THE ALGORITHM

1. Given $\boldsymbol{x}_f^{(1)} = \boldsymbol{x}_c^*$, $\lambda^{(1)} = 1$, $\delta^{(1)}$, α, $\boldsymbol{J}_f^{(1)} = \boldsymbol{J}_c^*$ and i=1.

2. Construct $V^{(i)}$.

3. Apply the optimization procedure

$$[\boldsymbol{B}^{(i)}, \boldsymbol{s}^{(i)}, \boldsymbol{t}^{(i)}, \sigma^{(i)}, \boldsymbol{c}^{(i)}, \gamma^{(i)}] = arg\left\{ \min_{\boldsymbol{B}, \boldsymbol{s}, \boldsymbol{t}, \sigma, \boldsymbol{c}, \gamma} \left\| \begin{bmatrix} \boldsymbol{e}_1^T & \boldsymbol{e}_2^T & \cdots & \boldsymbol{e}_N^T \end{bmatrix}^T \right\| \right\}$$

$$\boldsymbol{e}_j = \boldsymbol{R}_c(\boldsymbol{P}^{(i)}(\boldsymbol{x}_f^{(j)}, \psi_k), P_\psi^{(i)}(\boldsymbol{x}_f^{(j)}, \psi_k)) - \boldsymbol{R}_f(\boldsymbol{x}_f^{(j)}, \psi_k) \;\forall\, \boldsymbol{x}_f^{(j)} \in V^{(i)},\; \forall\, \psi_k,\; k = 1, 2, \ldots, N_\psi,\; N = N_p N_\psi$$

to obtain the mapping parameters.

4. Construct the surrogate model

$$\boldsymbol{R}_s^{(i)}(\boldsymbol{x}_f) = \lambda^{(i)} \boldsymbol{R}_m^{(i)}(\boldsymbol{x}_f) + (1-\lambda^{(i)})(\boldsymbol{R}_f(\boldsymbol{x}_f^{(i)}) + \boldsymbol{J}_f^{(i)} \Delta \boldsymbol{x}_f),\; \lambda^{(i)} \in [0,1]$$

where $\boldsymbol{R}_f(\boldsymbol{x}_f, \psi_j) \approx \boldsymbol{R}_m^{(i)}(\boldsymbol{x}_f, \psi_j) = \boldsymbol{R}_c(\boldsymbol{P}^{(i)}(\boldsymbol{x}_f, \psi_j), P_\psi^{(i)}(\boldsymbol{x}_f, \psi_j))$, j=1, 2, …, N_ψ

and

$$\begin{bmatrix} \boldsymbol{P}^{(i)}(\boldsymbol{x}_f, \psi_j) \\ P_\psi^{(i)}(\boldsymbol{x}_f, \psi_j) \end{bmatrix} = \begin{bmatrix} \boldsymbol{B}^{(i)} & \boldsymbol{s}^{(i)} \\ \boldsymbol{t}^{(i)T} & \sigma^{(i)} \end{bmatrix} \begin{bmatrix} \Delta \boldsymbol{x}_f \\ \psi_j \end{bmatrix} + \begin{bmatrix} \boldsymbol{c}^{(i)} \\ \gamma^{(i)} \end{bmatrix}$$

5. Obtain the suggested step $\boldsymbol{h}^{(i)}$ by solving

$$\boldsymbol{h}^{(i)} = arg\left\{ \min_{\boldsymbol{h}^{(i)}} U(\boldsymbol{R}_s^{(i)}(\boldsymbol{x}_f^{(i)} + \boldsymbol{h}^{(i)})) \right\},\; \left\| \boldsymbol{h}^{(i)} \right\| \le \delta^{(i)}$$

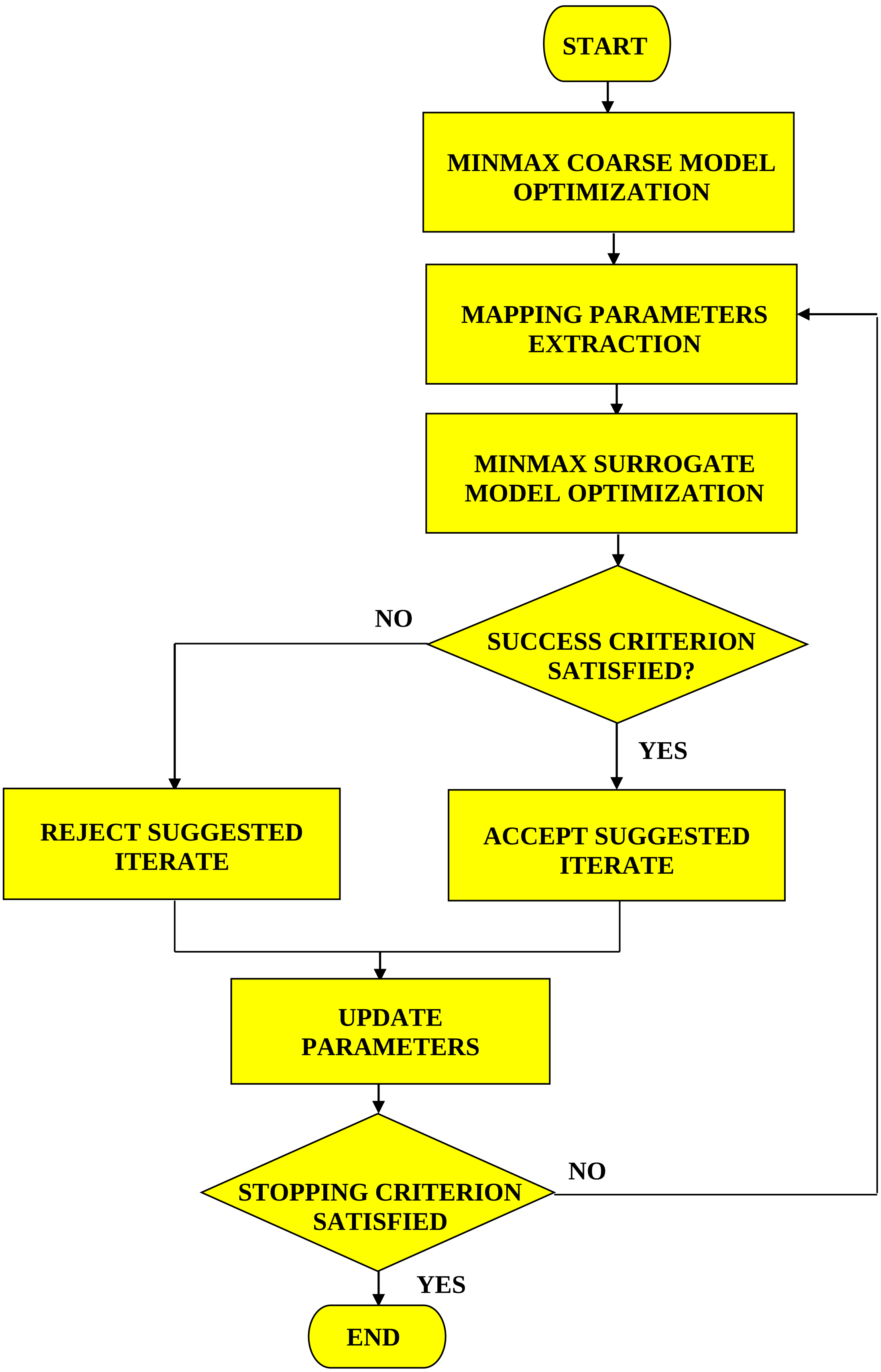
6. If $U(\boldsymbol{R}_f(\boldsymbol{x}_f^{(i)} + \boldsymbol{h}^{(i)})) < U(\boldsymbol{R}_f(\boldsymbol{x}_f^{(i)}))$, set $\boldsymbol{x}_f^{(i+1)} = \boldsymbol{x}_f^{(i)} + \boldsymbol{h}^{(i)}$ else $\boldsymbol{x}_f^{(i+1)} = \boldsymbol{x}_f^{(i)}$.

7. Update $\boldsymbol{J}_f^{(i)}$, $\delta^{(i)}$ and $\lambda^{(i)}$.

8. If the stopping criterion is satisfied stop.

9. Set i=i+1 and go to step 2.

ALGORITHM FLOWCHART



SOME USEFUL NOTATIONS

ψ : The independent parameter

$\boldsymbol{x}_c$: Vector of coarse model parameters

$\boldsymbol{x}_{c,\psi}$: Extended vector of coarse model parameters; the value of ψ is included as the last component of this vector

$\boldsymbol{\psi}$: Vector of simulated values of the independent parameter

$\boldsymbol{R}_{c,\psi}$ **:** Coarse model response at a single value of ψ

$\boldsymbol{R}_c$ **:** Coarse model response at all values of ψ

$\boldsymbol{x}_f$: Vector of fine model parameters

$\boldsymbol{x}_{f,\psi}$: Extended vector of fine model parameters; ψ is included as the last component of this vector

$\boldsymbol{R}_{f,\psi}$ **:** Fine model response at a single value of ψ

$\boldsymbol{R}_f$ **:** Fine model response at all values of ψ

$\boldsymbol{x}_s$: Vector of surrogate model parameters

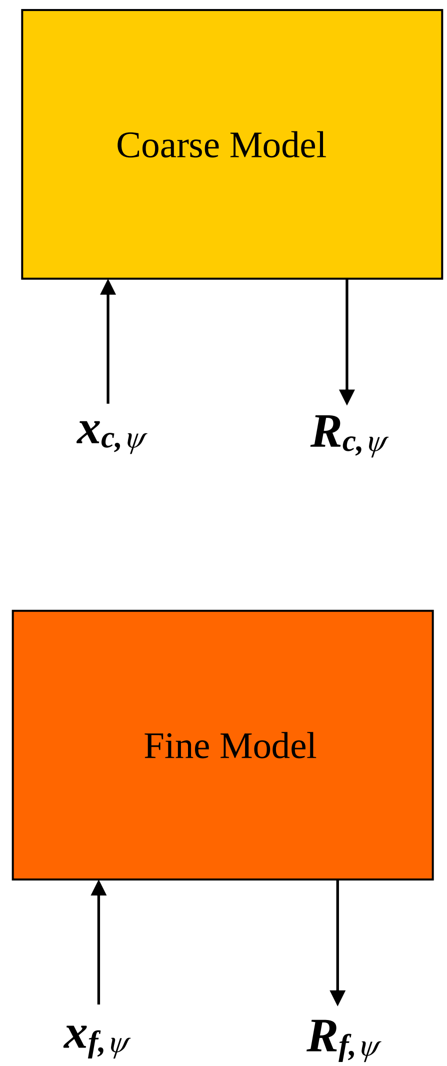
$\boldsymbol{R}_s$ **:** Surrogate model response at all value of ψ

$\boldsymbol{X}_E$: Vector of mapping parameters

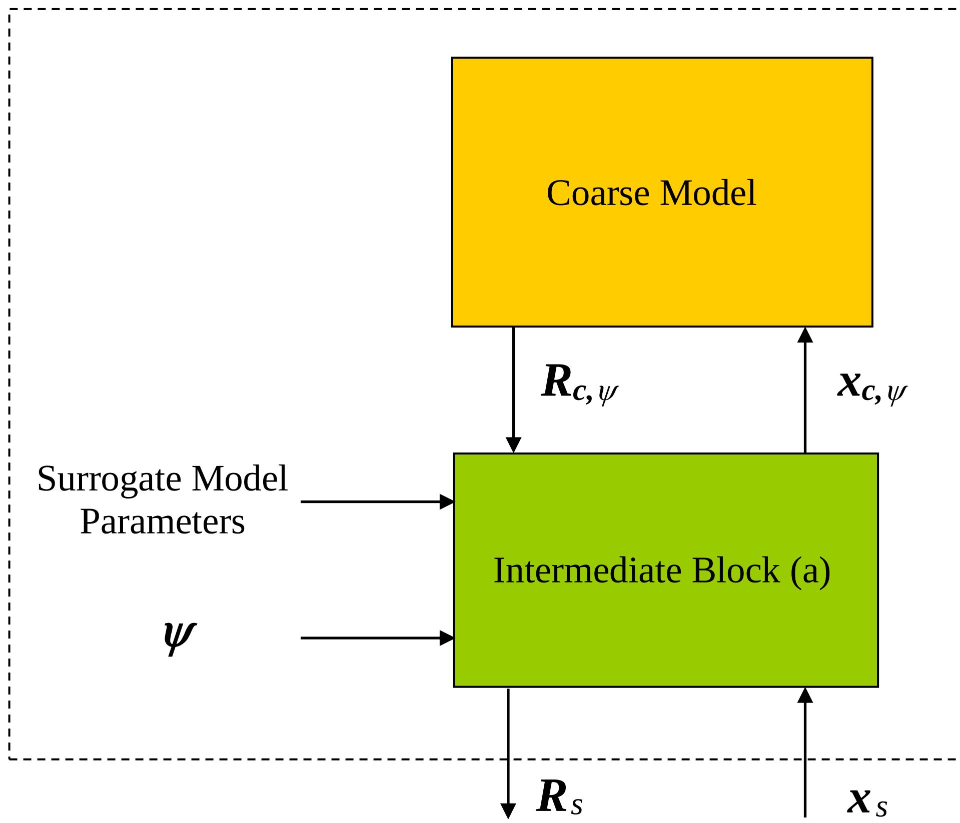
$\boldsymbol{R}_E$: Vector of matched responses

V: Set of used fine model points

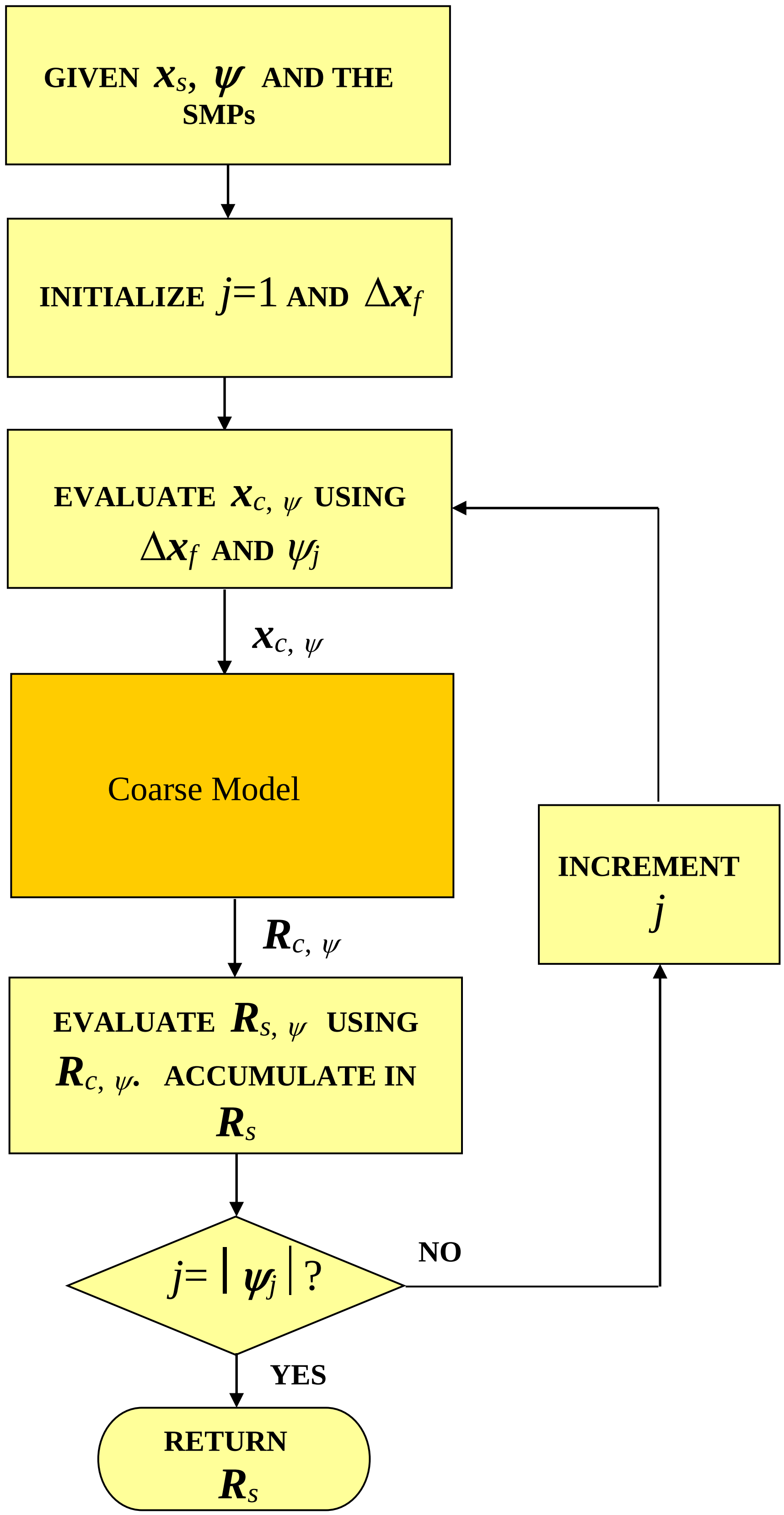
COARSE AND FINE MODELS



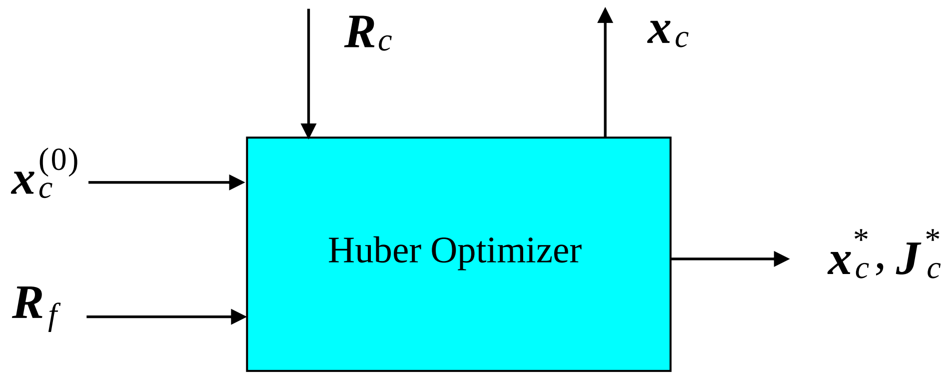
THE SURROGATE MODEL



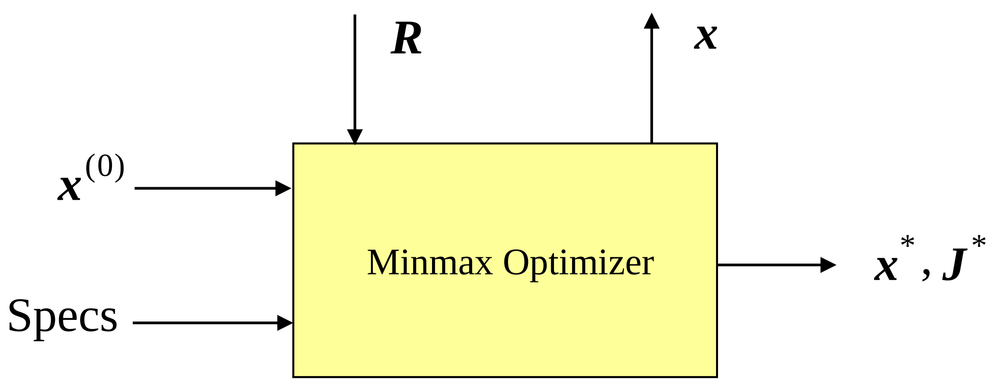
INTERMEDIATE BLOCK (a)



OPTIMIZERS

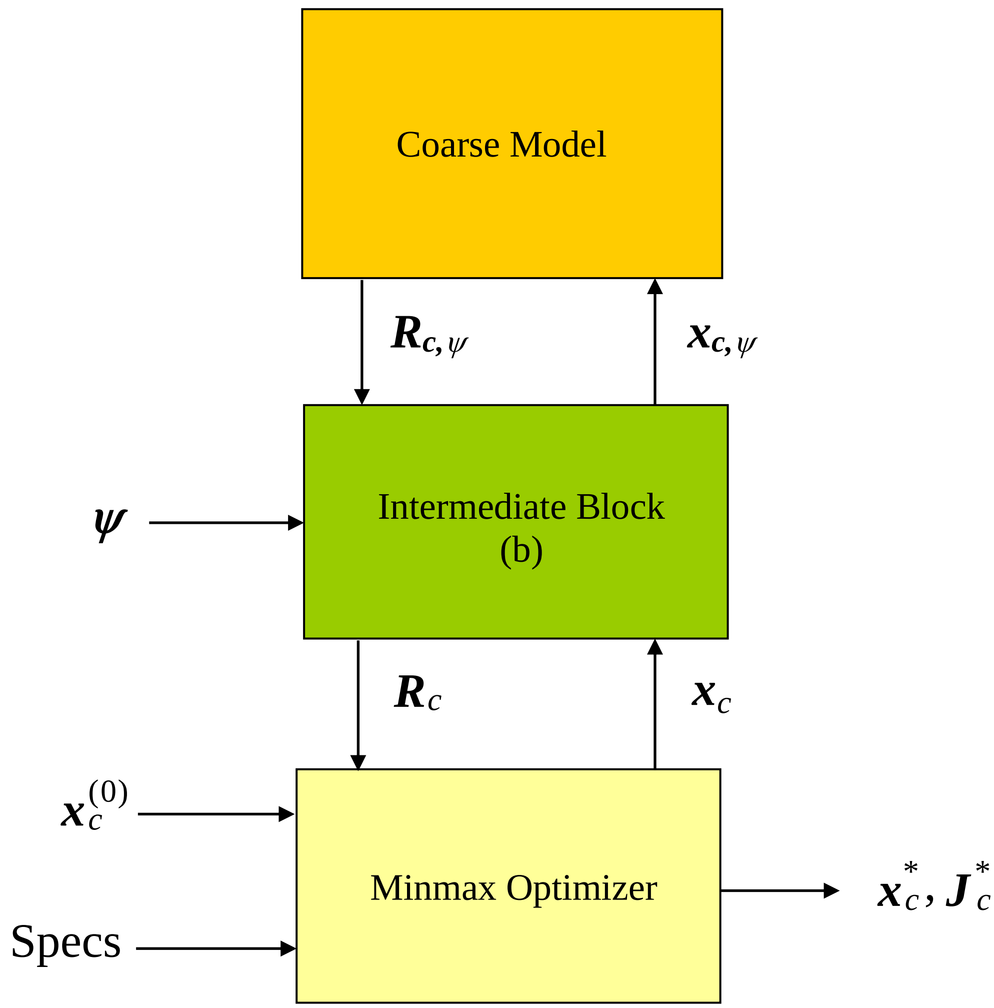


$\boldsymbol{R}_c$
$\boldsymbol{x}_c$
$\boldsymbol{x}_c^{(0)}$
Huber Optimizer
$\boldsymbol{R}_f$
$\boldsymbol{x}_c^*, \boldsymbol{J}_c^*$

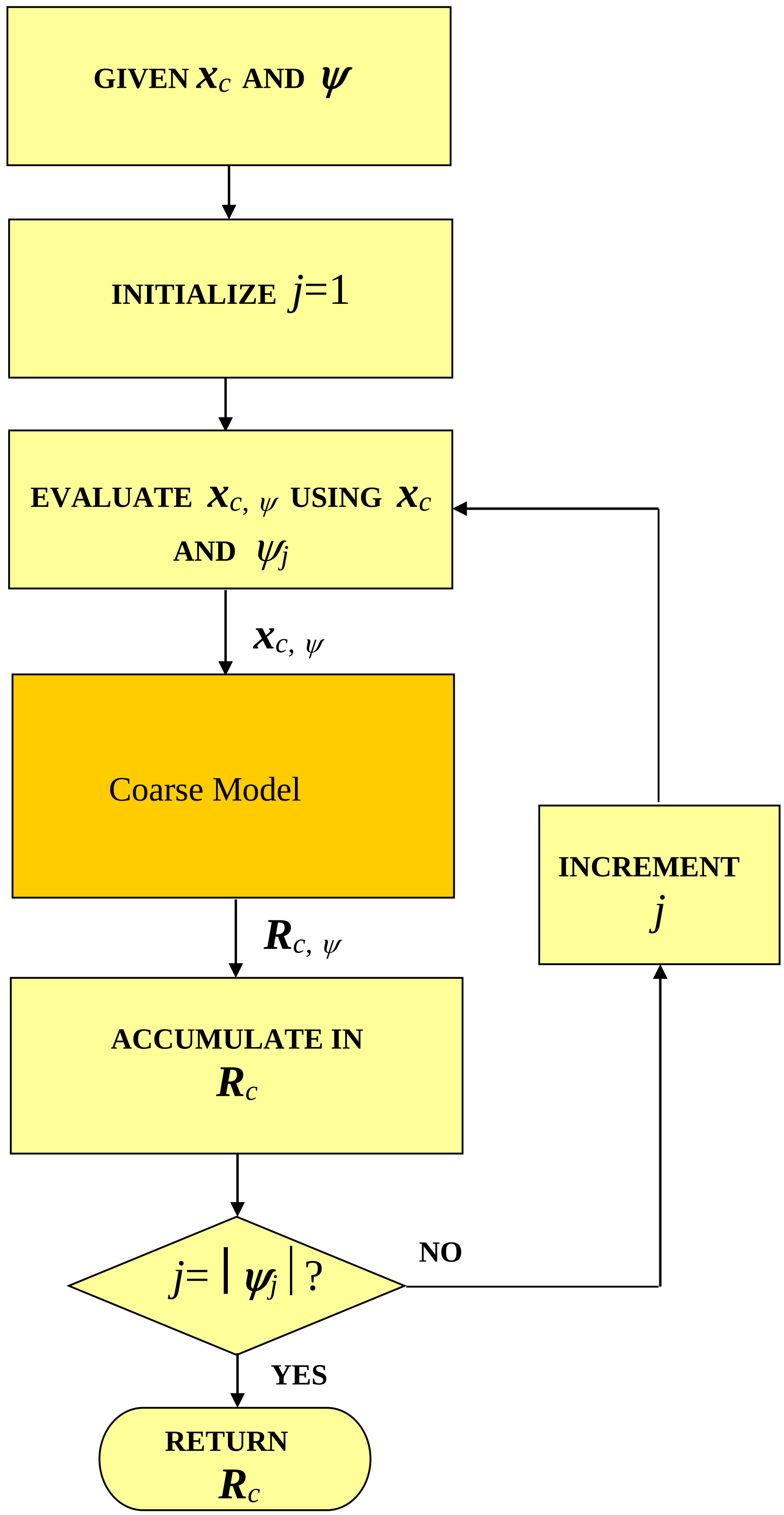


$\boldsymbol{R}$
$\boldsymbol{x}$
$\boldsymbol{x}^{(0)}$
Minmax Optimizer
Specs
$\boldsymbol{x}^*, \boldsymbol{J}^*$

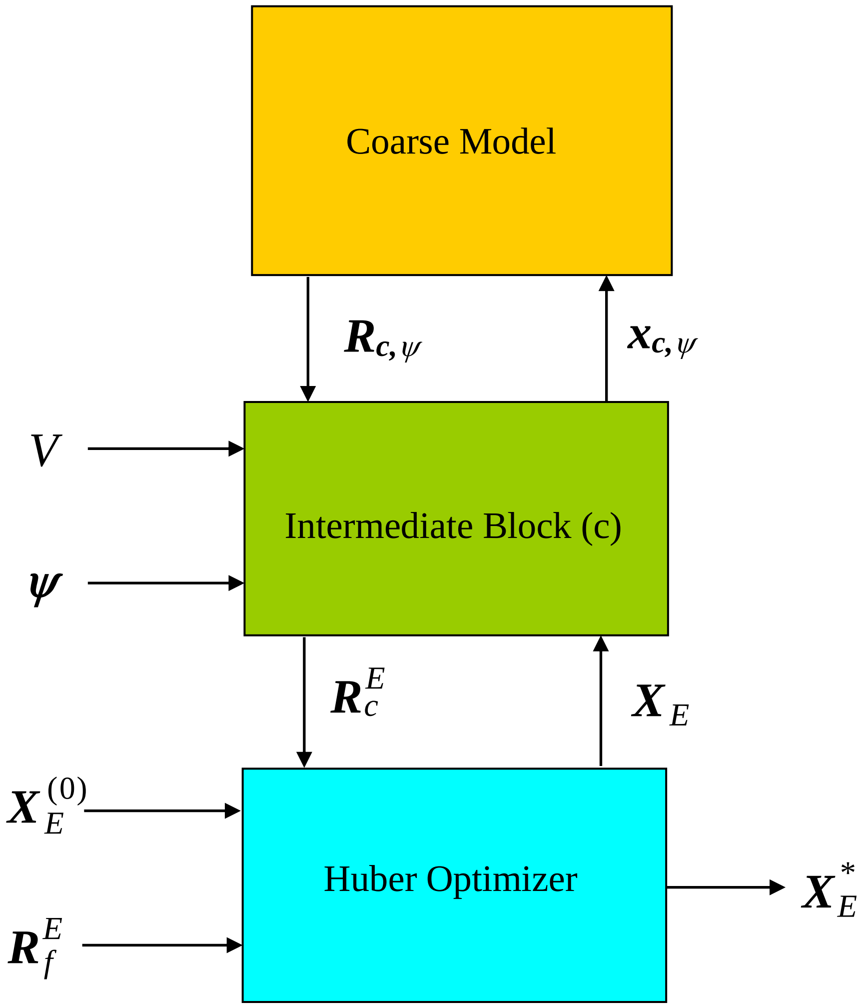
MINMAX OPTIMIZATION OF THE COARSE MODEL



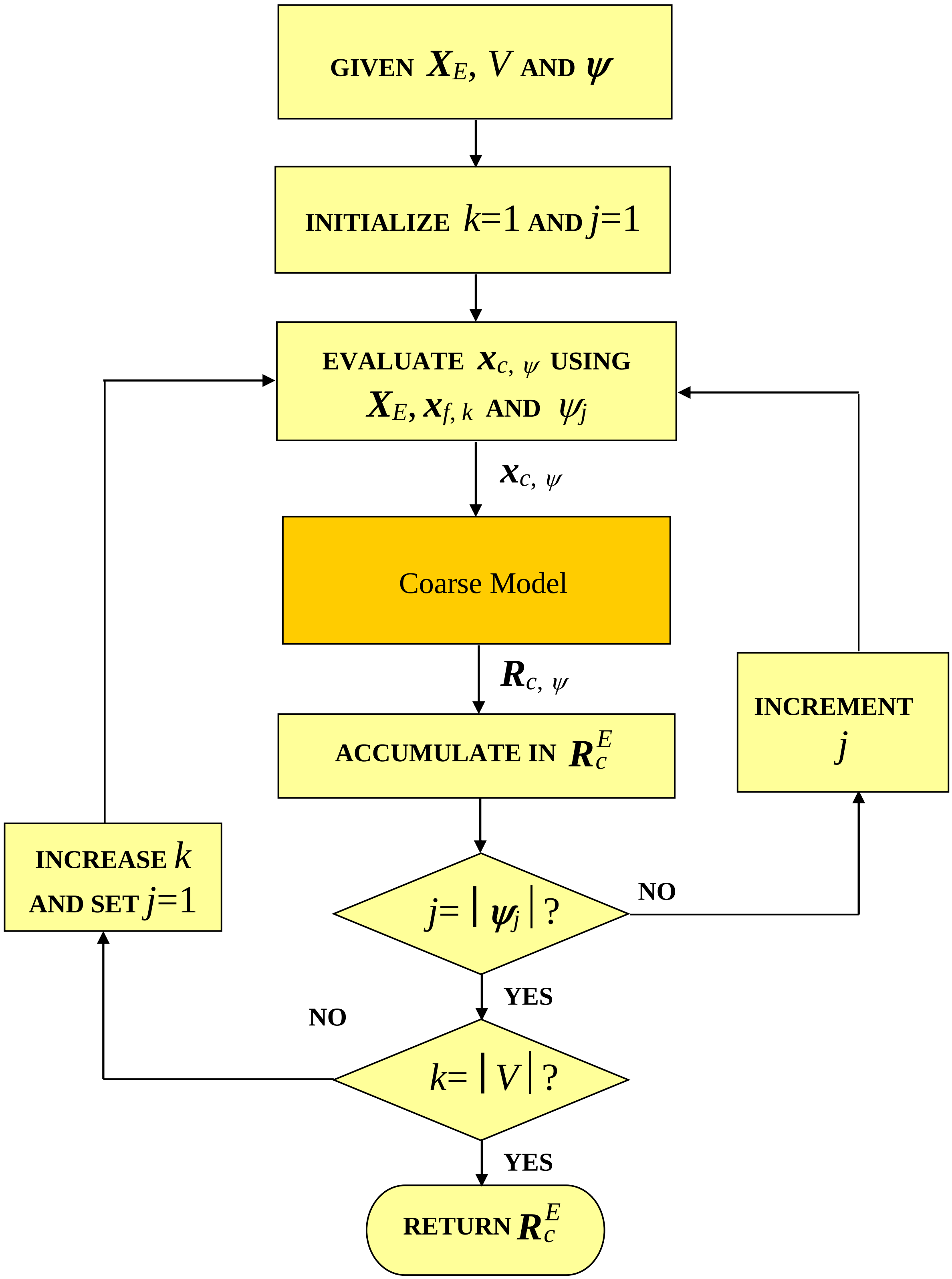
INTERMEDIATE BLOCK (b)



EXTRACTING THE MAPPING PARAMETERS



INTERMEDIATE BLOCK (c)



MINMAX OPTIMIZATION OF THE SURROGATE MODEL