

A Quantitative Measure of Telepresence

Abstract

This paper presents the foundation for a theory of presence that seeks to answer important questions about telepresence and virtual presence. The theory, which develops the definition of telepresence to include virtual presence as a special case, permits the precise definition of various types and degrees of telepresence. General categories of telepresence are defined, using different types of presence that are proposed in the paper. Three types of specifications are used to make the definitions more precise: (1) a set of tasks, (2) a transformation imposed on the human operator's control output and sensory input, and (3) a transformation of the region of presence. The proposed quantitative measure of telepresence involves both objective and subjective measures. The degree of (objective) telepresence is equal to the probability of successfully completing a specified task. The degree of *subjective* telepresence is equal to the probability that a human operator perceives that he or she is physically present in a given remote environment. The measure of subjective telepresence involves a psychophysical test and is analyzed using signal detection theory. Real-world complications are addressed and a practical example of a subjective telepresence test is described.

I Introduction

Telepresence¹ is a popular idea that is not well defined. In essence the idea is that a person is *in some sense* present in an environment that is physically remote from the person in space. Existing definitions of telepresence and the related concept, virtual presence, depend on the idea that the person *feels* present in the given environment.² Unfortunately the latter is not adequate for quantitative investigations (Held & Durlach, 1989, 1992).

This paper seeks to address the problem by defining telepresence in quantitative terms. The discussion also applies to virtual presence, which is shown to be a special case of telepresence. Indeed, the foundation for a theory of presence is developed that permits the precise definition of many different types and de-

1. The term was first introduced in a 1980 *Omni* magazine article written by Minsky (1980), who gave credit to his friend Par Gunkel for coining the term. The idea is evident earlier, however, in the work of Raymond Goertz in the late 1940s (Johnsen & Corliss, 1971, pp. 120-121; Vertut & Coiffet, 1986, pp. 25-27).

2. For example, Sheridan (1992a, p. 274) defines telepresence "to mean that the human operator receives sufficient information about the teleoperator and the task environment, displayed in a sufficiently natural way, that the operator feels physically present at the remote site." Note that virtual presence is simply the case where the teleoperator and the remote environment are simulated inside a computer.

degrees of presence. At the heart of the theory is the idea that *presence* involves objective interaction.³

1.1 Overview of the Theory

A person is *objectively present* in a *remote environment* where the person is *not* physically present, if there is some type of causal interaction between the person and the environment. For example, the person might cause or detect some remote event using a teleoperation system. Clearly, a person can also be objectively present in his or her *local environment* (where the person *is* physically present). It should also be clear to the reader that objective presence, without further specification, implies nothing about how the person *feels*.

The *degree* of objective presence may be defined based on the probability that a given task is completed successfully. For example, a baseball player's batting average is his or her degree of objective presence *in the task* of getting a hit. Similarly, one could define a degree of objective presence based on the probability that a person will perceive a particular word when presented with a given auditory stimulus (Kryter, 1972, p. 174).

Different *types* of objective presence may be defined based on what task is specified and I submit that this is the key to defining telepresence. An important question that is *not* addressed in the paper, however, is how the set of all possible tasks might be partitioned into important types of objective presence. The one case that is discussed in some detail is related to a person's *feeling of presence*.

1.1.1 Subjective Presence. An important category of objective presence is the case where the specified task is for a person to perceive that he or she is physically present in a given environment. For example,

3. This aspect of telepresence is often neglected, perhaps because it is so obvious. Nevertheless, telepresence is commonly described in terms of teleoperation, which *implies* an objective interaction between the human operator and the remote environment. The definition proposed by Akin, Minsky, Thiel, and Kurtzman (1983) recognizes objective performance explicitly. They state, "At the worksite, the manipulators have dexterity to allow the operator to perform normal human functions." Unfortunately, this definition neglects some important cases (Held & Durlach, 1989, pp. 28-2 to 28-3; 1992, p. 109) and it is not quantitative.

if you stop and think about it you will (no doubt) perceive that you are physically present in some environment (wherever you happen to be right now).⁴ This is *subjective presence*.

The *degree* of subjective presence is defined to be the probability that a person perceives that he or she is physically present in the given environment. Measuring the degree of subjective presence involves a psychophysical test. For example, one might use a procedure similar to the method of constant stimuli (Gescheider, 1985, pp. 38-39).

Figure 1 illustrates a simple example of such an experiment. In this hypothetical experiment there is a room with a door. The test subject would stand at various locations on a line running through the door and respond to the yes-no question, "are you in the room?" Far to one side of the door the subject would (always) respond, "yes" and far to the other side he or she would (always) say "no." In between the two extremes, the degree of subjective presence is equal to the relative frequency of "yes" responses. For example, I predict that the person would respond "yes" half of the time somewhere in the vicinity of the door; corresponding to a degree of subjective presence equal to $\frac{1}{2}$.

1.1.2 Subjective Telepresence. Existing definitions of telepresence can be made more precise simply using the idea of *subjective presence* rather than vague notions about how a person *feels*.

I propose a strict test of subjective telepresence. In the test a person is asked to decide between two cases presented at random: (1) where the person is physically present in an environment, or (2) where he or she is interacting with the environment via a teleoperation system (see Section 2.1). If the person cannot detect the difference between the two cases then he or she is subjectively telepresent in the given environment. The degree of subjective telepresence is equal to the probability that the person says that he or she is physically present when the person is in fact using the teleoperation system.

4. I will sometimes use the less formal pronoun "you" in discussions related to subjective presence because it is something that each of us can experience directly.

