Facial Recognition Using Rapid, Multi-spectral Scanning

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Abstract

Under this project, a novel laboratory-scale prototype of an automated facial recognition system will be developed and evaluated. This project addresses the commercial need for an automated, reasonably priced, and highly reliable face recognition system for security and identification marketplaces. Current commercial approaches to face recognition rely on image processing of two-dimensional video imagery and have recently experienced highly publicized failures. This project takes an entirely different approach to the problem by focusing on a different sensing method using a high-resolution coherent laser radar system combined with millimeter wave imaging. This project will evaluate the feasibility of the concept in meeting cost, speed and performance goals for the facial identification application.

Technical Approach and Significance

The approach utilizes the unique capabilities of PNNL staff experience and facilities in integrated wideband mod/demod electronics, millimeter wave imaging, laser radar, and image processing. The concept in this integration is to synchronize the unique multi-spectral, synchronous scanner, which is running at a very high laser modulation bandwidth (e.g. 500 MHz), with a fast signal detection and mapping schema down into a compressed-bandwidth (e.g., 6 MHz), video rate processor, where more standard detection is performed on a parallel set of images in real time (RT). The following sections highlight this approach.

Millimeter Wave Imaging

Millimeter-wave scanning devices have been under consideration for 3-D face recognition systems (biometric identification) for a number of reasons. These scanners use safe, low-power millimeter waves (radar signals) to illuminate the person being measured. The radar signals penetrate clothing material and are reflected from the human body. A high-speed computer processes the reflected radar signals, captures spatial coordinate data, and forms a single 3-D measurement of the human feature from that data. The significant advantage of millimeter-wave radar signals is that they can readily penetrate optically opaque materials such as body hair, disguises, and clothing.

The 3-D facial biometrics is comprised of dimensional information from the scanned individual's anatomy. Once an individual reaches maturity (adulthood), his or her skeletal anatomy will not normally change dramatically over time (except as result of accident or disease). Although the radar signals emanating from millimeter-wave scanner do not penetrate the subject's skin, ***the surface data will enable critical 1D,***

2D and 3D skeletal dimensions and anthropometric measurements to be calculated. The length and shape of various bones can be obtained from surface evidence (e.g., joints, skin protrusions). Because the skin covering the cranium is fairly thin, volumetric measurements of the skull and critical anthropometric data (e.g., placement, shape and distance between eye sockets) can be obtained.

Other types scanners can be used in combination with the millimeter-wave scanner to obtain the same or similar biometric information. However, the ***millimeter-wave scanner can quickly and unobtrusively scan through clothing, disguises and body hair***. When combined with another sensor process, such as the primary design for locating eyes using coherent laser radar and an optical scanning system, this security system could be almost foolproof using disguises.

The implementation of a standoff 3-D facial recognition system using millimeter-waves will require an interferometer operating at very high frequencies. Figure 1.0 shows a simplified millimeter-wave interferometer using a mono-static antenna arrangement. The very high gain antenna is required for a narrow beam pattern (spot size) to be mechanically scanned to measure facial dimensions. The system ideally would work at extremely high millimeter-wave frequencies (200 – 400 GHz) so that the size of the system would be very small.

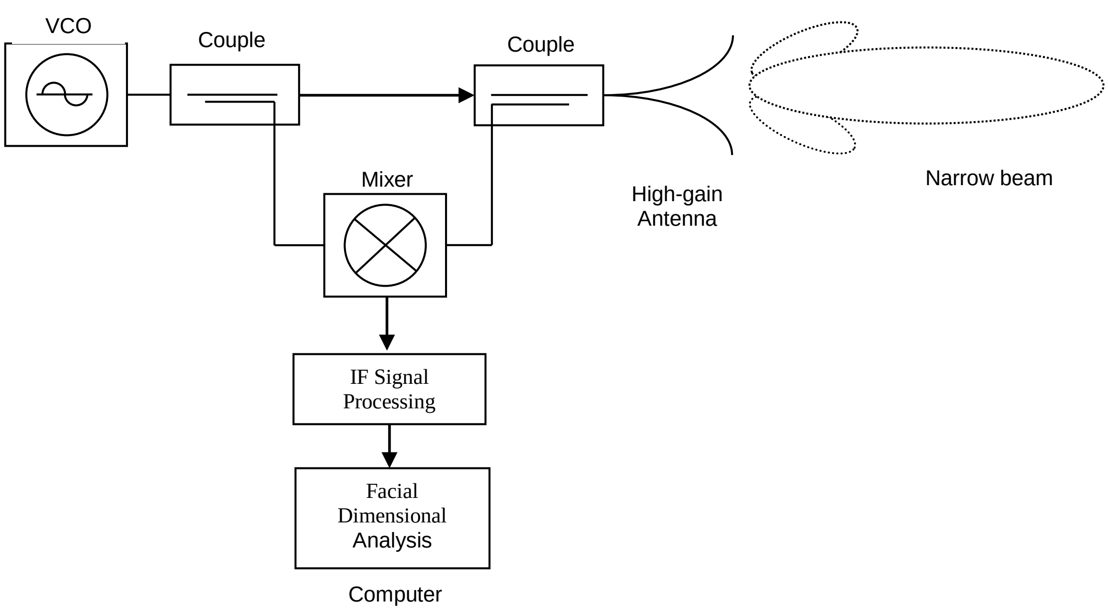

Figure 1.0. Simplified block diagram of millimeter-wave interferometer for 3-D facial recognition system

Coherent Laser Radar

Laser ranging can employ a number of techniques including time of flight, triangulation, interferometry, and phase detection methods. For short range of less than 30 meters, the phase comparison technique is generally recognized as having the best performance in terms of cost, performance, and complexity. Relative range resolutions of ~2 mm and 2-5 mm image pixels, based on the laser beam diameter, provide enough data to produce exceptionally detailed 3D target images.

Phase comparison laser ranging methods utilize amplitude modulated (AM) continuous wave (CW) laser diode transmitters (Figure 1.1). In the AM/CW laser radar scheme, the laser beam amplitude is modulated between zero and a maximum intensity at a specific frequency. Both intensity and phase shifting of the reflected beam (with respect to the launched one) are simultaneously detected. A highly accurate picture of the scene is obtained from the intensity signal. Comparing the transmitted and received signal phase provides high resolution target ranging.

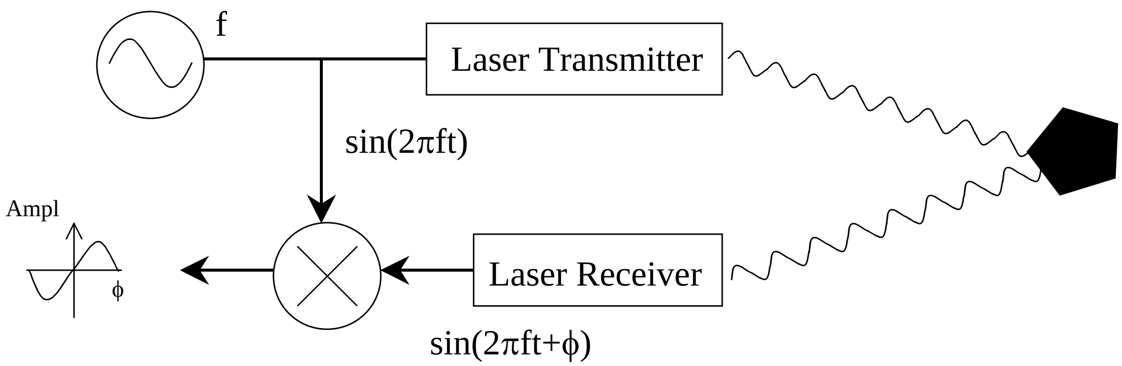

Figure 1.1. An AM/CW laser ranging method based on phase comparison

The range distance resolution D is determined by measuring the phase angle between the transmitted sine wave and the received sine wave. The relationship between phase angle $\Delta\phi_r$ (radians), time delay t_r, speed of light c, and modulation frequency f_o, is:

$$t_r = \Delta\phi_r / 2\pi\, f_o \qquad [1]$$

$$D = c\, t_r / 2 = c\, \Delta\phi_r / 4\pi f_o \qquad [2]$$

Given a desired distance resolution of D=2.0 mm, and a reasonable phase resolution measurement $\Delta\phi_r = 5°$, the required AM modulation frequency can be calculated by rearranging Equation (2):

$$f_o = c\, \Delta\phi_r / 4\pi D \qquad [3]$$

The working frequency becomes approximately $f_o = 1.0$ GHz. This modulation rate sets the ambiguity interval of the range measurement (Figure 1.2). The total range corresponding to a phase turn (0-360°) at this frequency is 0.300 m ($D_{range} = c/(2\, f_o)$). This ambiguity interval provides enough depth to fully image a target's face. The AM/CW transmitter can be switched to a time of flight measurement to measure the absolute distance to an identified target. This information is then used to scale the laser radar images to the millimeter wave and analog video images.

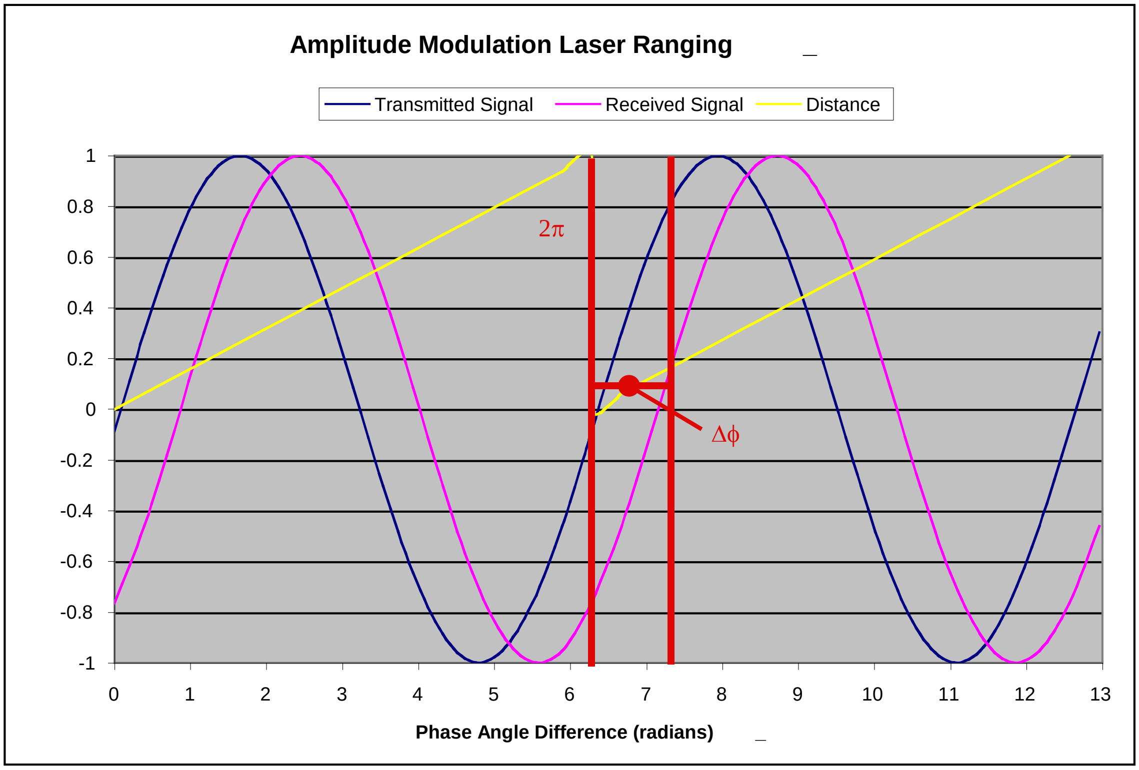

Figure 1.2. Amplitude modulation laser ranging showing the relationship between phase difference and range.