Abstract: In the ongoing synthetic aperture radar (SAR) methodology, precise and efficient identification of moving targets is a prominent task. Fractional FT (FrFT) accumulates the energy of the required chirp signal in order to separate it as noise from the chirp. The proposed SAR Moving Target Identification (MTI) process is based on FrFT being combined with the definitive adaptive genetic or neurofuzzy method. The correlation between the transmitted signal and the received signal's FrFT is determined, optimizing the appropriate signal energy and applying it to the decisive adaptive genetic fuzzy unit, which identifies the object location using the fuzzy linguistic rules adaptively. The simulation is conducted by changing the number of targets and number of iterations and the evaluation is performed based on parameters such as missed target rate, detection time and Mean Square Error (MSE), showing that the proposed Adaptive Genetic Fuzzy decisional MTI system located the object with a minimum missed target rate of 0.12 in 5.02s and MSE of 2.3774.

Index Terms: Adaptive Genetic Fuzzy Decisive Technique, Multichannel SAR, Fractional FT, function of ambiguity, correlation

I. INTRODUCTION

The use in a new generation of areaborne SARs of multiple (competitory) channels is used for the classical SAR single-channel working in various frequency bands after centuries of achievement. Against a strong ambiguity, the awareness of the moving target provides very important information on both the surveillance and intelligence scenario under observation. FrFT is commonly used in quantum mechanics, photo electrical signal processing and neural artificial networks, signal processing, and on through the development of the Fractional Fourier transform (FrFT). It has better energy-oriented focusing ability to process non-stationary signals, such as Chirp signal, than conventional Fourier Transform (FT). The FrFT of the chirp signal is more compact than the FT domain so that the energy of the required chirps signals can be below the FT level. The FrFT method provides the best refocusing and compute-efficient capabilities for SAR signals. In the SAR method, the Fuzzy Logic concept is capable of managing inconsistencies and ambiguities. The Fuzzy logic system takes care of the data from different remote sensors and generates an easy-to-use gui via adaptive control, avoiding uncertainties for potential remote sensing systems.

The sophisticated SAR information logic approach not only solves the complexity of the SAR signature, it can also provide reliable results by training the data. The article is structured in the following terms:

The multi-channel SAR MTI method of various approaches is introduced in part I. Section II reveals the computational handling of SAR signals. The adaptive fuzzy genetic approach for moving target identification is proposed in Section III and the results and discussions are presented in Section IV.

II. MATHEMATICAL MODELLING

Linear Frequency Modulated (LFM) wave used in Synthetic aperture radar is given as [8],

\[ w(n, y) = rect \left( \frac{n}{\rho} \right) \exp \left( j \pi \frac{\gamma}{y^2} \right) \exp \left( j2\pi f_c \left( n + \frac{y}{c} \right) \right) \]

(1)

where, \( \nu \) - average pulse repetition interval, \( n \) - slow time, \( p \) width of pulse, \( \gamma \) - modulation rate, and \( f_c \) - carrier frequency. The fast time is denoted as, \( y \)

The signal of reception is,

\[ u(n, y) = \gamma \exp \left( - jk_2 |n| \frac{1}{2} \right) \exp \left( - j4\pi k(n) \frac{1}{2} \right) \sin \left( c(a) \right) \]

(2)

where, \( \gamma \) is the coefficient of backscattering, \( C \) specifies the gains of range compression.

The \( K(n) \) instantaneous slant range is as,

\[ K(n) = K_0 - u_0 \cdot n - b_0 \cdot \frac{n^2}{2} \]

(4)

Substituting equation (4) in equation (2) implies,

\[ u(n, y) = \gamma \exp \left( - jk_2 \frac{K(n)}{2} \right) \exp \left( \frac{jk_2 u_0 - \frac{b_0}{2} n^2}{2} \right) \exp \left( \frac{2j\pi u_0 + \frac{b_0}{2} (n-m)^2}{2} \right) \frac{1}{c} \]

\[ \exp \left( \frac{jk_2 u_0 - \frac{b_0}{2} (n-m)^2}{2} \right) \exp \left( \frac{2j\pi u_0 + \frac{b_0}{2} (n-m)^2}{2} \right) \frac{1}{c} \]

(5)

Equation (5) says that the envelope of signal changes because of the target’s radial speed and radial acceleration. The moving object is not generally observable with changes in the signal process.

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III. PROPOSED METHOD OF ADAPTIVE GENETIC FUZZY DECISIVE BASED MOVING TARGET IDENTIFICATION

The paper's main intention is to track moving objects employing adaptive genetic fuzzy based approach in synthetic aperture radar set-up. The radar signals change their originality due to the presence of noise, glare, etc., which includes signal processing to accurately detect the position of the moving object within a minimum of time. The maximum energy of signal is obtained by correlating FrFT signal and original signal. In addition, the function of ambiguity of matched filter signal is correlated with original signal. Thus, two outputs are from matched filter and FrFT are fused using the adaptive genetic fuzzy decision approach. In the fuzzy decision strategy, fuzzy rules are used to explore the moving target in the search area. Fig 1 shows the illustrative diagram of the proposed method of MTI.

A. processing of SAR Signal using FrFT and MF

The uniform samples FrFT is,

$$T_o[x](g) = \frac{1}{U_r} \sum_{m=-\infty}^{\infty} \sum_{n,-\infty}^{\infty} R \cdot e^{j \frac{2\pi m \sigma}{U_r}} \cdot e^{j \frac{2\pi n \sin \theta}{U_r}} \cdot e^{j \frac{2\pi n \cos \theta}{U_r}} \cdot e^{-j \frac{2\pi n \sigma}{U_r}}$$

where, $U_r$ specifies the sampling of non-uniform points in each time period $n$. By applying AF to the FrFT signal of the original time signal $f(x)$, and is as,

$$F(0,0) = \int_{-\infty}^{\infty} T_o[x](g)^2 \, dx$$

where, $T_o[x](g)$ is the FrFT signal of the received signal $f(x)$. $T_o^-[x](g)$ is the complex conjugate of the FrFT signal with a time shift, and $F(0,0)$ denotes the normalization factor.

The dispose of correlation is stated as,

$$Cor(y,f) = \frac{1}{Cor(0,0)} \int_{-\infty}^{\infty} f(n) \cdot f^*(n+y) \cdot e^{j2\pi(n+y)} \, dn$$

where, $Cor(y,f)$ is the correlation function. The original signal and the time shift in the original received signal are notated as, $f(x)$ and $f^*(n+y)e^{j2\pi n}$. $A(y,f)$ refers to the AF of the original signal, and $|Cor(y,f)|$ specifies the maximum energy of the original signal.

$$F(y,f) = |Cor^*(y,f)|$$

(10)

Where, $A(0,0)$ is the factor of normalization, $f(n)$ is the received original signal. For finalizing the position of the target, $T_o[x](g)$ and the time time-shift signal $T_o^-[x](g) \cdot e^{j2\pi(n+y)}$ that gives the peak energy of the signal. $f(n)$ and $T_o^-[x](g)$ are respectively symbolized as, $T$ and $T^F$.

B. Fusing the decision of FrFT and matched filter adaptively

This section deliberates the fuzzy decisive approach of detecting the moving target in the search area.

Fig 2. Block diagram of AGFIS model

Fig 2 summarizes the block diagram of the Adaptive genetic fuzzy inference system (AGFIS), which integrates the prominent features of Fuzzy inference Systems and Artificial Neural Networks (ANN). The two inputs $T_o$ and $T^F$ applied to the fuzzification block to model the inputs in terms of the membership function of fuzzy which frames using the fuzzy rules to locate the target in the search area. ANN’s adaptive capabilities improve system performance. The defuzzifier translates the output variable into the reference crisp values. The required moving target detected using the fuzzy decisive approach is denoted as $T_{target}$. The proposed MTI based on AGFIS is capable of reporting rapidly moving targets and being able to effectively and accurately identify multiple targets.

IV. RESULT ANALYSIS AND DISCUSSION

Figs 3& 4 respectively shows the results of simulation using MATLAB. The objects detected after 50 rounds and 200 rounds are depicted

A. Simulation Results

Fig 3. Results of Simulation of moving object identification after 50 rounds
B. Discussion Of Results
The analysis of number of targets versus missed target rate, identification time and MSE is illustrated in figs 5, 6, 7 respectively by changing 5, 10, 15, and 20 targets. It was found that even with more targets, the proposed method provides less time to identify targets, less target rate missed and less MSE compared to existing methods.
Table I. Analysis of comparison for N=20 targets of the MTI methods

|       | FrFT | FFT | Proposed method |
|-------|------|-----|-----------------|
| DT (s) | 11.80 | 10.63 | 6.91 |
| MTR   | 0.573 | 0.476 | 0.233 |
| MSE   | 49721.6 | 41225.0 | 3077.5 |

Table II. Analysis of comparison for 5000 iterations of the MTI methods

|       | FrFT | FFT | Proposed method |
|-------|------|-----|-----------------|
| DT (s) | 12.91 | 11.37 | 6.88 |
| MTR   | 0.685 | 0.617 | 0.260 |
| MSE   | 42043.7 | 41047.7 | 2972.8 |

V. CONCLUSION

The proposed method used the Adaptive genetic Fuzzy based MTI system for Synthetic aperture radar signals to detect moving objects in the search area. The proposed method potency is intensified by employing AGFIS model, where fuzzy rules are used adaptively to get accurate output. Up to 20 moving targets and by changing number of iterations, the MATLAB simulation is performed. The execution parameters to measure the efficacy of proposed and current methods are missed target rate, Identification time and MSE. Comparative analysis substantiates that the proposed Adaptive genetic Fuzzy MTIdetect the targets precisely with minimum amount of time.

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