

the **New Science** of **FIXING THINGS**

d-TOOLSSM e-Learning

English Glossary

Glossary

Abduction

Abduction is one of the three separate reasoning processes. The objective of abduction is to determine which hypothesis to test (develop the question).

See *Deduction* and *Induction*.

Aggregation

Summarize a large amount of data values into smaller groups.

Analysis of Variance

Output variance is divided into parts, matching the different test variables.

Also known as *ANOVA*

ANOVA

See Analysis of Variance.

Average Range

The average of individual sub-group ranges.

Case-based Reasoning, Strategy

Diagnosis using knowledge of symptom causes. See *Symptomatic Knowledge, Strategy*.

Causal Explanation, Mechanism

One root cause is not adequate to explain machine behaviour. We understand better when we are able to describe system behavior as a function of component geometry and component properties.

Characterize

Map the behavior of product or process systems.

Cognitive Process

Human processing of information and application of knowledge.

Combinational Feature

Single features may be combined to form combinational features such as slots, grooves and tongues. For example, a tongue consists of a pair of parallel plane surfaces. It also has another plane at right angles to the parallel planes, and a median plane. Combinational features may need tolerances of position or symmetry.

Confounding

Grouping of input factors in an experiment, or *omnibus factors* in stratified sampling. For the purpose of reducing the total experiment, or sample size. If confounded factors have leverageable effect, additional tests or samples are required to separate the confounded effects.

Contrast

Find differences. For example, measurement of *geometry* or *properties* at different points on a *feature*. For example, performance differences of replicated systems. In the context of *DOE*, it is the difference between average output at varying input levels.

Convergence Split, Tree

Abductively reasoned questions or hypotheses can be summarized as branches on a tree. A branch can split into two to six alternatives, and once the answers are obtained, the weaker branches are crossed out. The remaining branch can then be split again, recording the *progressive search* until the dominant factor driving observed variation is identified as the root cause.

Correlation

The strength and direction of a linear relationship between two variables.

Data Map

Graphic relating locations and event occurrences to see concentration patterns. Also called Concentration Plot, Picasso Plot.

Decision Bands, Limits

Calculated estimates of the 95th percentile of variation (*repeatability*) from a reversible function. Similar to statistical process control limits, used to determine statistically significant changes for the Dissection Search tactic. Calculation is based on *Dixon's Q-Test* for extreme values in small samples.

Deduction

Deduction is one of the three separate reasoning processes. The objective of deduction is to draw exact conclusions from facts. Deduction also tests question effectiveness beforehand: What will I learn if I do this test? What will I do next? See *Abduction, Induction*.

Dependent Variable

An output variable of a function being measured, also known as response variable; responding variable; explained variable; or regressand.

Deterministic Model

Model that produces the same output for a given starting condition. No uncertainty is involved in predicting future states of the system.

Diagnosis

The cognitive process of explaining machine behavior from the geometry and properties of its constituent parts. Diagnosis is the inverse of *simulation*.

Discriminate

Distinguish accurately for comparative analysis.

Dissection Strategy, Tactics

The overall strategy is to divide a system structurally into subsystems or elements in a hierarchical manner. The objective is to find the element with the most influence over the observed variation. The primary tactics are *Half-Split* and *Search*.

Dixon's Factor, Q-Test

Dixon's Q-Test determines if suspected outliers in small samples are actually from a different distribution. Based on the statistical distribution of "subrange ratios" of ordered data samples drawn from the same normal population (hence, a normal distribution of data is assumed). The test can be represented by a single multiplying factor depending only on the sample size used in an *Isolation* repeatability study.

DMAICR

From the Six Sigma methodology for process improvement. Each letter stands for one of the six-steps in the process: define, measure, analyze, improve, control, and report.

DOE

Design of Experiment. See *Experimental Design*.

Effect to Cause Strategy

Also called Y to X, this is the overall approach of working backwards from the observed performance behavior of a system to identify the geometry and or properties with the greatest influence on that behavior.

Experimental Design

The design of an information gathering exercise to establish the effect at different input levels of some process or intervention (the treatment) on objects (the experimental units).

Expert System

An expert system, also known as a knowledge-based system, is a database that contains some of the subject-specific knowledge, and contains the symptom-cause knowledge of human experts.

Families of Variation

Families are *Contrasts* or *Hierarchical* levels employed in the *Matryoshka* tactics. Structural families fall into two main groups: individual component *topography* and either manufacturing or operating system *topography*. Functional families must be defined by working from the output back to the input. The strata, or layers of data are often called Families of Variation because each represents many variables or Xs.

FAST

Function Analysis Systems Technique. A top-down decomposition in which the functions of a product or process are described using blocks. The blocks describe sub-functions using simple verb-noun logic. The interdependency logic of these functions are shown in both the how and why directions.

Fault Tree Analysis

An undesired effect is written as the top event of a tree of logic. Each situation that could cause that effect is added to the tree as a series of logic expressions, using conventional logic gate symbols. When individual situations are assigned values for occurrence probabilities, it is possible to calculate the failure probability.

Feature

An elemental geometry of an object, such as a plane, a cylindrical surface, an axis, a profile.

Forensic Evidence

Trace evidence used in an investigation (forensic means associated with legal justice), but used here in the context of machine failure.

Full-factorial Experiment

A full factorial design of experiment (DOE) measures the response of every possible combination of factors and factor levels. These responses are analyzed to provide information about every main effect and every interaction effect. A full factorial DOE is practical when fewer than five factors are being investigated.

Functional Decomposition

Dividing the overall function of a system into sub-functions which describe the how-why logic for achieving the system function. This is done hierarchically, with each function being further subdivided into three to six sub-functions at each level.

Functional Dimension, Feature

A dimension that is essential to the function of an object. A feature that is essential to the performance or serviceability of the object of which it is a part. It may be a location feature (e.g. a spigot which serves to locate a component in an assembly) or a working surface (e.g. a bore of a bearing).

Gage R & R

Amount of variability induced in measurements coming from the measurement system itself, compared to the total variability observed, to determine the viability of the measurement system. There are two aspects of a Gauge R&R: Repeatability and Reproducibility (see separate entries)

Geometric Tolerance

Specification which defines the allowable variation for the form, and possibly the size, of individual features, or the allowable variation in orientation and location between features.

Half-Split Tactic

One of the tactics for executing the *Dissection Strategy*. Essentially it is to build all four combinations of two systems, one high and one low performance, each split into two sub-systems

Histogram

Graphic used to relate proportions of populations to single variable. A graphical description of the distribution of data, primarily used for summarizing. Can be used qualitatively.

Hypothesis

A suggested explanation for a phenomenon. A *progressive search* is a series of alternative hypotheses starting with very broad, and progressing to narrower explanations.

Independent Variable

Dependent variables respond to independent variables.

Induction

One of three separate reasoning processes, induction is to adopt one hypothesis based on empirical data and derive general rules from limited observations. Conclusions are probably and approximately true based on the strength of the evidence. See *Abduction, Deduction*.

Interaction Effect

In statistics, an interaction is a term in a probabilistic model in which the effect of two or more variables is not simply additive.

Interdependent variables

Variables involved in an interaction effect. Two or more variables have a (multiplying) effect upon one another's causal relationship with the dependent variable.

Isolation Strategy, Tactics

The tactics of the Isolation strategy analyse a system as a function with inputs, and tests to see which has the greatest leverage over the output.

Isoplot™

Isoplot™ is a trademark of Red X Technologies and is a Youden plot with the 95th percentile envelope of repeatability variation superimposed on the graphic.

Leverageable X

See *Steep X*

Matryoshka Strategy, Tactics

The tactics of the Matryoshka Strategy decompose a system into its hierarchical levels, either functionally or structurally. Matryoshka can be used to identify leverageable contrasts and/or patterns early in a project.

Model-Based

See *Topographic*

Multivari Plot

Multivari plots (Leonard Seder, 1950) are an example of *Small Multiples* good for displaying *Matryoshka* results graphically.

Novel Problem

When we are unable to diagnose a cause from the symptoms (*Symptomatic, Case-Based Reasoning*) because we have inadequate case history knowledge, the problems are referred to as novel.

Occum's razor

A principle stating that the explanation of any phenomenon should make as few assumptions as possible, eliminating, or "shaving off," those that make no difference in the observable predictions of the explanatory *hypothesis* or theory.

Omnibus Factors

Another term used to describe subsystem elements that group together many variables. Particularly relevant to reproducibility. Examples include different machines or vendors producing the same parts.

Paired Data Plot

Graphic used to show dependence/independence between sets of associated values, the range in both X and Y directions, and concentrations of results. Often used intuitively and qualitatively. Regression analysis quantifies X-Y relationships. Also called *Scatter Plot*.

Pareto Distribution, Chart

A power-law probability distribution that coincides with many types of observable phenomena in which an equilibrium is found in the distribution of the "small" to the "large". Sizes of sand particles are Pareto distributed for example.

Picasso Plot

See *Data Map*.

Poke and Hope

Weak Hypothesis testing method which does not use a *Progressive Search*.

Polar Plot

Two-dimensional chart (data map) in which each point is defined by an angle and a distance. Especially useful in situations where the data is most easily expressed in terms of angles and distances. The coordinates are usually called r (the radial coordinate) and θ (the angles coordinate). r and θ can be converted to the Cartesian coordinates x and y by using the trigonometric functions sine and cosine:

$$x = r \cos\theta, y = r \sin\theta.$$

PPM

A measure of defective products; count defective parts per million produced.

Probabilistic Model

Causal explanation expressed as likelihoods of potential events occurring, and likelihoods of the underlying mechanisms of systems working in the manner we describe. An element of randomness is thus involved in predicting future states of a system.

Progressive Search

A series of alternative hypotheses starting with very broad, and progressing to narrower explanations. A *hypothesis* is a suggested explanation for a phenomenon.

Property

The functional response of a system, sub-system or component to a source of energy. There are three classes of property of importance; inertance, compliance and resistance. Specific properties depend upon the energy domain of interest; mechanical, hydraulic, electrical etc. For example, compliance in the electrical domain is capacitance, in the mechanical domain it is stiffness.

Repeatability

The ability of a whole system, or sub-system, to provide consistent results. The variability from that system

Reproducibility

Variability between systems or subsystems.

Response Variable

See *Dependent Variable*

Reversible Function

A function that can be reversed and repeated. In manufacturing, many assembly and measurement functions are reversible

Robustness

The inverse of sensitivity. A *response*, Y, is sensitive to a *steep* X, but robust to a flat X. An interaction (interdependent Xs), creates a range of sensitivities (slopes).

Root Cause

If a root-cause is eliminated or corrected, we can prevent problem occurrence.

Scatter Plot

Graphic used to show dependence/independence between sets of associated values, the range in both X and Y directions, and concentrations of results. Often used intuitively and qualitatively. Regression analysis quantifies X-Y relationships. Also called *Paired Data Plot*.

Simulation

The process of using models to determine machine behavior from the geometry and properties of its constituent parts. Models may be mathematical (virtual) or physical prototypes. Simulation is the inverse of *diagnosis*.

Small Multiple

Graphic showing *Data Maps*, *Time Series Plots*, *Histograms*, or *Paired Data Plots* (and combinations of these) repeated for one or more *families of variation*.

Spatial

Data organized with respect to a reference (datum) in space.

Square-Root-of-Sum-of-Squares axiom

Also known as Root-Sum-Square (RSS) axiom, this is simply a statement that when the various effects of several *independent variables* on the same *dependent variable* are added statistically, the individual ranges or standard deviations must be squared for the first step, the squares summed for the second step, and the square root of this sum taken as the third step. The implication is that if the ratio of variation effect was 3 to 1, the leverage ratio is actually 9 to 1. Therefore, only *Steep Xs* are important, but they are also easy to flush out.

Statistically Designed Experiments

Information gathering exercise to establish the effect of some process or intervention (the treatment) on objects (the experimental units). Experiments, are greatly improved by adhering to some important design principles, which are statistical in nature. This is because of the presence of reproducibility and repeatability variation.

Steep X

An independent variable, to which the dependent variable is very sensitive; within their normal operating ranges.

Strategy

A convergent diagnostic strategy is the plan for managing the acquisition of information in a systematic manner to explain machine behavior. Diagnostic strategies are essentially the way we model and decompose the models of the systems. Strategies are independent of specific information gathering tactics.

Stratify

Stratification is the process of grouping members of a sample into homogeneous subgroups or *families*.

Structural Decomposition

Hierarchical division of a system into sub-systems or elements based upon what the system is made up from, or machines that it is manufactured by.

Sudoku Puzzle

A logic-based number placement puzzle. The objective is to fill a 9x9 grid so that each column, each row, and each of the nine 3x3 boxes contains the digits from 1 to 9. The puzzle setter provides a partially completed grid.

Symptomatic Knowledge, Strategy

Prior knowledge of cause-effect relationships. In expert diagnosis, fault hypotheses are generated by mapping symptoms to case-based knowledge. Symptomatic strategy is the process of quickly identifying causes from symptoms. Experts rapidly retrieve information, and only that which is relevant for the current case.

Tactic

Convergent diagnostic tactics are the specific tests carried out to obtain data, and the analytic method used to evaluate the data to generate explanation.

Temporal

Data organized in time sequence.

Time Series Plot

Collect data sequentially, plot Y values against time on the X axis. Compare each reported value to the rest. Time-series charts are extremely sensitive to choice of intervals, and start-end points. Suffers from the weakness that chronology is not a causal explanation.

Tool

A technique for organizing, displaying and/or analyzing data into information in order to answer a diagnostic tactical question.

Topographic Strategy

Model-based approach to diagnosis, developing *causal explanation* from basic principles. Most effective when applied as a *hierarchical decomposition*, either *structural* or *functional*.

Trial and Error

Weak Hypothesis testing method which does not use a *Progressive Search*.

Youden Plot

Paired Data Plot in which the axes of the plot are 'square' – same data ranges and same physical dimensions on the x and y axes. Two sets of results for any function repeated on the same sample of product are paired up, one on each axis. Function repeatability is manifested as the distribution of points perpendicular to the 45 degree line, not parallel to either axis as in a regression.