

Retrospective of Output Analysis in SESDYN

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Initial motivation: Formal validity testing

- Barlas, Yaman; 1985; '*Validation Of System Dynamics Models With A Sequential Procedure Involving Multiple Quantitative Methods*'; Ph.D. Dissertation; Georgia Institute Of Technology; Atlanta.
- Barlas, Yaman; 1989; '*Multiple Tests For Validation Of System Dynamics Type Of Simulation Models*'; European Journal Of Operation Research; Volume 42; 59-87.
- **Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. *System Dynamics Review*, 12(3), 183–210.**
[http://pisis.unalmed.edu.co/cursos/material/3004639/1/Barlas1996Formal aspects of model validity.pdf](http://pisis.unalmed.edu.co/cursos/material/3004639/1/Barlas1996Formal%20aspects%20of%20model%20validity.pdf)

Behavior Testing Software (BTS)

A BEHAVIOR VALIDITY TESTING SOFTWARE (BTS) (ISDC '97)

- By Yaman Barlas, Hüseyin Topaloğlu, Serkan Yilankaya
- A portfolio of statistical metrics and tests that can be used for dynamic output comparison
- Also suggests a workflow (i.e. a sequence of operations and calculations to be conducted for a proper comparison)

BTS-II

- Developed by (Esen Bozyayla) in Delphi
- An executable software with user-friendly (!) interface

steady state

Is the behavior
steady state or
transient?

transient

Statistical Measures & Tests

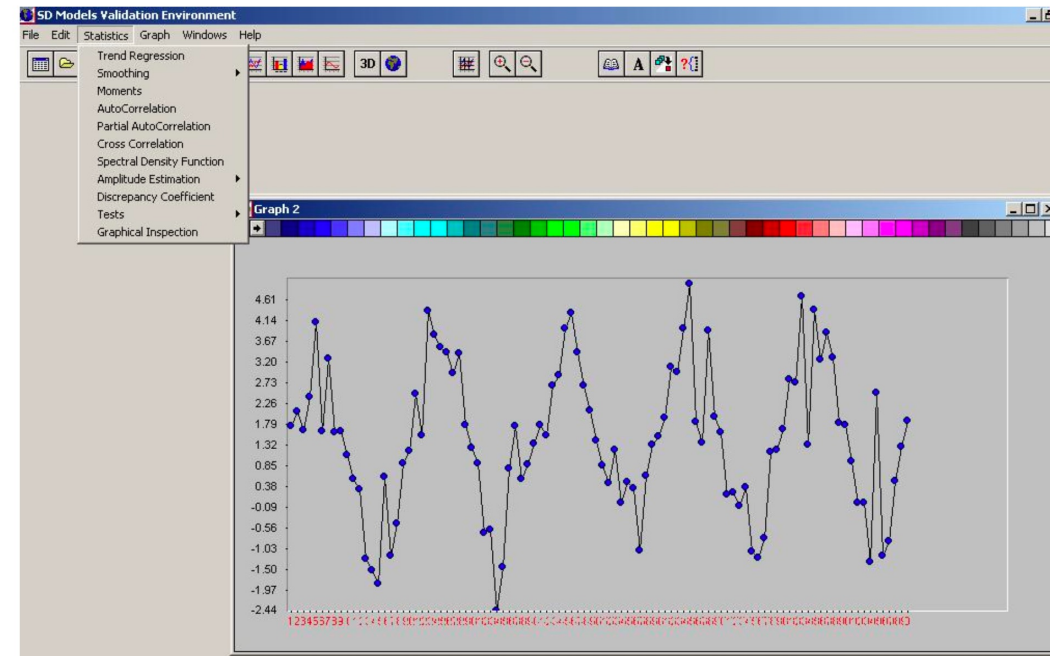
- Trend Regression
- Smoothing
- Moments
- Autocorrelation
- Partial Autocorrelation
- Spectral Density Function
- Cross correlation
- Amplitude Estimation
- Discrepancy Coefficient
- Trend in Amplitude
-
- Autocorrelation Test
- Partial Autocorrelation Test
- Multistep Validation Test

Multi-Step Procedure By Barlas

- Trend Comparison & Removal
- Period Comparison Using Autocorrelation Function
- Testing For Phase Lag Using Crosscorrelation Function
- Comparing The Averages
- Comparing The Variances
- Comparing The Amplitudes
- Overall Summary Measure: Discrepancy Coefficient

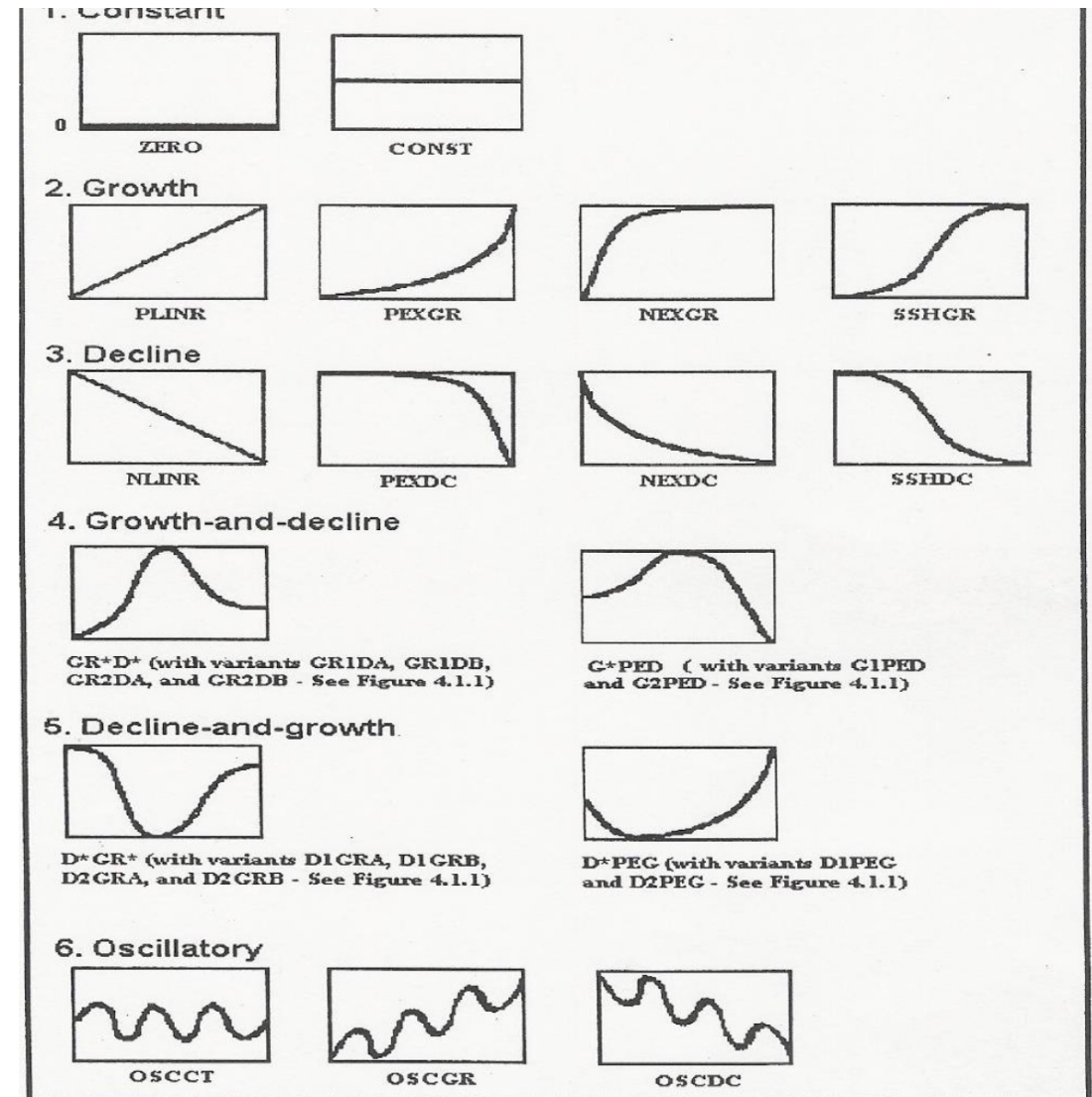
Graphical / Visual Measures Of Typical Behavior Features

- Maxima
- Minima
- Inflection Points
- Distances



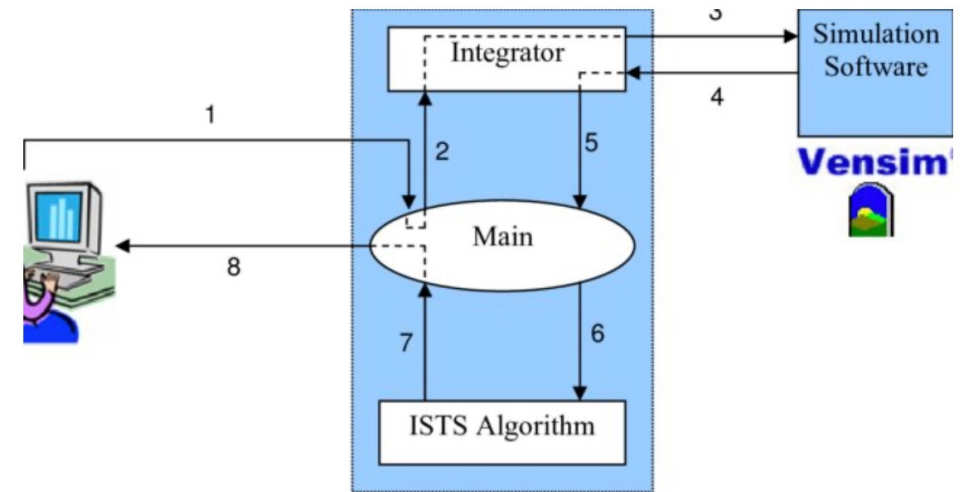
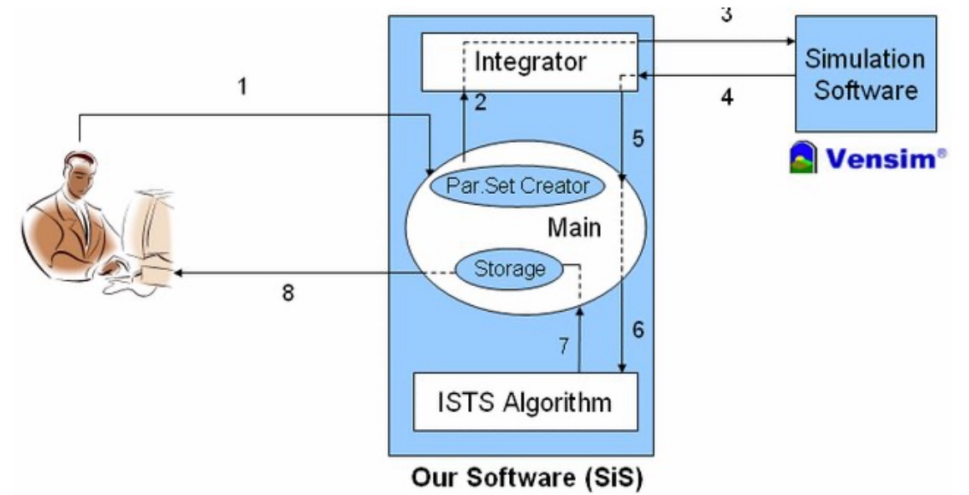
Indirect Structure Testing Software (ISTS)

- MSc Thesis of Korhan Kanar (1999)
- A classification algorithm that can recognize main modes of behavior
- An hypothesis testing based on pattern-wise proximity



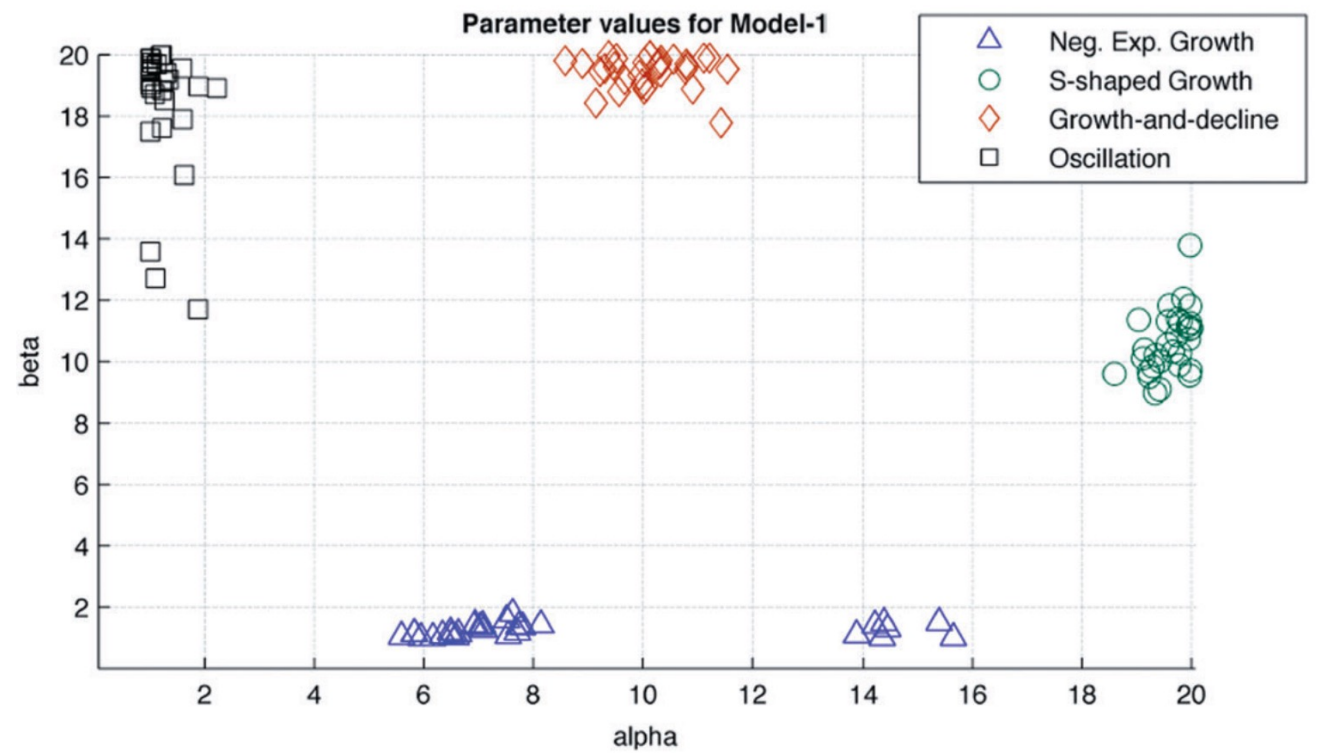
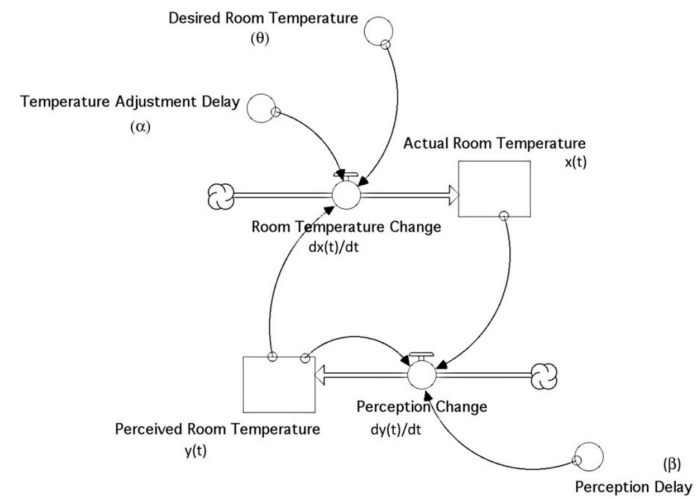
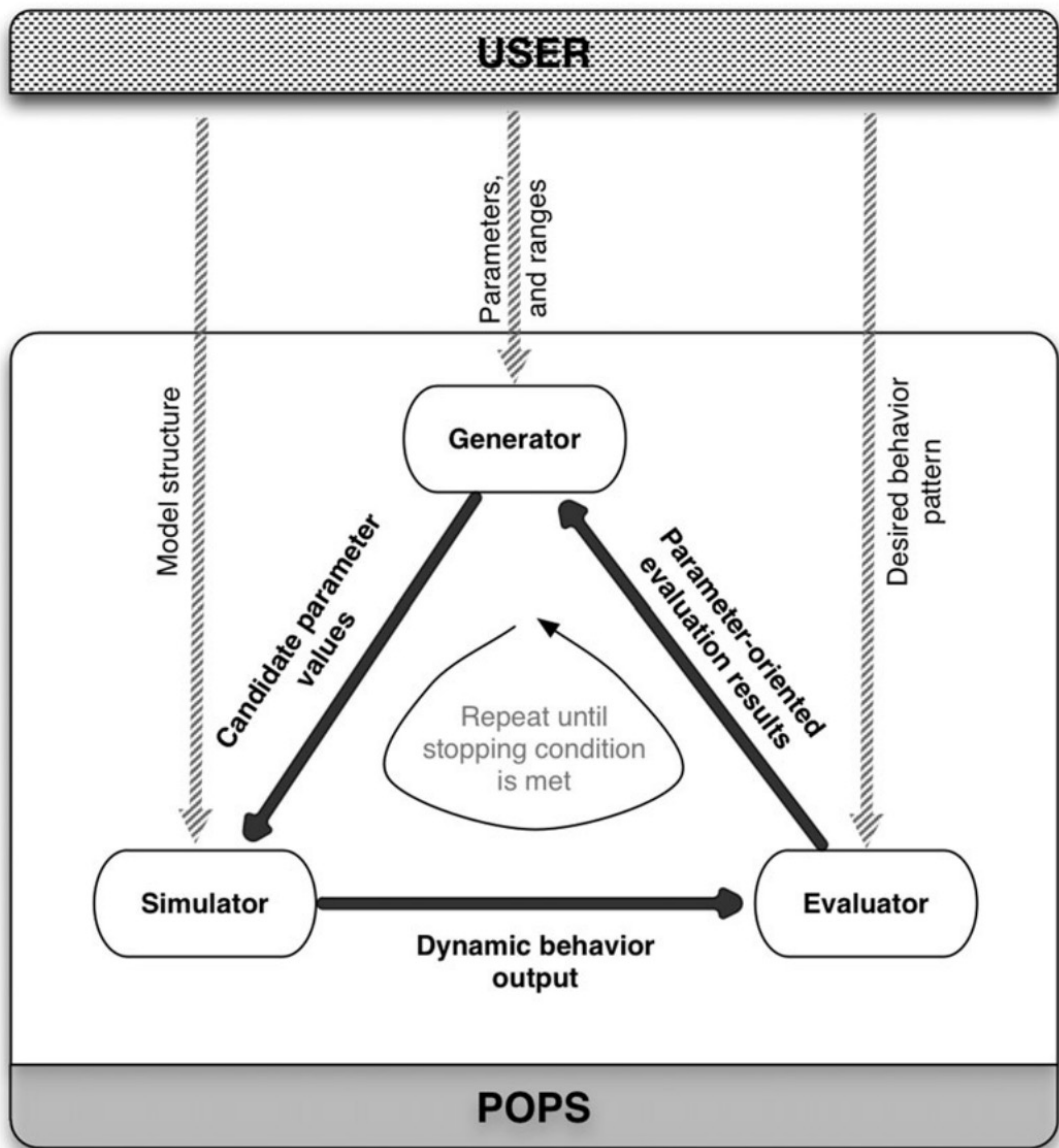
SİS BY SUAT BOĞ (IE 492 PROJECT)

- Implemented in JAVA
- Uses the ISTS algorithm
- Can perform automated indirect structure tests, and also parameter calibration to some extent



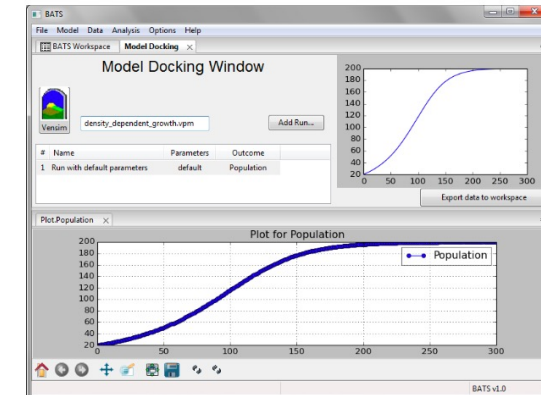
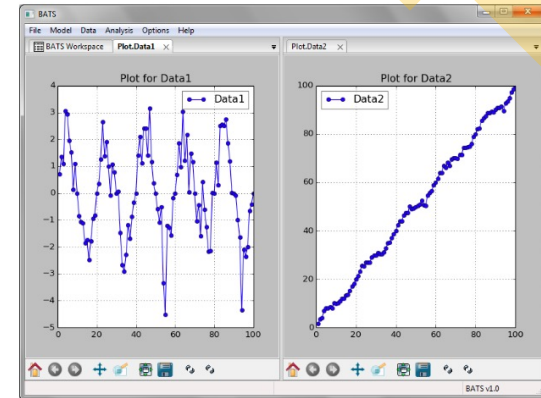
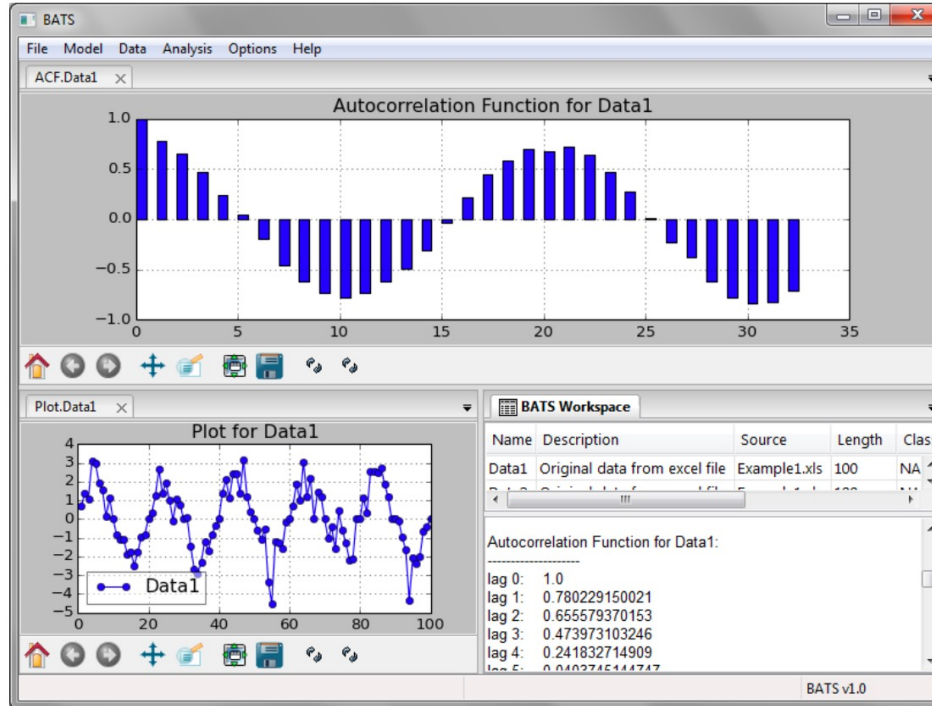
Pattern-oriented Parameter Specifier (POPS)

- Yücel, G., & Barlas, Y. (2011). Automated parameter specification in dynamic feedback models based on behavior pattern features. *System Dynamics Review*, 27(2), 195–215. <https://doi.org/10.1002/sdr>
- ISTS for output evaluation, implemented in MatLab
- Uses genetic algorithm in order to search the behavior space of a model in order to find parameter combinations that lead to the desired output pattern



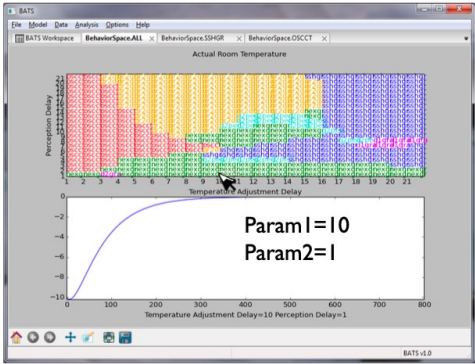
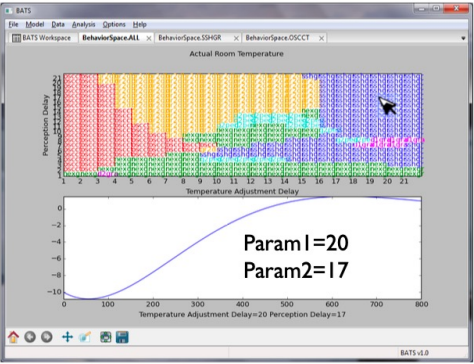
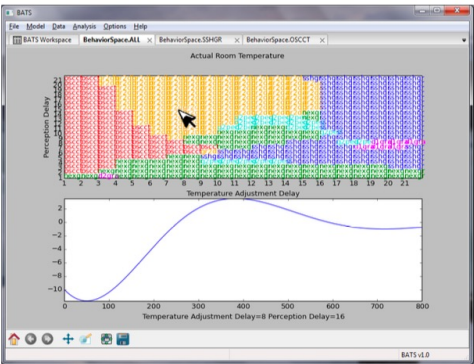
Behavior Analysis and Testing Software (BATS)

- MSc thesis by Can Sücüllü (2014)
- Combines the functionality of BTS and ISTS
- Implemented in Python, compiled as an executable program (.exe)
- Sücüllü, C., & Yücel, G. (2014). Behavior Analysis and Testing Software (BATS). *International Conference of the System Dynamics Society*.



BATS Behavior Space Classifier

(The plot is dynamic)



BATS Behavior Class Mapper

Pre-specified class is **sshgr**
(s-shaped-growth)

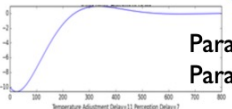
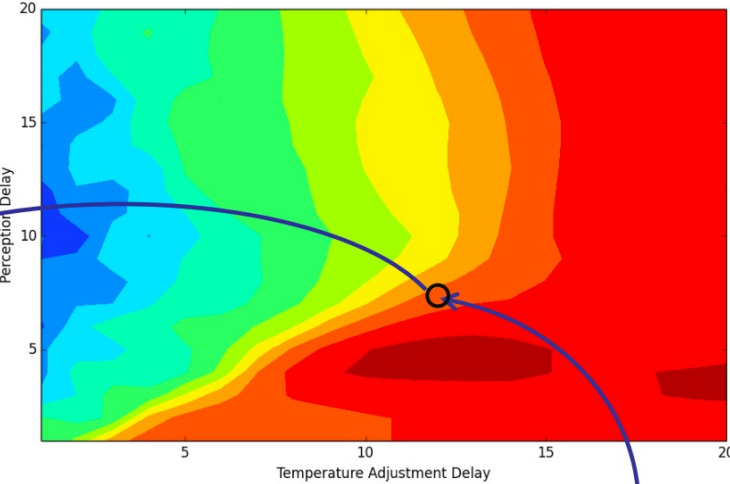
For each point, a simulation run is made

Model output is taken from Vensim

ISTS Algorithm is called

25 likelihoods are obtained

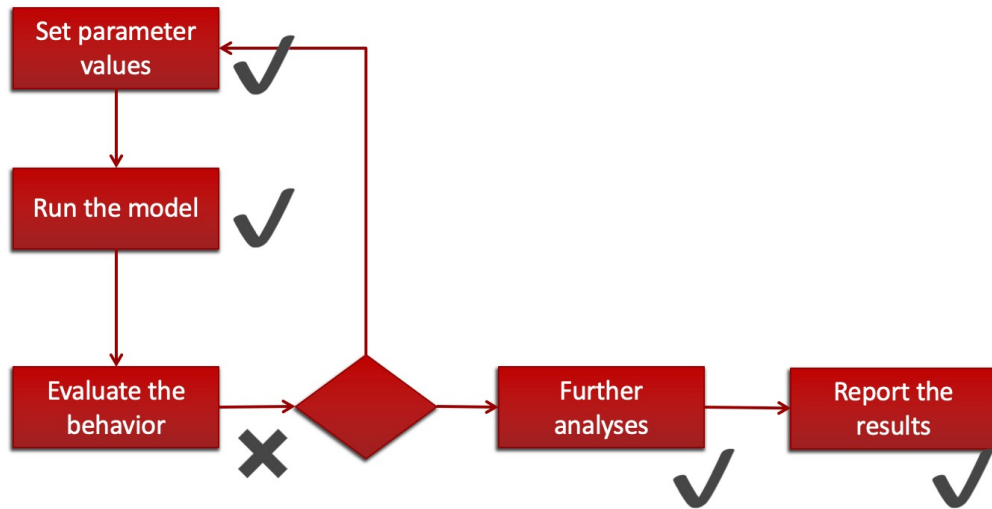
The likelihood value for pre-specified class is plotted on the graph



-3.99

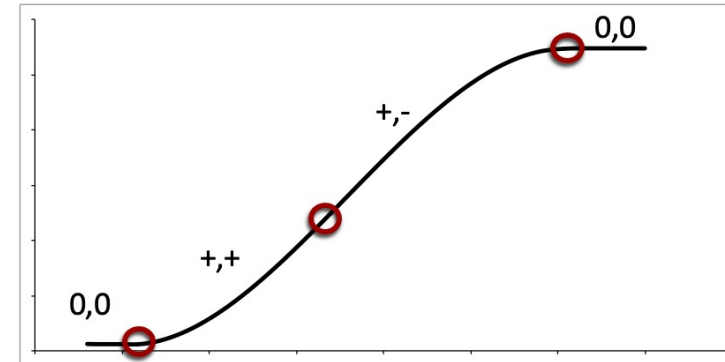
Towards pattern-oriented measurement

An automated analysis flow



➤ The algorithm works as follows;

- Go through the output, and identify points where slope or curvature changes sign
- Label the sections between these points according to the signs of slope and curvature
- Construct the sequence vector for the behavior
- Compare it with other sequence vectors



0	+1	+1	0
0	+1	-1	0

Vs.

0	+1
0	+1

- Yücel, G. (2012). A novel way to measure (dis)similarity between model behaviors based on dynamic pattern features. *The 30th International Conference of the System Dynamics Society*.

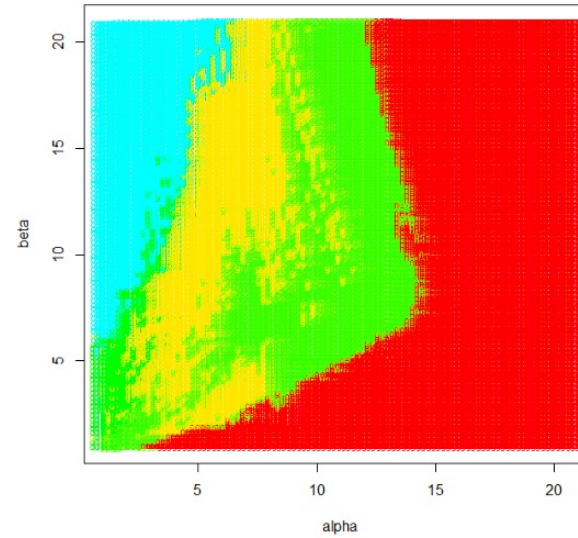
- Yücel, G., & Barlas, Y. (2015). Pattern Recognition for Model Testing, Calibration, and Behavior Analysis. In *Analytical Methods for Dynamic Modelers* (pp. 173–206). MIT Press.
- Önsel, N., Önsel, E. İ., & Yücel, G. (2013). Evaluation of alternative dynamic behavior representations for automated model output classification and clustering. *The 31st International Conference of the System Dynamics Society*.
- Edali, M. Yücel, G. (2018) A Comparative Analysis of Alternative Designs for Automated Clustering SD Model Output, ISDC

A novel classifier SMTS

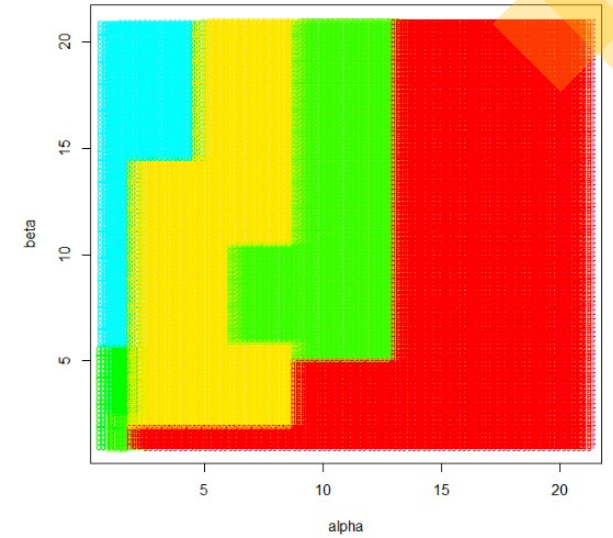
- Edali, M., Baydoğan, M. G., & Yücel, G. (2019). Classification of generic system dynamics model outputs via supervised time series pattern discovery. *Turkish Journal of Electrical Engineering and Computer Sciences*, 27(2). <https://doi.org/10.3906/elk-1711-394>
- Superior performance compared to ISTS

A showcase of SMTS

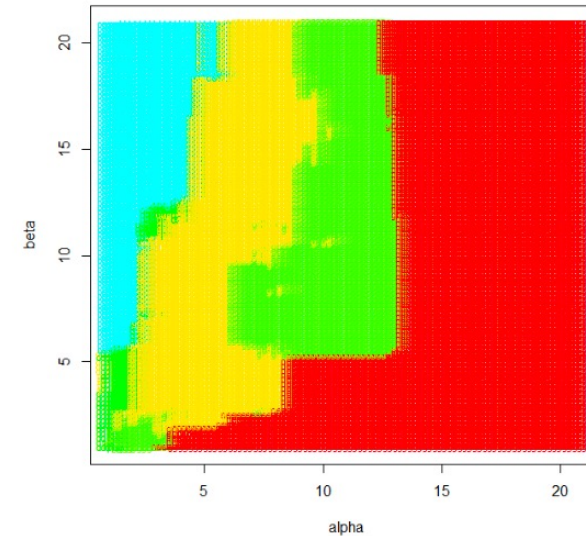
- Görgülü, B, Edali, M, Yücel, G. (2018) Efficient Parameter Exploration and Behavior Mapping for System Dynamics Models, ISDC
- Couple the classifier (SMTS) with decision trees for behavior space mapping



(a) Original 2-D Behavior Map Generated by 10000 Points

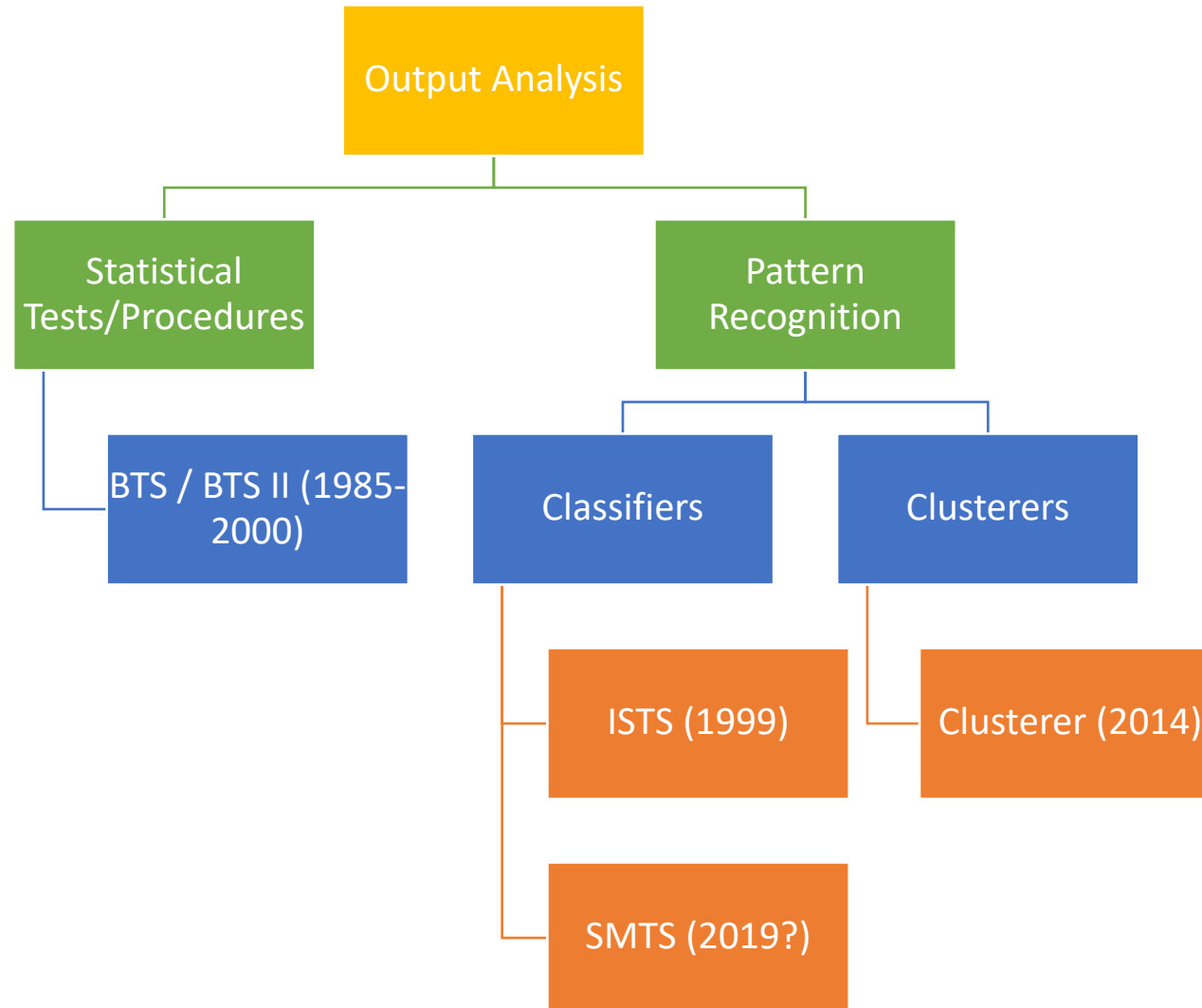


(b) 2-D Behavior Map Constructed by Uncertainty Sampling of 300 Points with Decision Tree



(c) 2-D Behavior Map Constructed by Uncertainty Sampling of 300 Points with Random Forest

Summary



What is next?

- A customizable output characterization that enables “measurement of similarity”
- A sustainable implementation for dissemination
- Common repository of tools and resources
 - <https://bitbucket.org/sesdyn/>
 - Datasets for testing
 - ISTS (python implementation)
 - Clusterer (python implementation)
 - BATS source code
 - Behavior space mapper code