

Model Evaluation

ACT-R, IMPRINT, and Matlab

Comparisons, Parameter Optimizations, and Opportunities

- 'Unified test problems' Data Entry, and RADAR
- Computational speeds
- Some modeling results
- Parameter optimization Genetic algorithms / Simulated annealing
- Radial Basis Functions (RBFs) Opportunity to remove stochastic 'noise'
- Summarizing observations

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Optimization using Radial Basis Functions (RBFs)

RBFs discussed at length at the Training MURI kickoff meeting, November 4, 2005 (in Washington, DC).

- RBFs allow fast regularization and evaluation of multivariate functions
- We used RBFs to approximate the objective functions over our models' parameter spaces
- Parameter space optimizations speeded up by factor around 500.

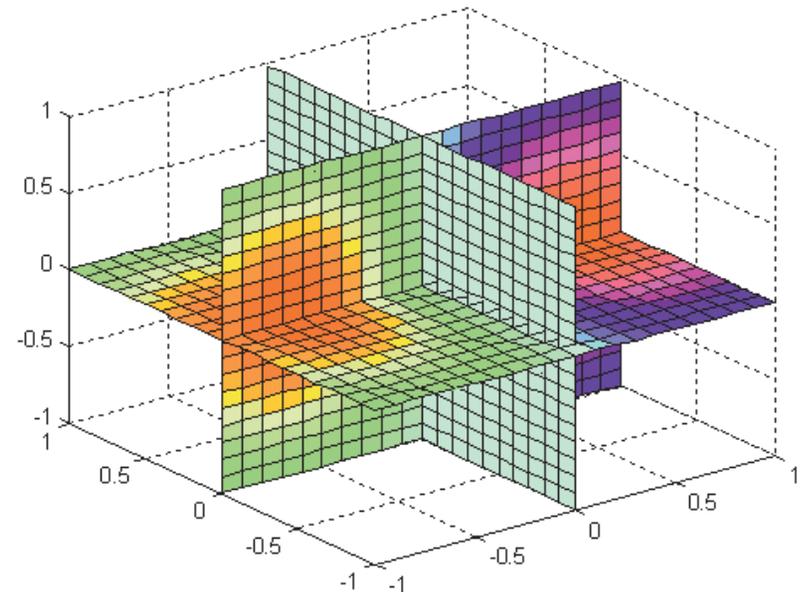
Visualization problematic already for a function of three variables

Varying two parameters at a time around a single point gives three 2-D slices:

Most of the 3-D parameter space has not been explored with these slices.

Specific application:

In the IMPRINT/Matlab model of the **Data Entry** task, we have five main parameters to be varied in order to optimize by minimizing the objective function (RMSE of difference between model and experiment)



Parameters:

Cognitive learning	(cognitive)
Motoric learning	(physical)
Repetition priming	(rep learn)
Left-hand penalty	(left penalty)
Cognitive slowdown	(fatigue)

'Reasonable ranges': 'Hand derived' values:

[-0.20, 0.00]	-0.045
[-0.10, 0.00]	-0.015
[0.00, 0.30]	0.050
[1.00, 1.50]	1.125
[0.00, 0.10]	0.0125

In order to visualize the 5-D parameter space, we can vary two parameters at a time from hand-derived values, which gives 10 slices.

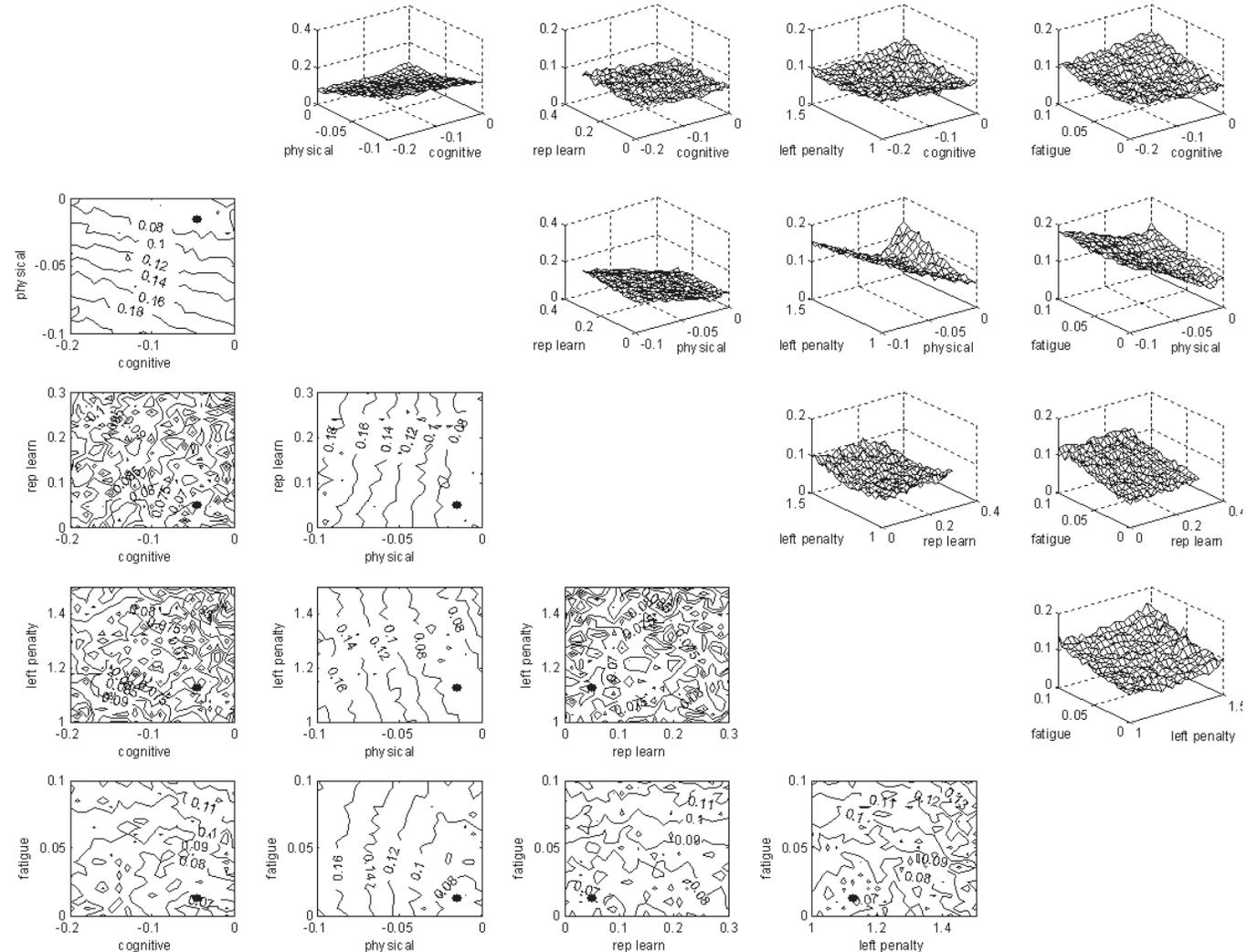
Partial visualization over the 5-D parameter space using the original Data Entry model



Computational speed is a critical issue:

The figures display a total of 4,410 surface points.

Each surface point takes 48 minutes in IMPRINT but only 0.17 seconds in Matlab



This is still completely insufficient to illustrate the objective function in the full 5-D parameter space

The RBF approximation can be used to regularize and evaluate the objective function

Partial visualization using RBF approximation of the objective function:

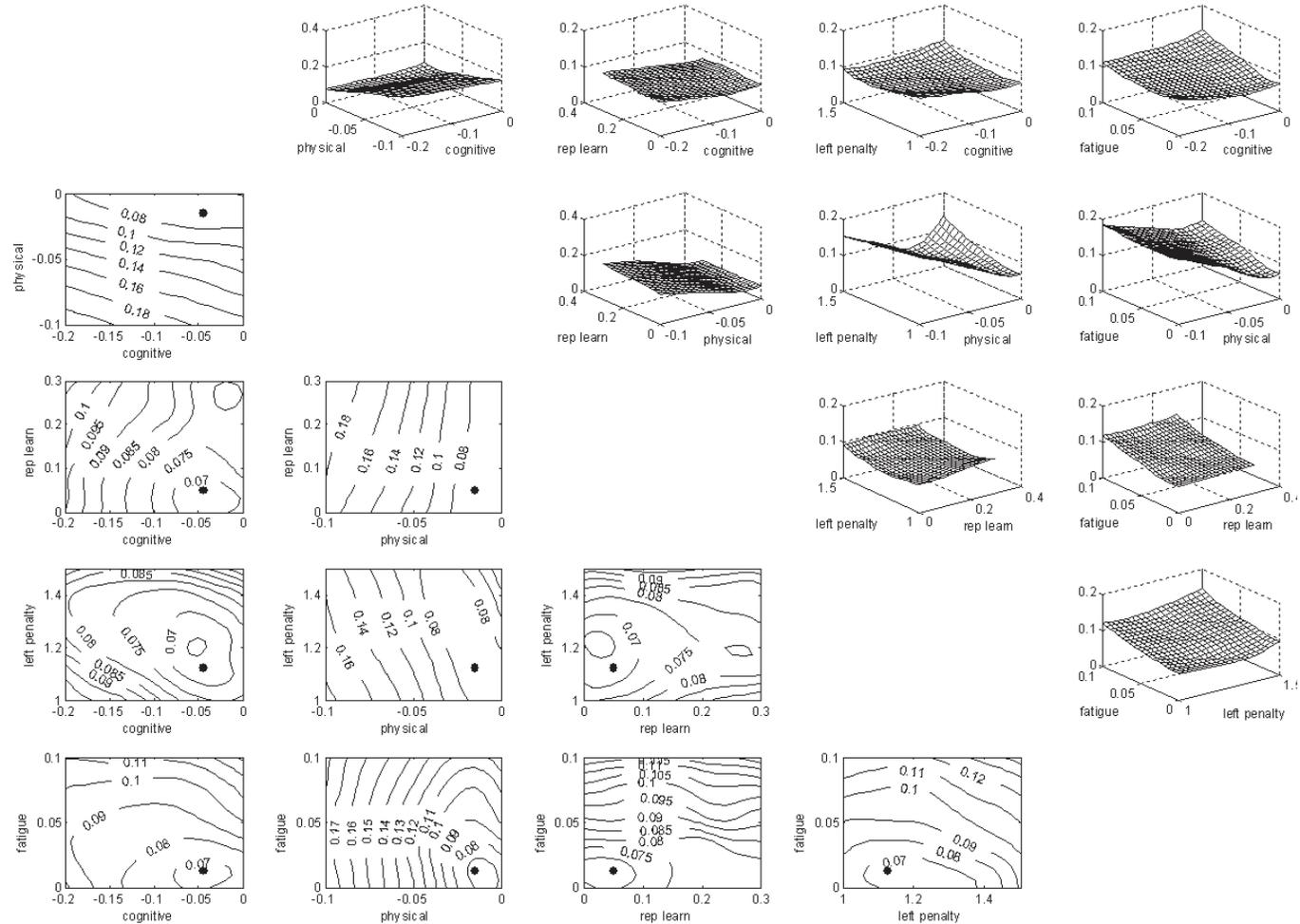


Once the RBF approximation has been created, each surface point now takes **0.0003 seconds** to evaluate.

Stochastic noise has been eliminated.

Speed gain in evaluating objective function:

Over Matlab: 560
Over IMPRINT: 5,000,000



This speed gain is crucial for improved visualization.

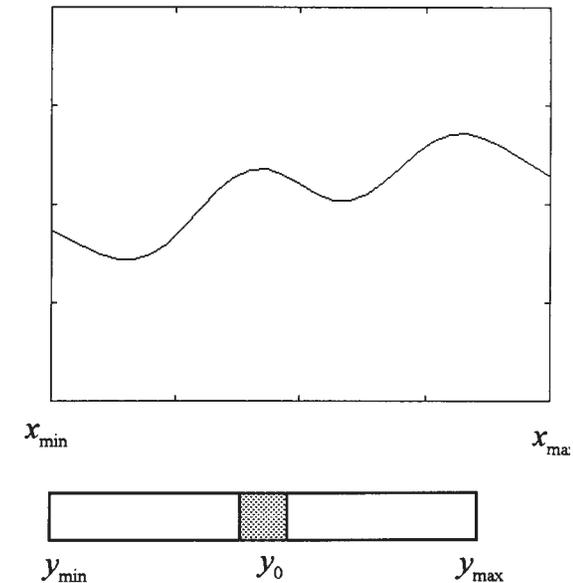
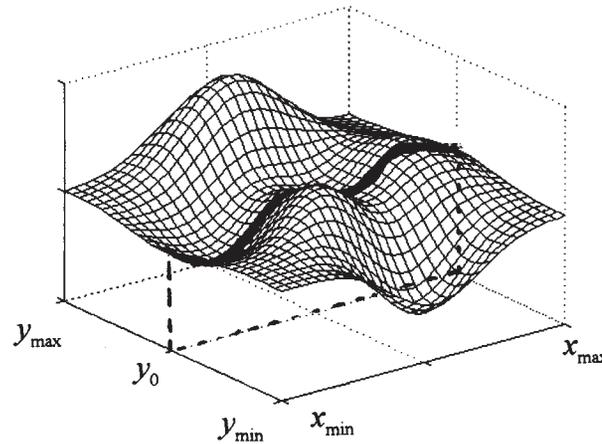
Effective visualization requires fast and noise-free evaluations, as offered by RBFs

Illustration of how a 2-variate function can be visualized in 1-D: →

'Slider' (bottom right) can be dragged by mouse to display different slices (dashed in left plot)

Similarly, functions in $n - D$ can be represented by RBFs and shown as 2 - D surfaces with $n - 2$ 'sliders'

Novel way to visually explore multi-variate data - It overcomes the traditional limitation of no higher than 2-D data when displaying on a 2-D computer screen.



Some concluding thoughts and future opportunities

Computational scaling to much larger and more complex scenarios

We have realized major improvements in computational efficiencies:

- Matlab can be some 10,000 times faster than ACT-R / IMPRINT.
- RBF approximations over the parameter space can both remove stochastic 'noise' and add a further factor of 100 - 1,000 in evaluation speed.

Opportunities: We are still far from any present hardware (or software) limitations:

- Transfer of code from PC to large-scale supercomputer might offer another factor of 10,000. In some programming environments, this can be done with addition of just a few lines of code.
- Numerical tasks should, through appropriate interfaces, be handled by systems specifically designed for them.

Parameter optimization

- It has been found to be possible to optimize many parameters using relatively little data.
- Although all parameter optimization results (Data Entry - 5 parameters and RADAR - 16 parameters) were found to be fairly close to hand-derived values, optimization can now be done in a much more automated way.

Opportunity: To optimize parameters that are NOT directly measurable. This will allow assessment of cognitive variables that are more abstract or more general (e.g. situation awareness, attentional allocation, or motivation).

Visualization

Opportunities:

- Very advanced multivariate visualization has been developed for many applications. Attempts should be made to apply these capabilities to psychological data: experimental as well as simulated.
- RBFs will be particularly useful in dynamic visualization thanks to their ability to quickly render noise-free versions of multivariate functions.