Use of equilibrium calculations for the experimental analysis: Function parametrisation

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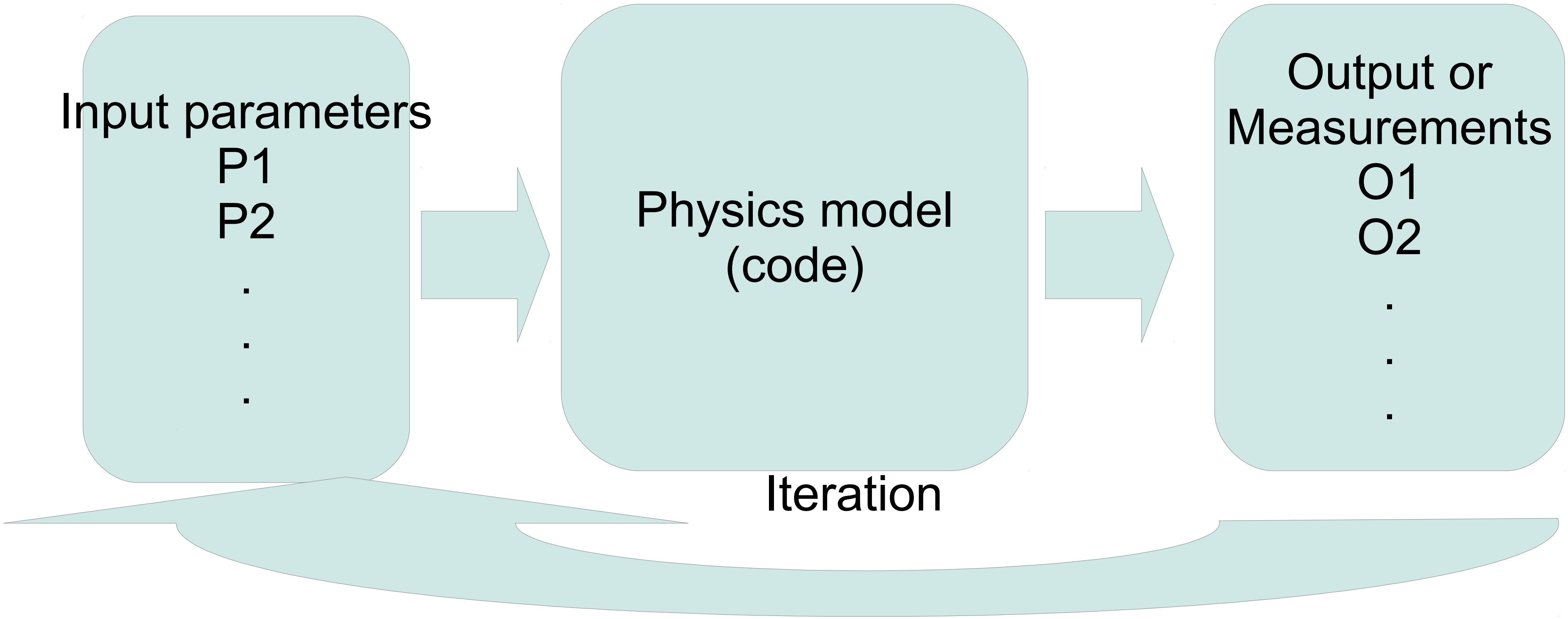
Evaluation of Experiments

Simplest Case: Data acquisition → conversion to physics data → comparison with physics models

In general, the conversion to physics data already contains or needs a physics model:

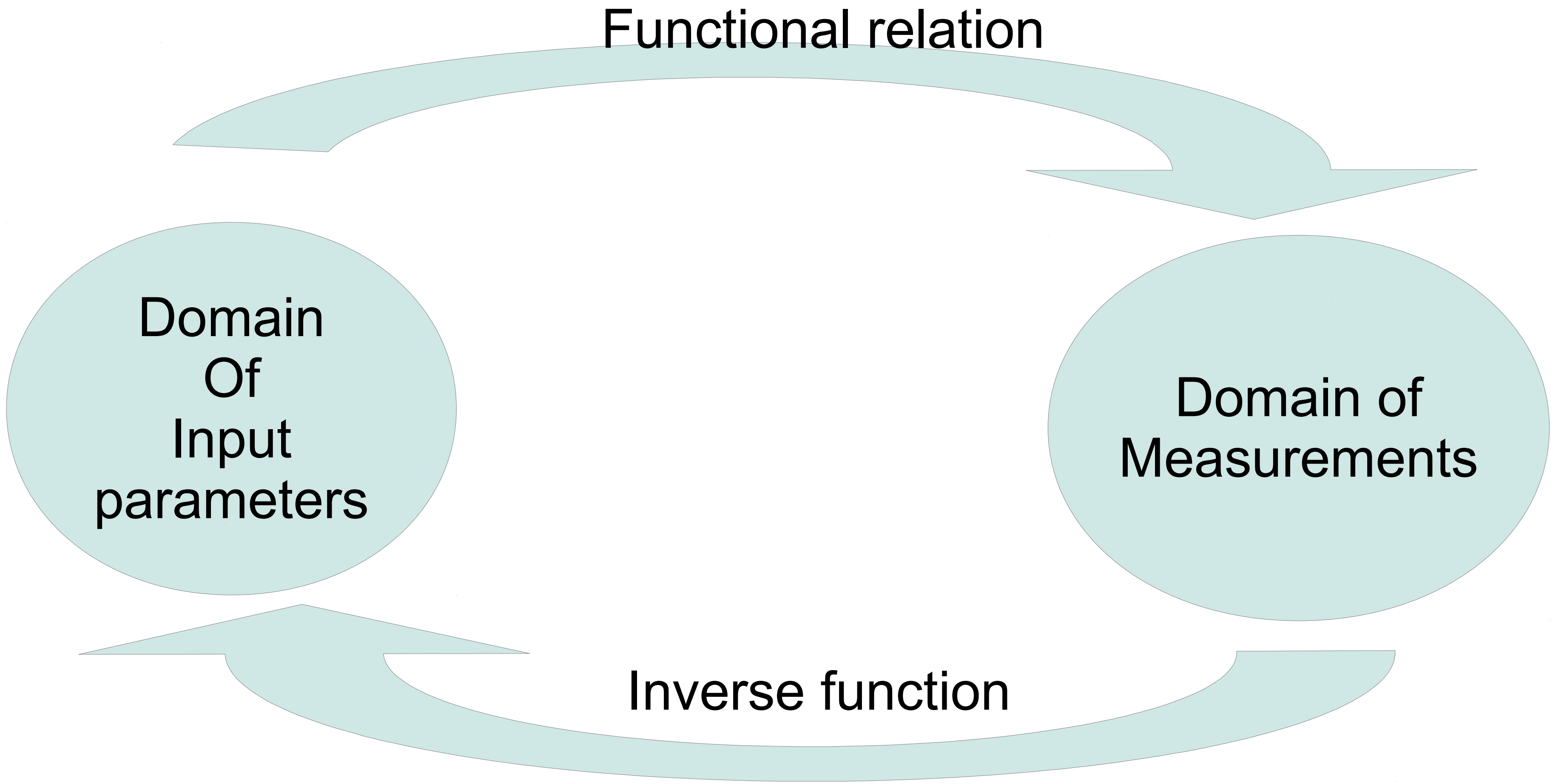
- diamagnetic signal
  - Voltage → flux displaced by plasma → plasma energy
    - Simple model from large aspect ratio approximation
    - MHD-equilibrium calculation and diagnostic simulation
      - Iterative parameter adjustments → many calculations → time consuming.

Interpretation of Experiments



Problem: Interest is in input parameters!

Function parametrisation (FP) tries to short cut the process



Function parametrisation:
Construct inverse functional relation on statistical basis.

Note: in terms of the statistics the role of input parameters and measurements can change dependent on whether the “function” or its inverse is investigated.

Work-program of FP:

- Sample domain of input parameters → calculate output
- Statistical analysis of relation of output parameters to input (Identify relevant dependencies, e.g. principle components)
- Construct inverse function as a simple relation for fast evaluation (Taylor series expansion to second order of inverse function)

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- Considerations on use of statistical methods
  - Advantage: smaller datasets required for sampling of input domain
  - Unbiased sampling important
  - Sampling of full input domain → otherwise extrapolation (unsure!)
  - Drawbacks:
    - Not extendable:
      - New model or parameter or larger input domain → new dataset (avoid bias) → new analysis
    - Accuracy: global function → details or fine structures not resolvable → needs FP on restricted data set
      Reason: “Taylor expansion” needs a small parameter for a good approximation → more “expansions” needed to cover full input parameter domain.

Example:

- Classical application:
  - diamagnetic signal on basis of vmec/diagno W7-AS (H. Callaghan) : $W(\Delta\Phi, I_m, I_5, I_t, I_v)$ (neglect of plasma current)
  - Reconstruction of flux surface geometry (vmec-calculations) W7-AS (W7-X) by H. Callaghan (A. Sengupta)
    - $R_{mn}(r_{eff}, \{I_j\}, \{p\}, \{I_{pl}\})$, $z_{mn}(r_{eff}, \{I_j\}, \{p\}, \{I_{pl}\})$, etc.
    - W7-X: implementation as web-service (J. Svenson)
    - Use for:
      - Mapping of diagnostics
      - Simulations of diagnostic measurements (SX-ray)

Note: “forward-function” (inputs → measurements) useful for Integrated Data Analysis (IDA) approach.

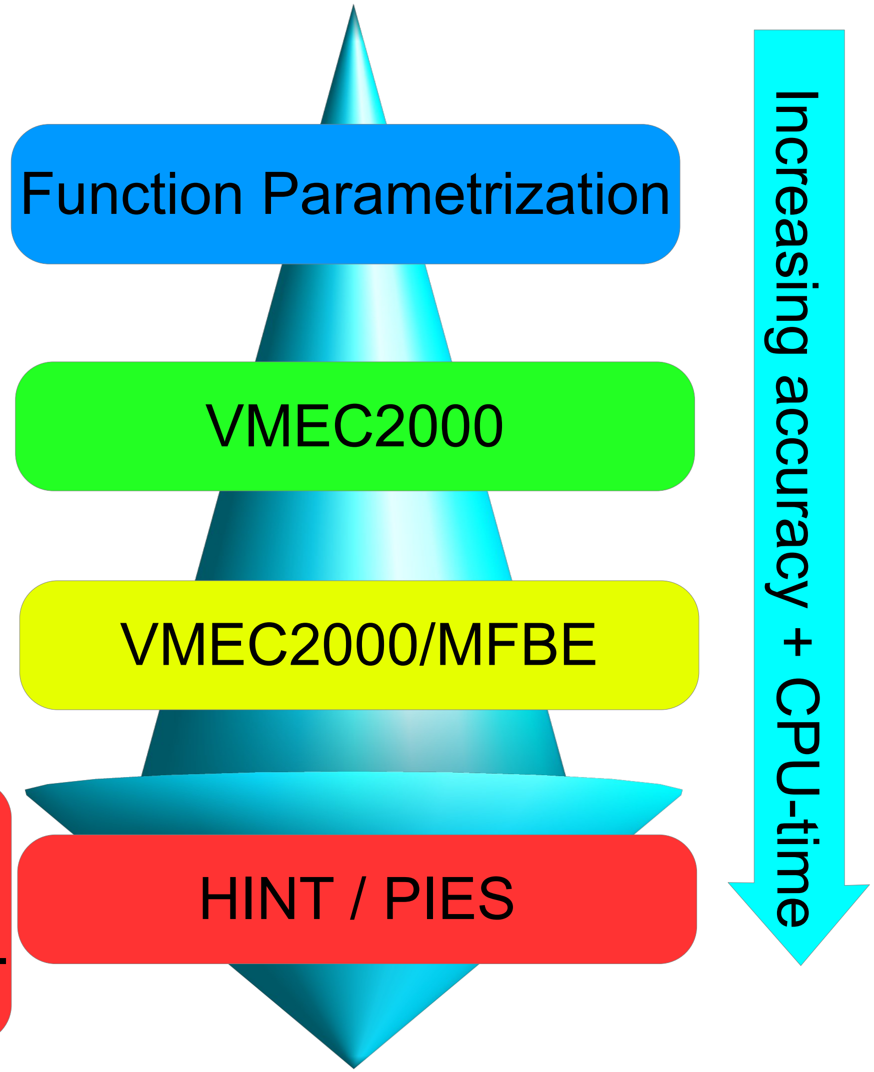
Proposed scheme for equilibria with increasing accuracy

Fast, but not accurate.
Usage: transformation/mapping

Slower, more accurate.
True equilibrium, but boundary?
Usage: stability and where FP proofs to be insufficient

Change in boundary in a first approximation, boundary islands.

Most consistent change of boundary, islands inside and outside the plasma.



Two input parameters x1, x2
One dependent value f

$$f\left(x_{1,} x_{2}\right)=\sum_{i=0}^{2} \sum_{j=0}^{i} c_{ij} x^{i} x^{j}$$

Equivalent to Taylor expansion to second order.
In FP: mixed quadratic model.