Camera Tracking System: Problem Statement

An interesting application of fuzzy control is the camera tracking control system at the Software Technology Laboratory, NASA/Johnson Space Center, used to investigate fuzzy logic approaches in autonomous orbital operations [Lea and Jani, 1992]. The camera tracking control system utilizes the tracked object's pixel position on the image as input and controls the gimbal drives to keep the object in the field of view (FOV) of the camera as shown in Fig. 1(a). Thus, tracking an object means aligning the pointing axis of a camera along the object's line of sight (LOS). The LOS vector is estimated from the sensory measurements.

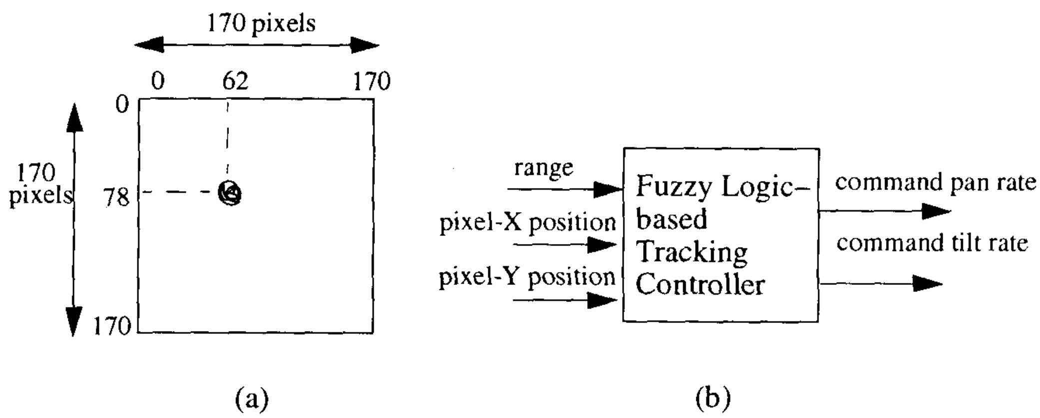

Figure 1 Camera tracking system. (a) Camera field of view. (b) Input-output of fuzzy logic-based tracking controller.

In this camera tracking control system, the monitoring camera is mounted on the pan and tilt gimbal drives, which can rotate the camera or, equivalently, the pointing axis of the camera within a certain range. The camera frame (viewing plane) consists of three axes: vertical, horizontal, and pointing vectors. This plane is a Cartesian coordinate plane of 170 X 170 pixels with the origin at the upper left corner as shown in Fig. 1(a). When an image is received, it is processed to determine the location of the object in the camera frame. Using an appropriate image processing technique, the centroid of the image is computed and used as the current location of the object in the viewing plane.

As shown in Fig. 1(b), the inputs to a fuzzy logic-based tracking controller are the LOS vector and the range of the object (the distance of the object from the camera), and the outputs are the command pan and tilt rates. The LOS vector is expressed in terms of pixel position (x, y) in the camera's FOV. The range of the object is received from the laser range finder as a measurement. With these three inputs, the task of the FLC is to determine the proper pan and tilt rates for the gimbal drives so that the pointing axis of the camera is along the LOS vector of the object and the image location is at the center of the viewing plane [i.e., at (85, 84)]. In the camera's FOV, tilt upward is negative and pan right is positive.

Membership functions of the input variables (i.e., range, horizontal, and vertical positions) are shown in Fig. 2(a). Membership functions of the scale-factor and the output variables (i.e., pan rate and tilt rate) are shown in Fig. 2(b). The scale-factor parameter is used as an intermediate step to indicate the degree that a control action should propose to reflect the distance of the tracked object from the camera. The basic concept is that the movement of the object in the FOV caused by the movement of the camera is greater when the object is closer to the camera than when it is farther from the camera.

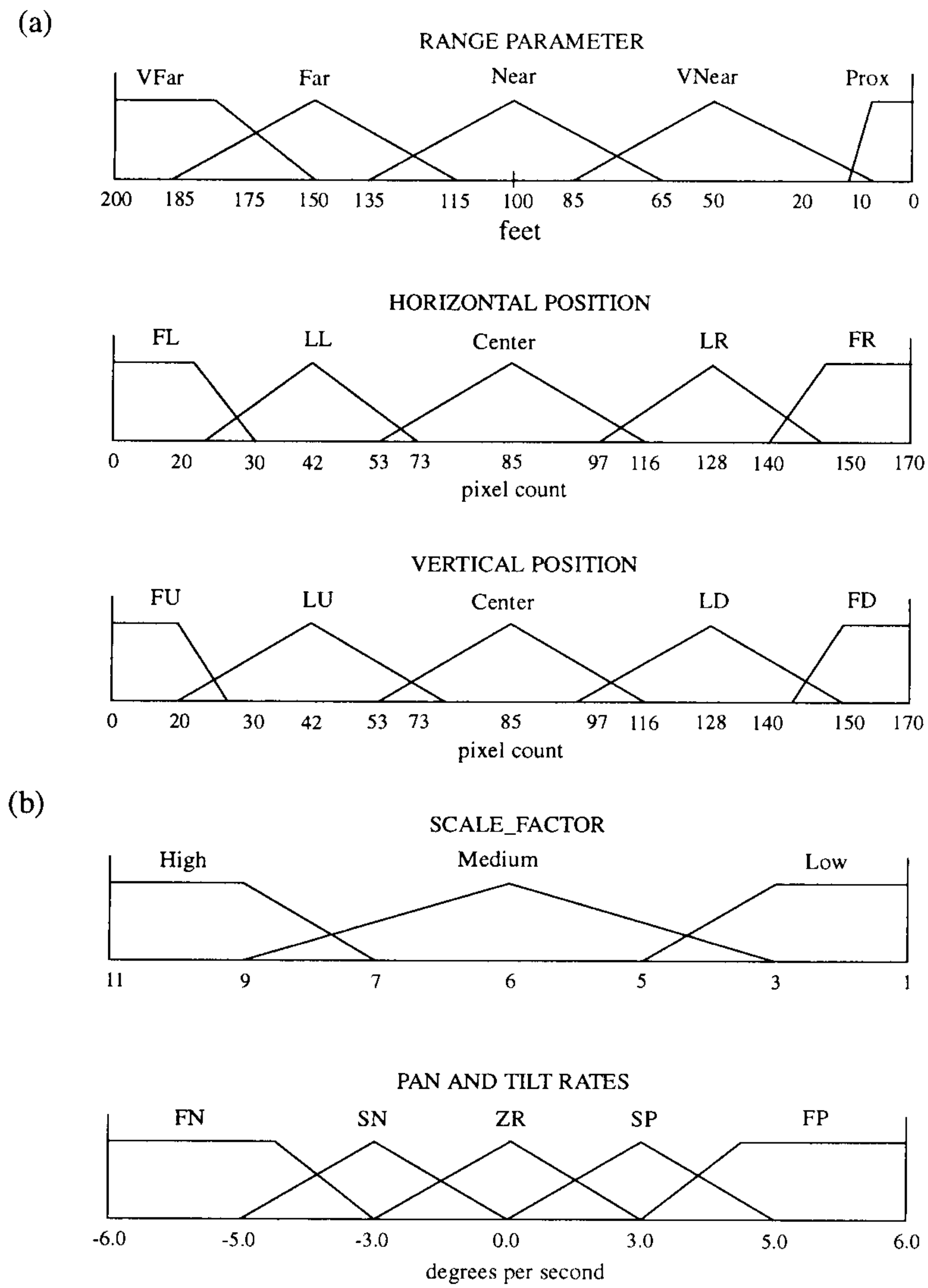

Figure **2** (a) Membership functions for input parameters. War, Very far; VNear, Very near; Prox, Proximity zone; FL, far left; LL, little left; LR, little right; FR, tar right; FU far up; LU, little up; LID, little down; FD, far down. (b) Membership functions for Scale Factor and Output parameters for camera tracking system. FN, Fast negative; SN, slow negative; ZR, zero; FP, fast positive; SP, slow positive. (Reprinted by permission of the publisher from "Fuzzy Logic in Autonomous Orbital Operations," by R. N. Lea and Y Jani, International Journal of Approximate Reasoning, Vol. 6, No. 2, pages 151-184. Copyright 1992 by Elsevier Science Inc.)

Three sets of fuzzy control rules are used [see Table (1)]. The first set of rules is for finding the scale factor, which will be used in the next two sets of rules. For example, one rule in the second rule set may read: "If the horizontal position of the object is to the far left of the center of tile viewing plane and the scale factor is low (i.e., the distance of the object is far), then set the pan rate fast negative (left)." This example also illustrates application of the chain rule technique of expert systems in FLC design; that is, the firing of a rule causes the firing of another rule. Normally, a FLC has only single-layer-rule firing.

Table (1):

Base Rule for a Camera Tracking Control System

	Distance Membership Functions				
	VFar	Far	Near	VNear	Prox
Scale_Factor	Low	Low	Med	High	High
	Horizontal Position Membership Functions				
Scale_Factor	FL	LL	Center	LR	FR
	Pan_Rate Membership Functions				
Low	FN	SN	ZR	SP	FP
Med	SN	SN	ZR	SP	SP
High	SN	ZR	ZR	ZR	SP
	Vertical Position Membership Functions				
Scale_Factor	FD	LD	Center	LU	FU
	Tilt_Rate Membership Functions				
Low	FP	SP	ZR	SN	FN
Med	SP	SP	ZR	SN	SN
High	SP	ZR	ZR	ZR	SN