Diagnostic Methods

Introduction to Diagnosis

Outline

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- Methods of diagnosis
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Overview

- With the increased complexity of industrial machines and processes, the task of fault diagnosis is becoming increasingly difficult and its complexity almost unmanageable using conventional techniques.
- The automatic diagnosis requires the ability to identify the symptoms automatically and map them to their causes as well as, eventually, to prescribe solutions for repairing/restoring the good functionality of the device or machine.

Overview

- Besides industry, Artificial Intelligence (AI) techniques and tools have been used in medical applications/diagnosis for over four decades.
- The overall objective was to improve health care by helping physicians in improving accuracy, cost efficiency and replication.

Definitions

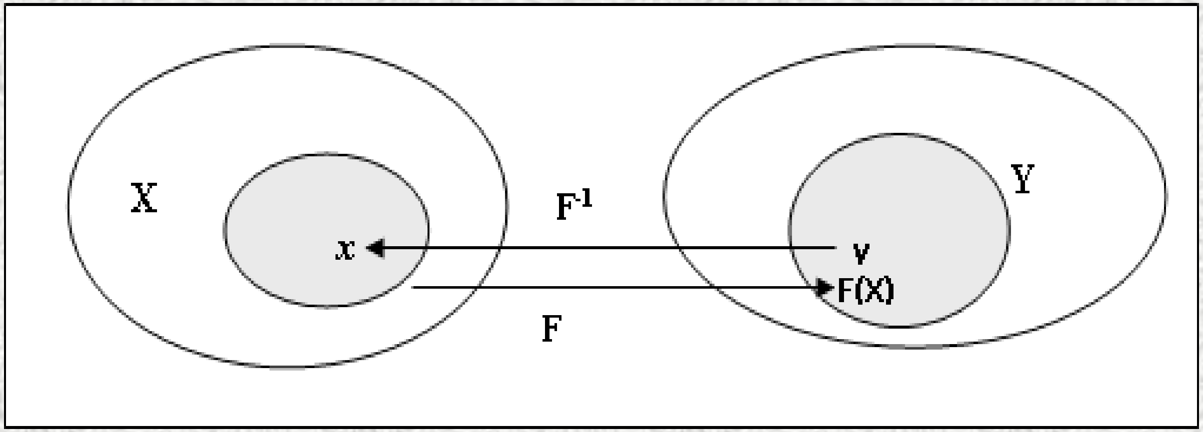
- In order to fully understand the methods of industrial diagnosis, we must proceed by a definition of the main basic concepts related to this term:
  - "Diagnosis is the identification of the probable cause of the failure (s) using logical reasoning based on a set of information from an inspection, control or a test."
  - The term Artificial Intelligence (AI) is well-defined as a stream of science and engineering.

Definitions

- This definition gives us the two main tasks of the diagnosis, namely:
  - Observe the symptoms of failure.
  - Identify the cause using logical reasoning based on observations.
- One of the models proposed to simplify the problem of industrial diagnosis is the purely formal mathematical approach, with which the problem is reduced to a relation between the cause and its effect.

Definitions

- The relation between the space of causes X and the space of symptoms Y:



Definitions

- X: Space of unknown parameters (all causes).
- Y: Spaces of observable quantities (all symptoms).
- The studied problem consists of the determination of x solution of y knowing the function F.
- We have F (x) = y, the obvious solution is given by:

$$x = F^{-1}(y).$$

Diagnostic System

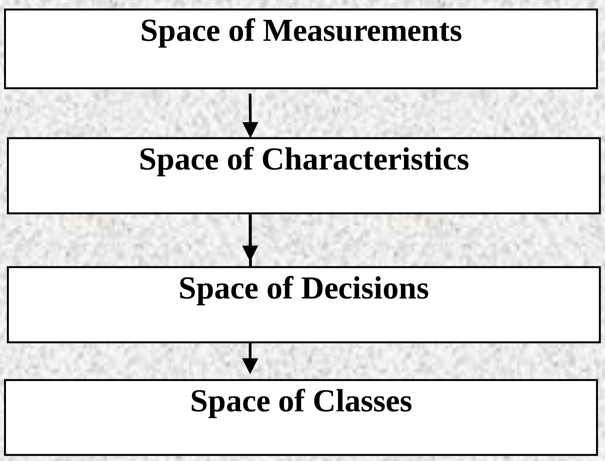
- The procedure for diagnosing failures and degradations is based on the following steps:
  - Extracting **information** necessary for shaping the characteristics associated with normal and abnormal cases.
  - The development of **characteristics** associated with symptoms of failures and degradations with a view to detecting a malfunction.

Diagnostic System

- The **implementation of a method** for diagnosing failure or degradation based on the use of knowledge of cause and effect relationships.
- **Decision-making** based on the future consequences of failures and degradations. In industry, this decision-making can lead to a shutdown of the installation if the consequences of the failure are important for the safety of people and goods or to a reconfiguration of the operation of the process to avoid a loss of production while waiting for the next production shutdown.

Transformation of measurements into a diagnostic system

- In general, the decision procedure in diagnosis can be viewed as series of transformations or relationships between data:



Transformation of measurements into a diagnostic system

- The series of transformations can be expressed as a composition of 3 applications on different spaces:
  - The space of measurements: This is the space of quantities x1, x2, x3, x4, ... xk without any a priori knowledge of the links between these quantities. These quantities are considered as inputs to the diagnostic system.

Transformation of measurements into a diagnostic system

- The characteristic space: This is the space of points y = (y 1, .., yi) where yi is the ith characteristic obtained by applying a specific function to the measures. The measurements are analyzed and combined using a priori knowledge of the process for the extraction of characteristics useful for diagnosis.

Transformation of measurements into a diagnostic system

- The decision space: It is the space of points d = [d1, d2, d3, .., dk], where k is the number of decision variables, obtained by an adequate transformation of the space of characteristics. The class space is a set of integers c = [c1, c2, .., cm], with m the number of failure classes.

Transformation of measurements into a diagnostic system

- The class space: This is the final interpretation of the diagnostic system delivered to the user. The transformation from decision space to class space is also achieved either through threshold or symbolic reasoning. After designing and implementing a diagnostic system, it is best to assess its effectiveness based on a set of criteria measuring the performance of the procedure developed.

Methods of diagnosis

- The taxonomy of diagnostic methods allows various classifications according to several points of view.
- Two possible classifications for these methods:
  - the first is based on the availability of a model describing the cause and effect relationships (model based methods).
    - Fault Tree
    - Structured Analysis and Design Technique (SADT)

Methods of diagnosis

- The second is based on the reasoning method used to trace the cause of the failure (non model methods).
- This includes machine learning algorithms:
  - Artificial Neural Networks (ANN)
  - K-Nearest-Neighbour (KNN)

Criteria for evaluating diagnostic methods

- In order for a diagnostic method to be evaluated, evaluation criteria must be developed. We can essentially summarize them in 10 criteria:
  - Rapid detection and diagnosis: The diagnostic system must respond quickly to detect and diagnose process failures.
  - Separability: It is the ability to distinguish between different failures.

Criteria for evaluating diagnostic methods

- Robustness: In the sense of tolerance to noise and uncertainties, performance should degrade step by step and not suddenly fail in the event of anomalies.
- Identification of new modes of malfunction: One of the necessary criteria for a diagnostic system is the ability to decide based on the current state whether the process is operating normally or is in a failed state. If so, determine the cause.

Criteria for evaluating diagnostic methods

- Classification error estimate: A practical need for a diagnostic system is its reliability, this can be expressed by estimating the misclassification that may occur.
- Adaptability: the diagnostic system must be adaptable to the changes (product quality and equipment in industry). It is necessary to have the possibility of developing an extension of the existing system to support the evolutions of the process when the data is available.

Criteria for evaluating diagnostic methods

- Ease of explanation: In addition to identifying the source of the malfunction, the system must be able to provide information on the degradation of the system in the current state. This is a very basic factor in the design of online decision systems.
- Modeling effort: The effort required in modeling for the development of classification systems is a strong constraint. For quick and easy deployment; it must be the minimum possible.

Criteria for evaluating diagnostic methods

- Computing and storage needs: Using complex algorithms may need large memory capacity!
- Identification of multiple failures: The ability to identify multiple failures is a desirable need but difficult to achieve because of the interplay between these failures.