Mathematical Statistician and Engineering Applications
ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v70i1.2306

Multiple Target Localization Using Wideband Echo Chirp Signals

Anmol Kundlia

Teaching Associate, Department of Computer Science, Graphic Era Hill University, Dehradun, Uttarakhand India 248002

Article Info
Page Number: 253-260
Publication Issue:
Vol. 70 No. 1 (2021)

Article History
Article Received: 25 January 2021
Revised: 24 February 2021
Accepted: 15 March 2021

Abstract

This work proposes a unique technique for wideband chirp signals-based detection and estimate of the range, velocity, and direction of arrival (DOA) of numerous far-field objects. A wide region is covered by the wideband signal that is created. The targets reflect them, and an echo signal is created. The range, radial velocity, as well as DOA of the echo signal are extracted to identify the objects. Using the LCT, the range, radial velocity, and DOA are determined. The main goals of the system under consideration are to transmit a wide band signal over an area, to detect targets nearby, to obtain an echo signal from a target that has been reflected, and to extract features from the echo signal, such as range, radial velocity, and DOA, in order to achieve superior performance metrics than previous ones.

1. Introduction

A sensor is an instrument that transforms physical quantities into signals that may be read by observers or instruments. Examples include mercury-in-glass thermometers, which translate the observed temperature into the expansion and contraction of a liquid that can be read on a calibrated glass tube. A voltmeter can read the output voltage produced by a thermocouple, which translates temperature. The majority of sensors have their accuracy checked against recognized criteria.

Sensors are employed in commonplace items like touch-sensitive lift buttons and lights whose bases may be touched to dim or brighten the light. Many individuals are unaware of the countless uses for sensors that exist. Applications span the automotive, industrial, aerospace, medical, manufacturing, and robotics industries.

An object known as a sensor is one that reacts to an input quantity by producing an output that is functionally relevant, often in the form of an electrical or optical signal. The sensitivity of a sensor describes how much the output of the sensor varies as the quantity being measured changes. The sensitivity, for instance, is 1 cm/°C if the mercury in a thermometer travels 1 centimetre when the temperature changes by 1 °C. High sensitivities are necessary for sensors that detect minute changes. Sensors can also affect the quantity being measured; for example, a thermometer placed in a heated liquid can chill the liquid while heating the thermometer.

Smaller sensors are frequently better at this and may offer additional benefits. Sensors must be made so that their influence on the object being monitored is minimal. Called technology advances, more and more sensors may be produced utilising MEMS technology at minuscule scales called microsensors. When compared to macroscopic methods, a micro sensor typically achieves a considerably greater speed along with sensitivity.

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The theoretical maximum information bit rate that may be sent via one or more connections in a region is the channel capacity of a wideband signal. The Shannon-Hartley theorem states that the channel capacity of a correctly encoded signal is inversely related to the channel bandwidth plus the logarithm of the signal-to-noise ratio (SNR). Huge channel capacity might be attained in theory without using higher-order modulations that need a very high SNR thanks to the huge bandwidths that UWB systems have by nature. In order to achieve channel performance close to the Shannon limit, forward error correction is utilised in high-data-rate UWB pulse systems. Most faults are normally corrected by a low density parity check code inner code in OFDM receivers, which is followed by another outer code that corrects the sporadic errors that occasionally get through the LDPC rectification inner code even at low bit-error rates.

WiMedia over a UWB channel utilises a hybrid automated repeat request, which uses frame check sequences for outer error correction and convolutional and Reed-Solomon coding for inner error correction. Ultra-wideband (UWB) technology's application in consumer goods has been constrained for a number of reasons, including the sluggish development of UWB standards, the high initial installation costs, and performance that was well below expectations. UWB is primarily a pulse-based signal, but it may be engineered to seem to a receiver not aware of the signal's intricate pattern as a modest increase in background noise. Narrowband technology struggles with multipath interference, hence some UWB systems employ "rake" receiver techniques to recover duplicates of the original pulse that multipath created in order to boost the performance of a receiver. To boost system throughput and reception dependability, antenna solutions like Distributed MIMO and multiple-antenna systems have been deployed. Real-time positioning systems and short-range applications like PC peripherals benefit from ultra-wideband features.

Additionally, it is utilised in precision time-of-arrival-based localization methods, "see-through-the-wall" locating and tracking, and precision radar imaging technology. It has been suggested that UWB radar serve as the active sensor in an application called Automatic Target Recognition that is intended to find people or items that have fallen into tube rails.

2. Literature Survey

A significant use of sonar systems is the detection and location of submarines. It is well knowledge that a target's reflected signal can be very aspect-dependent, making it such that only receivers situated in a certain zone established through the source/target receive-geometry plus the target aspect is able to recognise the return signal. Using a distributed sensor network made up of simple sensors that solely provide binary detection results, this research suggests a target localisation paradigm. We create optimum maximum likelihood as well as suboptimal line-fitting-based estimators based on the binary outputs plus the sensor locations, and we then calculate the Cramer-Rao lower bound on estimate accuracy. Our numerical findings attest to the viability of the suggested estimators. We localise based on discrete detection findings rather than continuous variables like signal intensity, direction of arrival, time, or time-difference of arrival. Our numerical findings demonstrate that a network of "detection only" sensors may successfully locate targets [1].

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In this study, a brand-new digital beamformer is suggested for uniform concentric circular arrays (UCCAs) with approximately frequency-invariant (FI) properties. The fundamental idea is to utilise a digital beamforming or compensation network to convert the received signals to phase mode and eliminate the frequency dependence of each particular phase mode. The recommended adaptive UCCA-FIB is numerically better conditioned than the traditional broadband tapped-delay-line-based adaptive beamformers thanks to the FI property along with substantially less adaptive parameters, according to findings from simulations using broadband Gaussian and multisinusoidal inputs. Computer simulation also serves to validate the suggested UCCA-FIB's utility in broadband DOA estimate [2].

In recent times, methods that create a direction-finding spectrum based on the eigenstructure of the sensor covariance matrix have garnered a lot of attention. If the available signal-to-noise (SNR) is strong enough to discern two separate peaks in the predicted spectrum, these methods are capable of achieving Cramer-Rao direction-finding accuracy limitations for closely spaced emitters. The approaches for lowering the SNR needed for resolution are discussed in this study, including looking at the roots of the spectrum polynomial and using the characteristics of the so-called signal-space eigenvectors to build a rational (pole-zero) spectrum function. It is demonstrated that whereas the ith greatest eigenvalue is proportional to 2(i-1) or 4(i-1), the biggest signal-space eigenvalue is largely indifferent to signal separation. The findings are incredibly broad and may be used for time-series analysis of sinusoids, exponentials, plus related signals as well as planar far-field direction-finding issues involving nearly any scenarios [3].

In this study, two short-time FrFT variations are created that may be used to analyse multicomponent and nonlinear chirp signals. The method for selecting the value of varies between the two short-time implementations. The uncertainty principle in fractional domains is demonstrated to be compatible with comparative variance measurements based on the Gaussian function. The FrFT algorithm is given an effective FPGA implementation approach that requires less calculations and is ideal for FPGA realisation due to its parallel structure. The results of the FPGA implementation provide as proof of the new method's effectiveness. For the implementation of sophisticated digital computations, FPGAs have abundant resources of logic gates and RAM blocks. They may be employed to carry out any logical operation an ASIC might. A hierarchy of reconfigurable interconnects and programmable logic components known as "logic blocks" are also features of FPGAs. In addition to their digital capabilities, some FPGAs also contain analogue features, such as output pins with configurable slew rates and drive strengths. The peripheral analog-to-digital converters (ADCs) plus digital-to-analog converters (DACs) with analogue signal conditioning blocks are integrated into mixed signal FPGAs [4].

It is a comprehensive literature review on the history and current state of underwater acoustic signal processing and provides insight into the future of this field. The paper begins by discussing the challenges of underwater acoustic signal processing, including the effects of multipath propagation, signal attenuation, and environmental noise. It then reviews the historical developments in underwater acoustics, including the development of sonar technology during World War II, and the subsequent advancements in signal processing

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techniques. It then looks to the future of underwater acoustic signal processing, discussing potential research directions and emerging technologies that could enhance the field. Overall, the paper provides an excellent review of the historical and current state of underwater acoustic signal processing, making it an essential read for researchers interested in underwater acoustic signal processing. Additionally, it serves as a valuable resource for those interested in learning about the challenges and opportunities in this field [5].

3. Proposed System

An antenna is used to transmit the broad band signal that has been created first. The targets in the vicinity will reflect the signal. The targets are identified using the echo signal produced by reflection. The range, radial velocity and DOA of the echo signal are measured using FFT. The closely positioned targets cannot be readily detected is the shortcoming of present technique.

In the beginning an antenna is used to transmit the resulting wide band signal. The targets in the vicinity will reflect the signal. The targets are identified using the echo signal produced by reflection. LCT is used to calculate the echo signal's range, radial velocity, and DOA. The benefit of the suggested technique is the extremely accurate target identification.

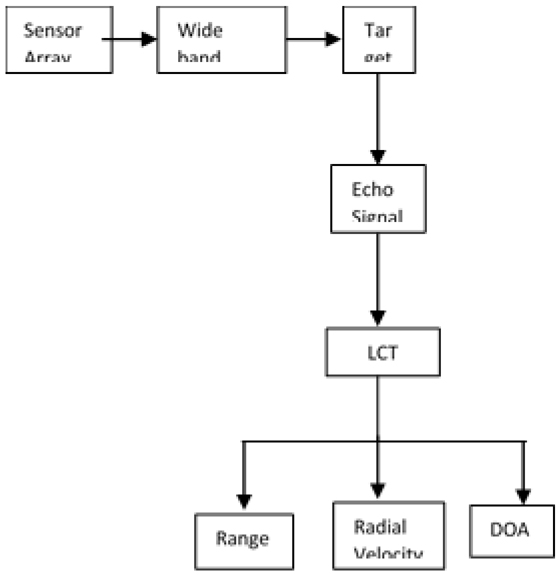

Fig 1: System Architecture

The next section provides an explanation of the many phases that are involved in putting the suggested technique into practise:

1. Wide band signal generation

Wireless radios with a wide band transmit brief signal pulses. For instance, a UWB signal with a 5 GHz centre frequency often spans 4 to 6 GHz. With a range of just a few metres, UWB can support high wireless data rates of 480 Mbps to 1.6 Gbps. QPSK modulation is used to amplify the broad band signal that is created. A DSBCS modulation method called QPSK transmits two bits of digital data at a time without the usage of a different carrier frequency.

More users can utilise the channel since the quantity of radio frequency spectrum needed to send QPSK signals reliably is half that of BPSK transmissions. Even bits from the data stream are removed and multiplied with a carrier at the modulator's input to create a BPSK signal (also known as PSKI). In order to create a second BPSK signal (referred to as PSKQ), the data's odd bits are simultaneously removed from the data stream subsequently multiplied with the same carrier. But before being modulated, the carrier of the PSKQ signal is phase-shifted by 90 degrees.

2. Initializing Targets

Here, the term "target" refers to any moving or still object inside the field of view. The targets are initialised after being given a target count.

3. Echo signal generation

A sensor array, or collection of sensors placed in a certain geometric pattern, is what produces and transmits the wideband signals. The benefit of utilising a sensor array over a single sensor is that the gain of the antenna may be increased in the direction of the signal while being decreased in the direction of noise and interferences. It also has the ability to identify the direction and range of impinging signal sources. In this procedure, a certain kind of sensor array called RADAR is employed, where the broad band signal is reflected by the targets and the echo signal is produced. The echo signal that is produced is often highly loud.

4. Estimation of Range

By using LCT, the range is approximated. A target's range is a measurement of how far it is from the signal source.

5. Estimation of Radial velocity

An object's speed in the direction of the line of sight is called its radial velocity. Every motion with a certain velocity has a direction, making it a vector. This motion-vector may be divided into two halves according to an observation direction.

- The movement parallel to that radial (known as tangential velocity);
- The motion along that radial (either straight towards or away from the observer, termed radial velocity).

6. Estimation of DOA

The term "direction of arrival" refers to the direction that a wave typically travels from before arriving at a location where typically a group of sensors are situated. This collection of sensors makes up a sensor array. The beam shaping approach, which is often used, estimates the signal coming from a certain direction. (DOA) estimate is crucial in a variety of sensor systems, including radar, sonar, electronic security, and seismic research. Numerous applications require high-resolution frequency estimation, with large flexible space structures and robot design and control being two recent examples.

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4. Results

In his study, a novel method for wideband chirp signals-based detection and estimate of the range, velocity, and direction of arrival (DOA) of various far-field objects is put forward. The generated broad band signal is transmitted via an antenna, and the nearby objects are located using the echo signal created by reflection. The range, radial velocity, and DOA of the echo signal are determined using the LCT. The incredibly precise target identification is an advantage of the suggested method. A method has been proposed for computing the locations and velocities of several objects using a concentric uniform circular array.

It comprises a modal preprocessing step that transforms the signals acquired at the sensor array into signals at different modes in order to utilise narrowband techniques for DOA estimation. Many targets' parameters can be determined using the fractional Fourier transform.

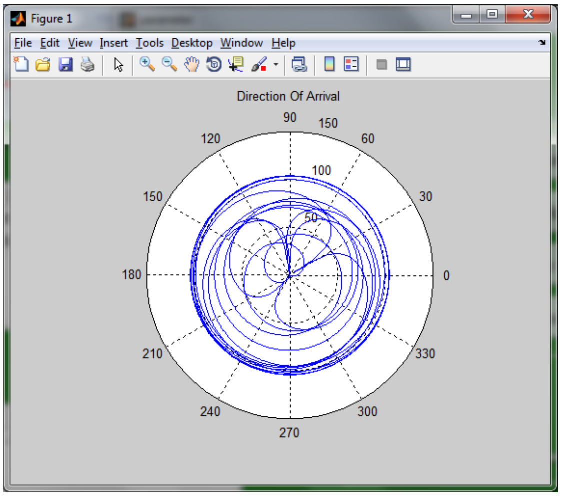

Fig 2: Direction of Arrival

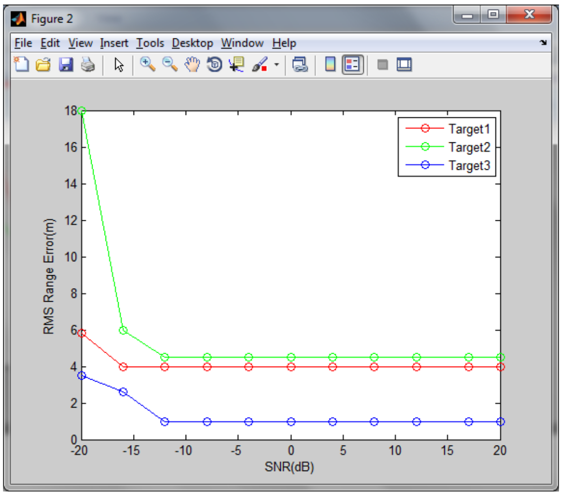

Fig 3: RMS Range Error

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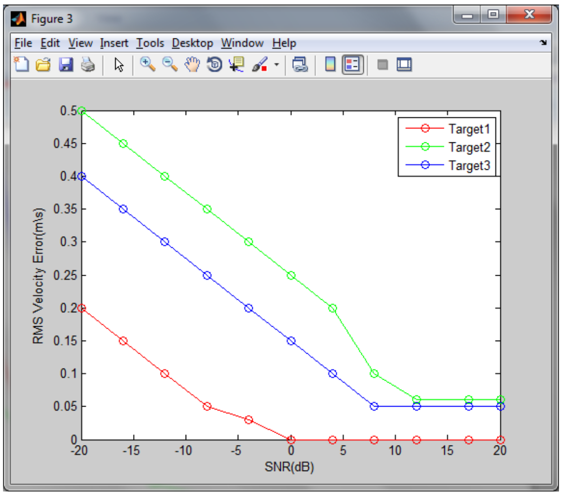

Fig 4: RMS Velocity Error

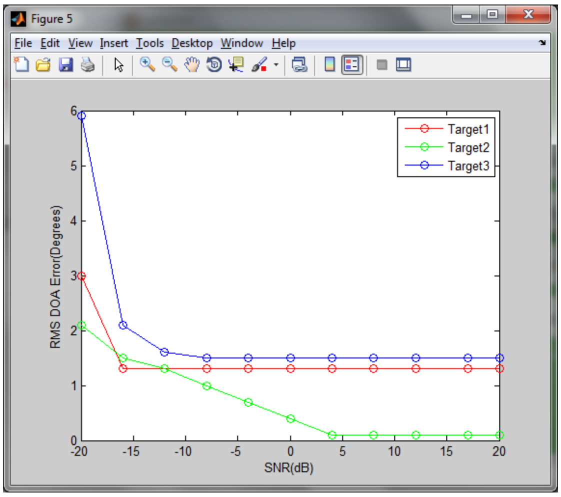

Fig 5: RMS DOA Error

5. Conclusion

A technique for calculating the positions and velocities of many targets employing a concentric uniform circular array has been put forward. To apply narrowband approaches for DOA estimation, it includes a modal preprocessing phase that converts the signals received at the sensor array into signals at various modes. The suggested approach makes it feasible to figure out the parameters of many targets by including the fractional Fourier transform.

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