Chapter 15
Measurement Uncertainty in Decision-Making: How to Take Reliable Decisions under Uncertainty

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ABSTRACT
In this paper, the authors examine a common issue concerning the influence of measurement uncertainty on decisions. In fact, in some practical applications, it can be necessary to put in comparison measurement data with thresholds and limits. It occurs when the conformity with fixed specifications has to be verified or if warning and alert levels have to be not exceeded. In such a circumstance, to take reliable decisions in presence of uncertainty is a concrete problem. Measurement uncertainty may reasonably be the cause of unreliable decisions. In order to manage properly the uncertainty effect, the authors have developed a decision making procedure based on a methodical approach to measurement uncertainty. In detail, a fuzzy logic algorithm estimates the probability to take a wrong decision because of the uncertainty. Such information is so used in order to optimize the decisional criteria, improving the consistency of the final computing results. Risks and costs associated to the possibility to take a mistaken decision are minimized. Consequently the algorithm singles out the most reliable decision.

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INTRODUCTION

Typically measurements are used in order to get information on a phenomenon. Or, at times, merely it is required to know the behavior of a specific quantity. Such a task is not so simple. Often the available a priori information on the phenomenon is not sufficient. Therefore knowledge is not only by means of measurements. Sometimes measured data are subsequently put in comparison with fixed limits or warning thresholds (law limits or quality target) in order to verify the conformity with predetermined specifications or to control the occurrence of an alarm state. So decisions have to be taken about the possible limit overcoming. Generally when a parameter or value has to be compared with a limit or threshold, the simple mathematical comparison between the two values has to be avoided. In fact, the result of any measurement is affected by uncertainty. So, according to the Guide to the expression of Uncertainty in Measurement (JCGM, 2008), the result of a measurement is simply an approximation or estimate of the value of the measurand. The uncertainty characterizes the dispersion of the values that could reasonably be attributed to the measurand. Consequently the comparison does not concern two mere numerical values, but rather a value (limit or threshold) and an interval of values (measure). High values of uncertainty are cause of wide intervals and so the probability to take a mistaken decision is higher. Therefore the result of the comparison depends strongly on the measurement uncertainty, for that reason it cannot be disregarded. An underestimation of the uncertainty effects may be cause of wrong decisions. Consequently specific requirements on the reliability of measured data are required. Reliable data can be guaranteed not only by means of the choice of an appropriate measurement system. Although it should allow a decrease of the uncertainty to be got, an opportune analysis of the measurement process is needed too. In detail, in practice there are numerous possible sources of uncertainty in a measurement. The main contributions include: a) an incomplete definition of the measurand; b) an inadequate knowledge of the effects of environmental conditions; c) the used measurement method and procedure; d) the used measurement system. Therefore further information on measurement process is necessary in order to qualify the reliability of the decision making stage. In this sight, the comparison between measurement data and limits needs opportune decisional rules. In the state of art, several procedures and models have been proposed, but few ones keep into consideration the influence of uncertainty about the possibility to make a wrong decision. A methodical approach to such problems would require a suitable analysis of the possible risks and costs associated to the decisional alternatives. According to the number of decisional alternatives, it is possible to single out two categories of decision problems. In the present manuscript, attention is focused on Multi-Attribute problems where the number of alternatives is finite and determined, (Yuxun, 2010; Wang, 2010). With reference to the literature, the Standard EN ISO 14253-1, (International Organization for Standardization, 1998), provides a simple decisional rule for problems of conformity with specifications. Unfortunately in practice, it is a “rule of thumbs” because of some restrictions. In order to fix the problem, let us consider a generic process under control. Typically specific parameters or quantities are considered in order to monitor the process (Zingales, 1996; Catelani, 1998). So the occurrence of an out-control situation happens when the measured parameter or the quantity overcomes the specification limit or threshold. Such case includes several practical problems like environmental monitoring applications, the control of an industrial process, the check of compliance with specifications, or the observance of laws and regulations. The problem rises from putting in comparison the measured data with a fixed reference value. Often the overcoming of similar warning or threshold levels entails adopting