROI)
- Similarly, now the next highest peak is identified and ROI is formed
- In this way, the top 10 ROIs are identified and located on the image
- The 10 ROIs are matched with the training templates in all orientations
- The highest correlation peak of all the matched planes is considered as the most probable target

### 3.6. Orientation

The orientation of the target in the test image can also be determined using the MACH-matched and SOBEL MACH-matched filters which is shown in **Fig. 15**. A number is determined when the filter is implemented when the output is obtained and correspondingly the orientation is found from the **Table 1 and 2**.
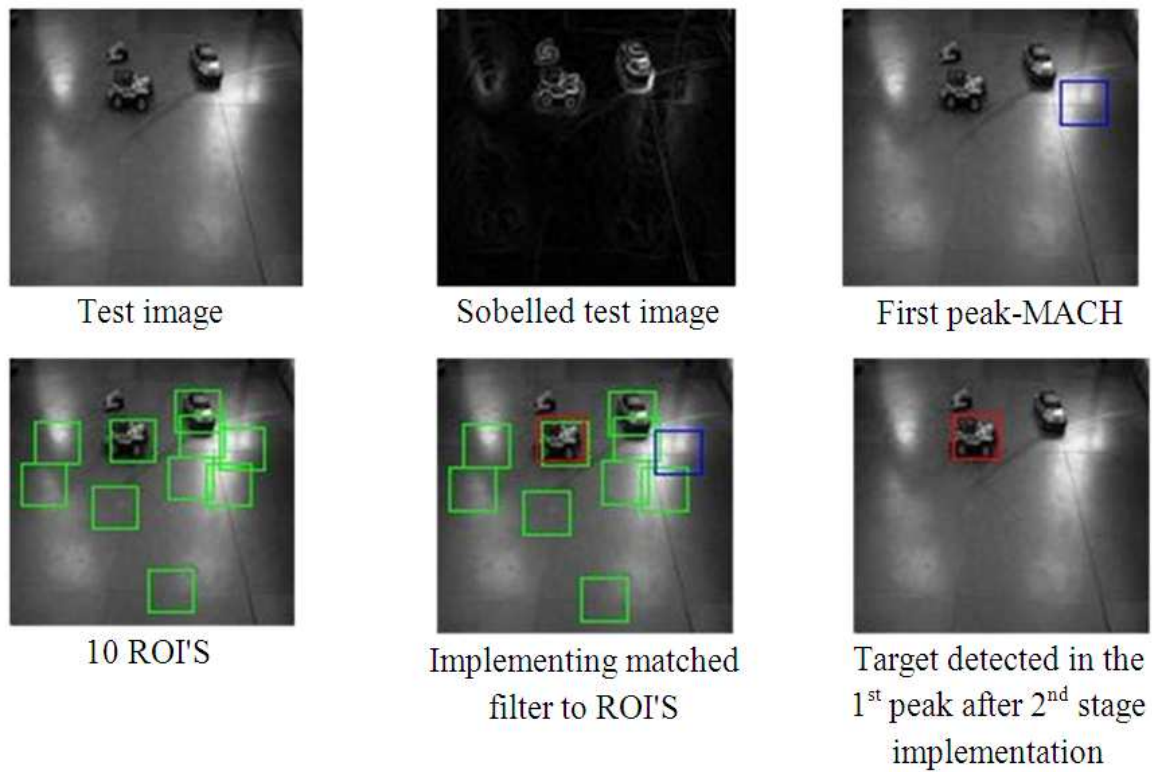
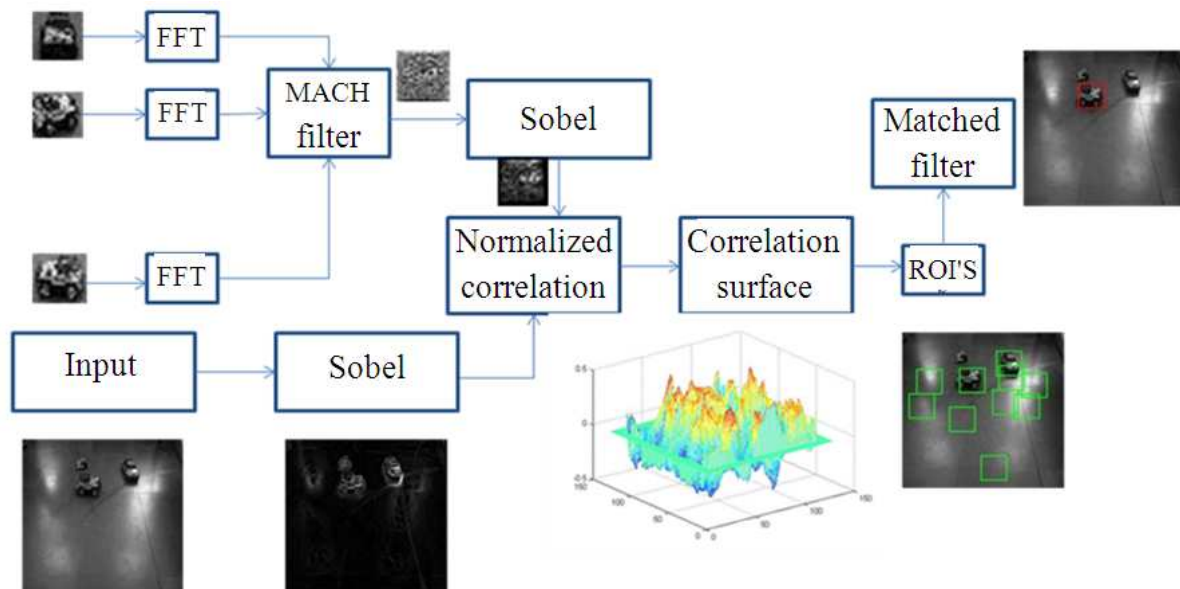Fig. 12. Step by step procedure of SOBEL MACH-matched filter



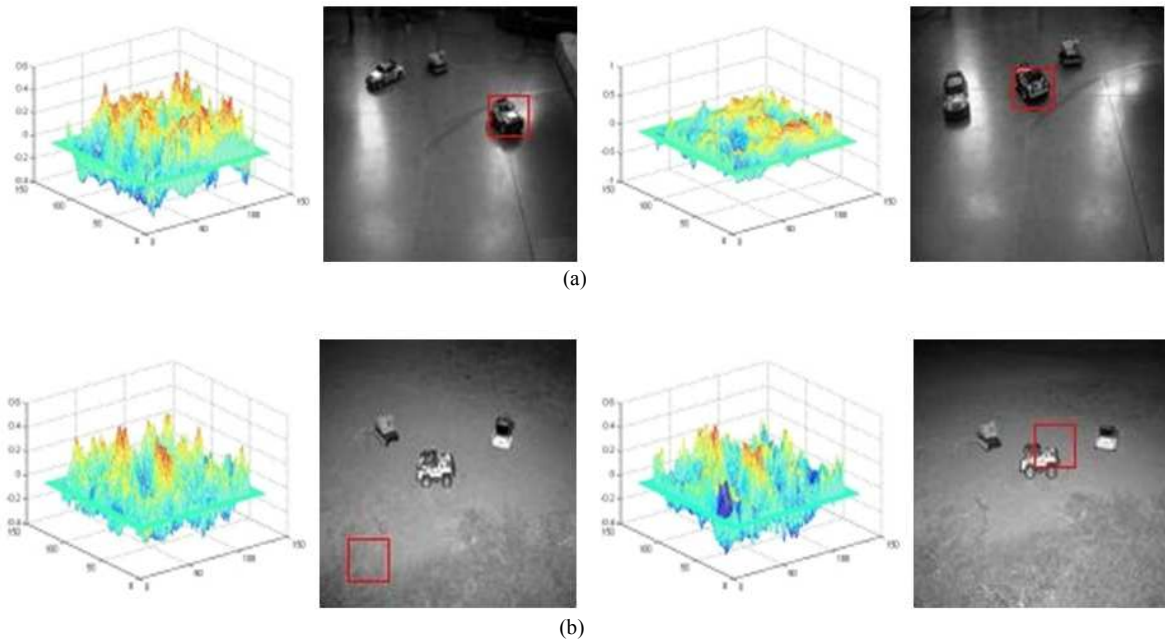Fig. 13. SOBEL MACH-matched filter block diagram

(a)



(b)

**Fig. 14.** (a) SOBEL MACH-matched filter output for indoor images with correlation planes (b) SOBEL MACH-matched filter output for outdoor images with correlation planes
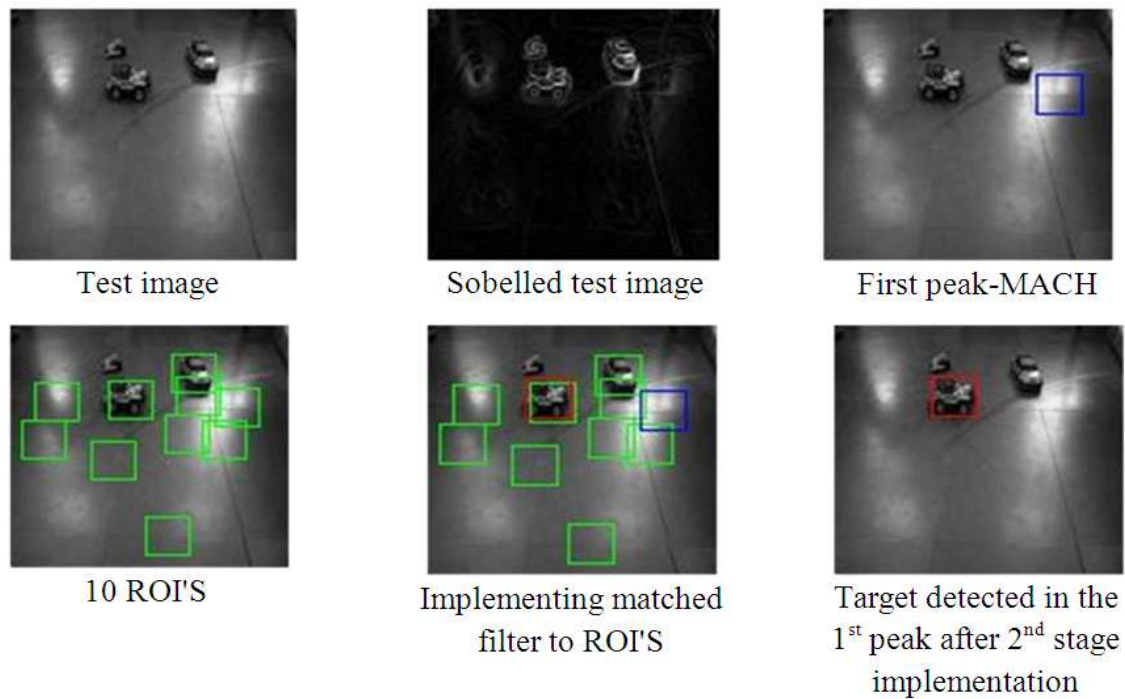


Test image

Sobelled test image

First peak-MACH

10 ROI'S

Implementing matched filter to ROI'S

Target detected in the 1st peak after 2nd stage implementation

**Fig. 15.** SOBEL MACH-matched filter output for an outdoor image

**Table 1.** Orientation of target in the test image

| Template number | Orientation | Template number | Orientation |
|---|---|---|---|
| 1 | South | 9 | North |
| 2 | South/South-East | 10 | North/North-West |
| 3 | South-East | 11 | North-West |
| 4 | South-East/East | 12 | North-West/West |
| 5 | East | 13 | West |
| 6 | East/North-East | 14 | West/South-West |
| 7 | North-East | 15 | South-West |
| | North-East/North | 16 | South-West/West |

**Table 2.** Performance analysis

| Filter | 1st peak indoor imgs | 1st peak outdoor imgs | Top 10 peaks indoor imgs | Top 10 peaks outdoor imgs |
|---|---|---|---|---|
| MACH | 70% | Very poor | 98% | 95% |
| MACH -matched | 95% | 45% | - | - |
| SOBEL MACH -matched | 95% | 70% | - | - |

### 3.7. Implementation Steps

Output: template no = 5

∴ The template number shown: 5 i.e., the orientation here is facing "east".

## 4. DISCUSSION

The complete implementation time for the SOBEL MACH-matched filter is 1.5 sec.

## 5. CONCLUSION

The previous assumption was that MACH filter is the optimum filter for ATR in cluttered imagery. But the results obtained showed very low accuracy. Implementation of matched filter in the second stage helped greatly in enhancing the output. Whereas SOBEL operating the input images and the MACH filter template showed that edge enhancing greatly helped in detecting the target rightly in almost all the indoor as well the outdoor cluttered images. These results show that the methods employed provided higher performance for ATR than the previous available works.

The proposed 2nd stage implementation of matched filter and 3rd stage implementation using SOBEL is a novel approach. In the proposed approach, matched filter is applied to the ROIs obtained from the MACH outputs. These ROIs contain probable targets. In the third stage, SOBEL, which performs edge enhancement, is applied to the input test image and the MACH template to give us a better accuracy in ATR. The implementation of matched filter in stage 2 helped in obtaining the right orientation of the target. This 3 stage approach also greatly reduced the implementation time.

In future, classification of the targets in the image can be achieved by using a DCCF-Distance Classification Correlation Filter which helps in detecting and differentiating various targets present in the area. The filter can be further used in surveillance by adapting detection in video by extracting frames and also by background-fore ground analysis.

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