Société de Calcul Mathématique SA
*(Mathematical Modelling Company, Corp.)*
*Tools for decision help*
*since 1995*

# Data Fusion

Quite often, a measurement is obtained from different devices, or from the same device, used at different times or at different locations. For instance, a position may be estimated from the GPS, from inertia, and so on. An angle may be estimated from several points of view. The problem arises constantly nowadays with the projects of "autonomous vehicles", which always carry a lot of sensors.

Each time, the same question comes: how to "conciliate" the measurements? The different devices do not give the same answers, and even a single device gives different answers at different times.

This problem is known as "data fusion". It is often solved practically in an empirical manner. For instance, one attributes "weights" to each device, considering the level of confidence that one wants to give to them.

In order to solve this type of problem, SCM has developed a simple and robust methodology, which relies entirely upon probabilities. This method takes into account systematic biases, when they exist, and the scale factors: a scale factor appears when the device does not have the same precision all over the measurement scale, which is the case in practice (most devices are less precise at the end points of the measurement scale).

Our method explains how to realize "calibration tables", which are in fact conditional probabilities, in the mathematical sense, and how to use them for data fusion.

There are no a priori assumptions upon the errors of each device. For instance, the errors are not supposed to be gaussian. The method does not use filters, such as Kalman filters.

What we obtain is not just the most likely value, combining all the data. What we get is in fact a complete probability law: given all the available information, the method indicates what is the probability of any location. The most likely value is the expectation, and we also get intervals or ellipsoids of dispersion, when they are needed.

It applies to all situations where data fusion is needed, from two measurements or more. It indicates how the devices must be calibrated, and, when this calibration is made, how to treat and combine the measures. Our method does not reduce to a computational protocol but also covers the measurement phase. It provides a solid methodology for the treatment of complex data fusion problems.

# References

## 1. Books

[IEPE] Bernard Beauzamy : Introduction à l'étude des Probabilités Expérimentales. SCM SA, ISBN 979-10-95773-02-3, ISSN 1767-1175. hard bound, 192 pages. January 2023 (in French).

[MPPR] Bernard Beauzamy : Méthodes Probabilistes pour l'étude des phénomènes réels. SCM SA, ISBN 2-9521458-0-6, ISSN 1767-1175. Second Edition, 2016 (in French).

## 2. Recent contracts

The theory was initially developed by us for the "Service des Missiles Tactiques", Délégation Générale pour l'Armement, French Ministry of Defense, between 1997 and 1999. It was used and validated in 2000, in a joint contract between Matra BAe Dynamics and SCM, for the "Service des Programmes de Missiles Tactiques": our method led to a very significant improvement of the final precision of an air-to-ground missile, using the information given by an infra-red camera.

- SNECMA Propulsion Solide, 2009-2010: Probabilistic Methods for reliability
- Groupe Total, 2010: Probabilistic methods for the evaluation of the amount of pollutant
- IRSN, 2011: Probabilistic methods for nuclear safety
- International Stainless-Steel Forum, 2011: Probabilistic tools for the forecast of Nickel prices and sales
- Commission Européenne (with the Poyry Group), 2011-2012: Probabilistic methods for water quality
- IFSTTAR, 2011-2015: Probabilistic methods for precise positioning, using GPS in an urban environment
- Suez Environnement, 2011-2012: Probabilistic methods for water quality
- ArcelorMittal, 2011-2012: Probabilistic methods for the quality of an industrial process
- Air Liquide, 2011: Hierarchy of parameters and construction of a similarity index between pipelines
- Areva, 2013: Hierarchy of parameters in an industrial process.
- DCNS, Indret, 2013: Hierarchy of parameters in an industrial process.
- Coop de France Déshydratation, 2013: Hierarchy of parameters and their influence upon a deshydratation process.
- RATP (Metropolitain Tranportation, Paris Region), 2016-2018: Modelling the behavior of the trains in a situation of emergency braking.
- Atlandes (Highway, south of France), 2018: Analysis of the behavior of the vehicles on the exits of the highway.
- Bouygues Energies & Services, 2022: Methodological support for the design of a "Malfunctions and Maintenance" information system.