Parallel PySAL

Autoregression and Complex System Framework Integration

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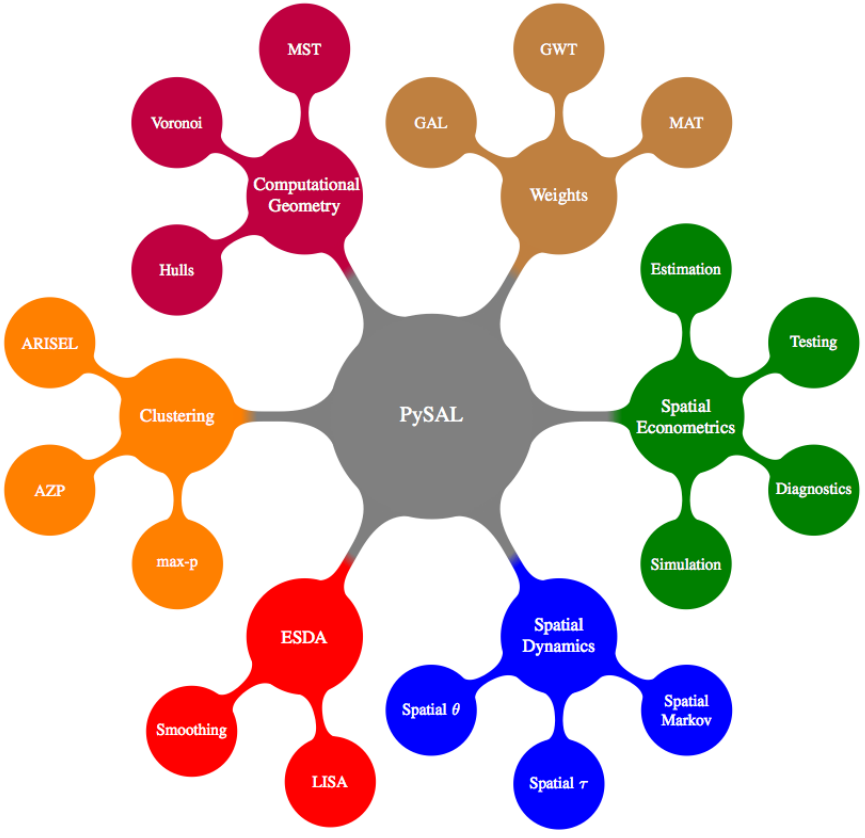
Outline

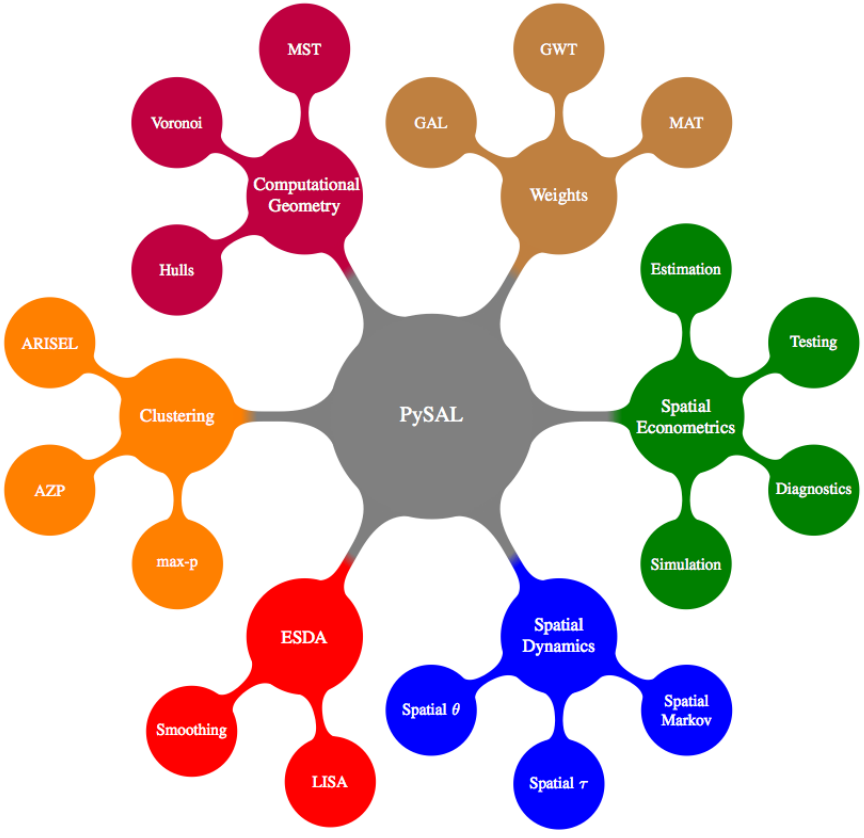
PySAL

- Spatial analysis library
- Big data world
- v 1.8 July 2014



pPySAL

- contiguity builder
- max-p region
- p-lisa
- fisher jenks
- spatial regimes



Lessons Learned

- Hardware dependence
- No holy grail of automatic parallelization
- Need a roadmap = Taxonomy
  - Guidance on "best practice"
  - Identify dead ends

Spatial Econometrics

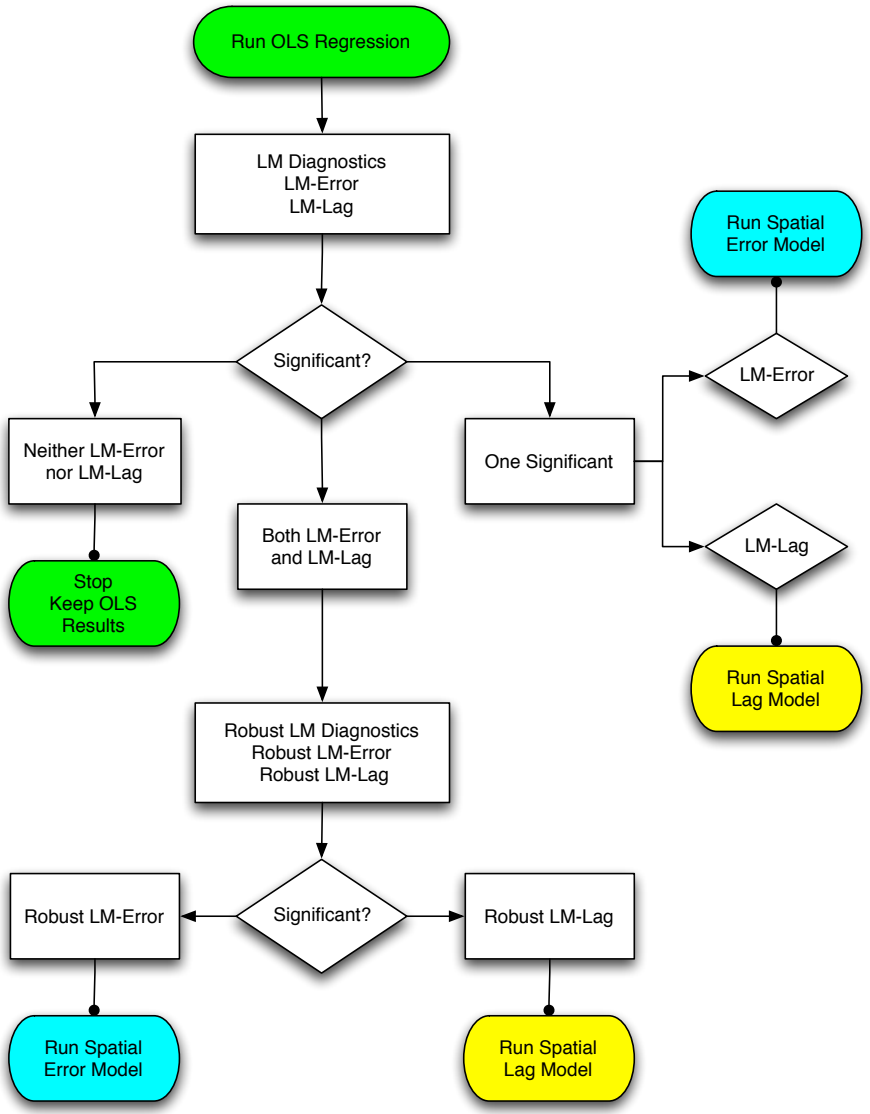
GeoDaSpace

- GUI ontop of spreg
- Subset of spreg functionality
- Cross-platform

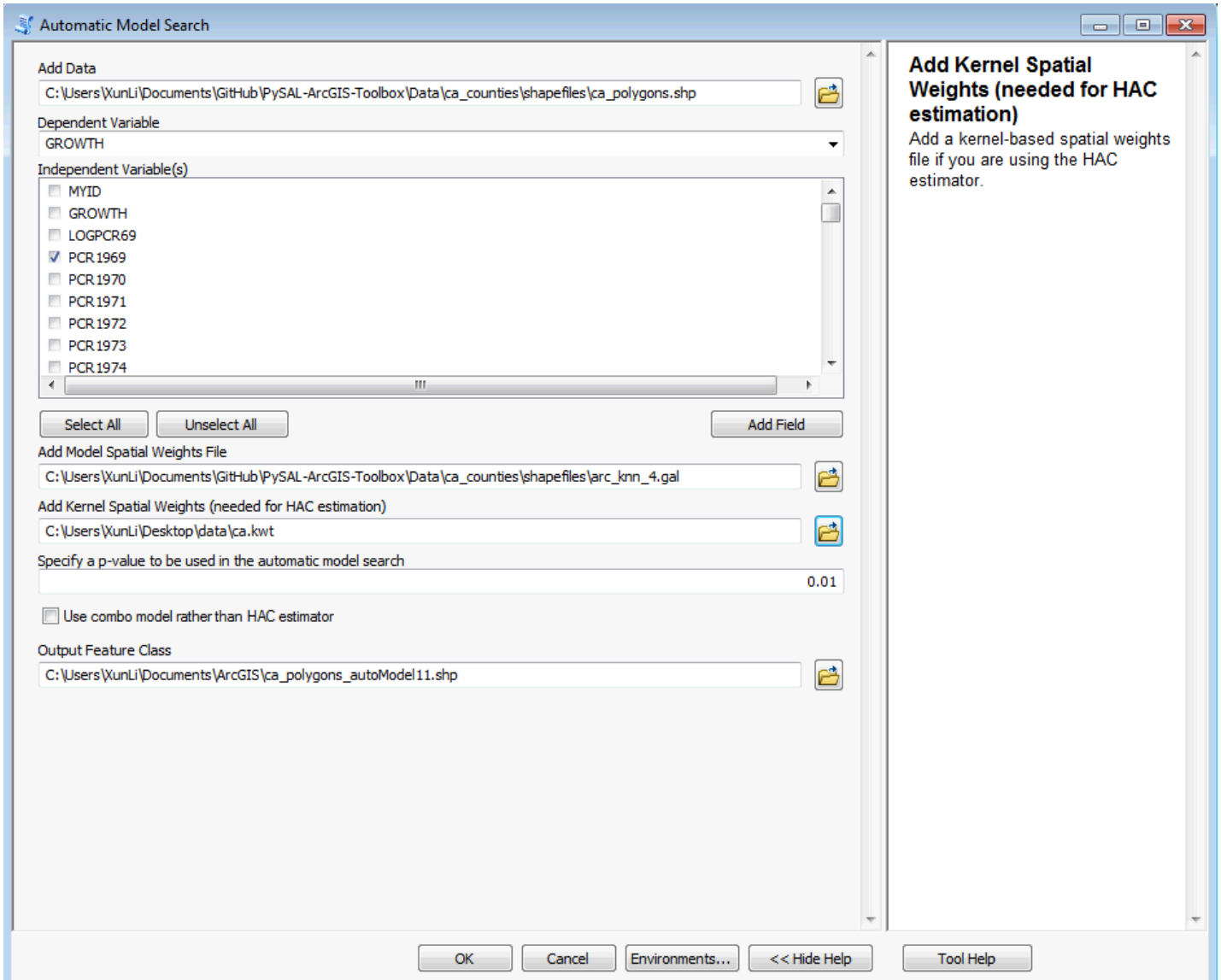
Specification Searches

- Specific to General
  - $y = X\beta + \epsilon$
  - OLS + Lagrange Multiplier Tests
- General to Specific
  - $y = \rho Wy + X\beta + (I - \lambda W)^{-1}\nu$
  - ML + Restrictions

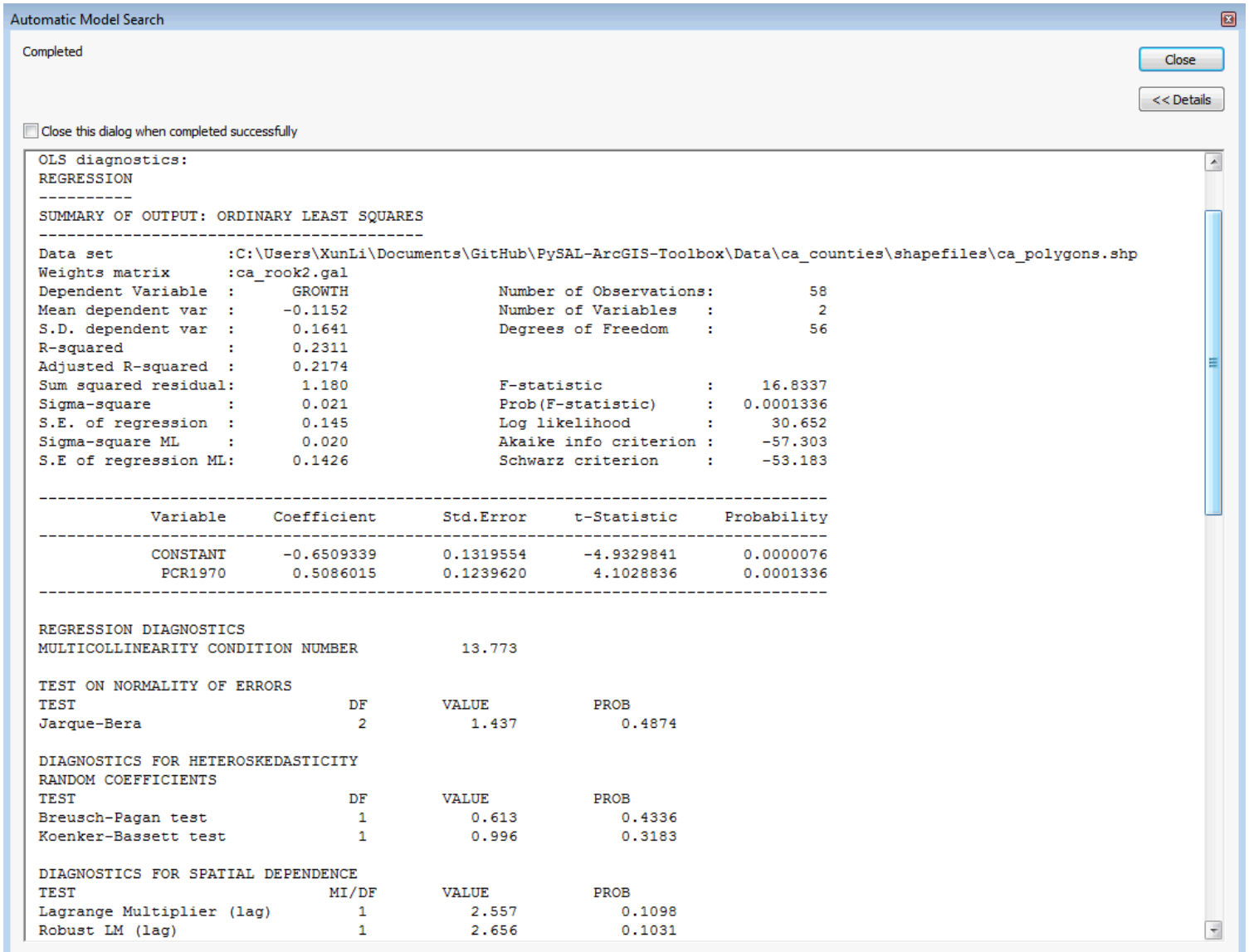
LM Based Specification



ArcGIS Toolbox



ArcGIS Toolbox




```
OLS diagnostics:
REGRESSION
----------
SUMMARY OF OUTPUT: ORDINARY LEAST SQUARES
-----------------------------------------
Data set            :C:\Users\XunLi\Documents\GitHub\PySAL-ArcGIS-Toolbox\Data\ca_counties\shapefiles\ca_polygons.shp
Weights matrix      :ca_rook2.gal
Dependent Variable  :      GROWTH                Number of Observations:          58
Mean dependent var  :     -0.1152                Number of Variables   :           2
S.D. dependent var  :      0.1641                Degrees of Freedom    :          56
R-squared           :      0.2311
Adjusted R-squared  :      0.2174
Sum squared residual:       1.180                F-statistic           :     16.8337
Sigma-square        :       0.021                Prob(F-statistic)     :   0.0001336
S.E. of regression  :       0.145                Log likelihood        :      30.652
Sigma-square ML     :       0.020                Akaike info criterion :     -57.303
S.E of regression ML:      0.1426                Schwarz criterion     :     -53.183

------------------------------------------------------------------------------------
            Variable     Coefficient       Std.Error     t-Statistic     Probability
------------------------------------------------------------------------------------
            CONSTANT      -0.6509339       0.1319554      -4.9329841       0.0000076
             PCR1970       0.5086015       0.1239620       4.1028836       0.0001336
------------------------------------------------------------------------------------

REGRESSION DIAGNOSTICS
MULTICOLLINEARITY CONDITION NUMBER           13.773

TEST ON NORMALITY OF ERRORS
TEST                             DF        VALUE           PROB
Jarque-Bera                       2           1.437          0.4874

DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS
TEST                             DF        VALUE           PROB
Breusch-Pagan test                1           0.613          0.4336
Koenker-Bassett test              1           0.996          0.3183

DIAGNOSTICS FOR SPATIAL DEPENDENCE
TEST                           MI/DF       VALUE           PROB
Lagrange Multiplier (lag)         1           2.557          0.1098
Robust LM (lag)                   1           2.656          0.1031
```

Root Node: Ordinary Least Squares Regresion

Then

A. If Lagrange Multiplier Test for Spatial Error Model < p-value AND Lagrange Multiplier Test for Spatial Lag Model < p-value

1. If Robust Lagrange Multiplier Test for Spatial Error p-value < p-value and Robrust Lagrange Multiplier Test for Spatial Lag Model p-value < p-vlaue:
    a. If NOT combo
        i. twosls_sp.GM_Lag
        ii. "Spatial Lag with Spatial Error - HAC"
    b. Elif Koenker Basset Statistic p-value < p-value
        i. error_sp_het.GM_Combo_Het
        ii. "Spatial Lag with Spatial Error - Heteroskedastic"
    c. Else
        i. error_sp_hom.GM_Combo_Hom
        ii. "Spatial Lag with Spatial Error - Homoskedastic"

2. Else If Robust Lagrange Multiplier Test for Spatial Error p-value < p-value and RLM for Spatial Lag p-value > p-value:
    a. If OLS Koenker Basset Statistic p-value < p-value
        i. error_sp_het.GM_Error_Het
        ii. "Spatial Error - Heteroskedastic"
    b. Else If OLS Koenker Basset Statistic p-value > p-value
        i. error_sp_hom.GM_Error_Hom
        ii. "Spatial Error - Homoskedastic"

3. Else If RLM for Spatial Error > p-value and RLM for Spatial Lag < p-value
    a. If OLS Koenker Basset Statistic p-value < p-value
        i. twosls_sp.GM_Lag (robut:white)
        ii. "Spatial Lag - Heteroskedastic"
    b. Else If OLS Koenker Basset Statistic p-value > p-value
        i. twosls_sp.GM_Lag
        ii. "Spatial Lag - Homoskedastic"
4. Else If RLM for Spatial Error > p-value and RLM for Spatial Lag > p-value
    a. No PySAL Call
    b. No Model - Robust Test not Significant - Check Model.

B. Else If Lagrange Mutiplier Test for Spatial Error Model < p-value AND Lagrange Mutiplier Test for Spatial Lag > p-value
1. If OLS Koenker Basset Statistic p-value < p-value
    i. error_sp_het.GM_Error_Het
    ii. "Spatial Error - Heteroskedastic"
2. Else If OLS Koenker Basset Statistic p-value > p-value
    i. error_sp_hom.GM_Error_Hom
    ii. "Spatial Error - Homoskedastic"

C. Else If Lagrange Multiplier Test for Spatial Error Model > p-value AND Lagrange Mutliplier Test for Spatial Lag < p-value
1. If OLS Koenker Basset Statistic p-value < p-value
    i. twosls_sp.GM_Lag (robust-white)
    ii. "Spatial Lag - Heteroskedastic"
2. Else If OLS Koenker Basset Statistic p-value > p-value
    i. twosls_sp.GM_Lag
    ii. "Spatial Lag - Homoskedastic"

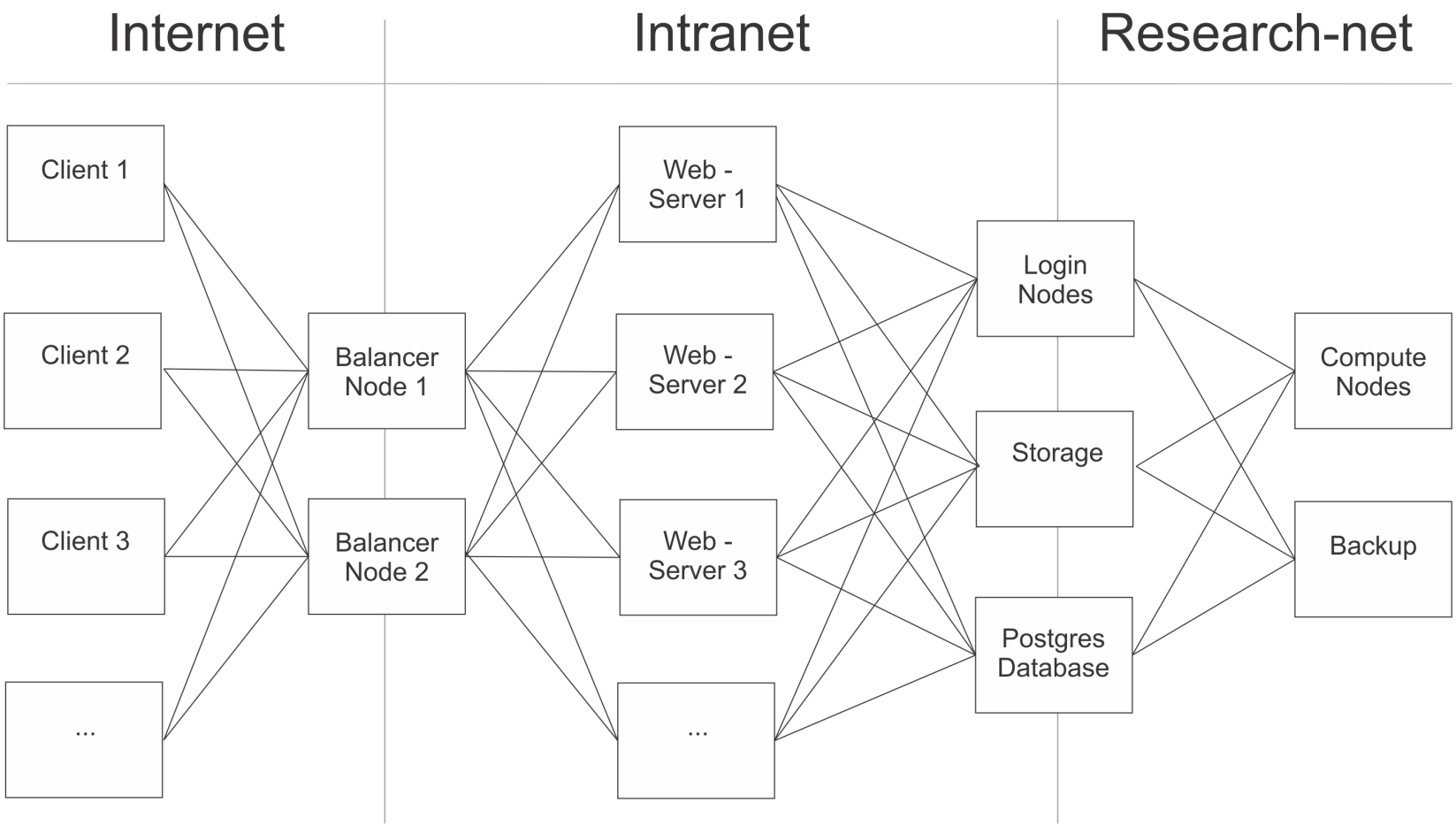
D. Else Lagrange Multiplier Test for Spatial Error Model > p-value AND Lagrange Multiplier Test for Spatial Lag > p-value

1. If OLS Koenker Basset Statistic p-value < p-value
    i. ols.OLS (robust-white)
    ii. "No Space - Heteroskedastic"
2. Else If OLS Koenker Basset Statistic p-value > p-value
    i. ols.OLS
    ii. "No Space - Homoskedastic"

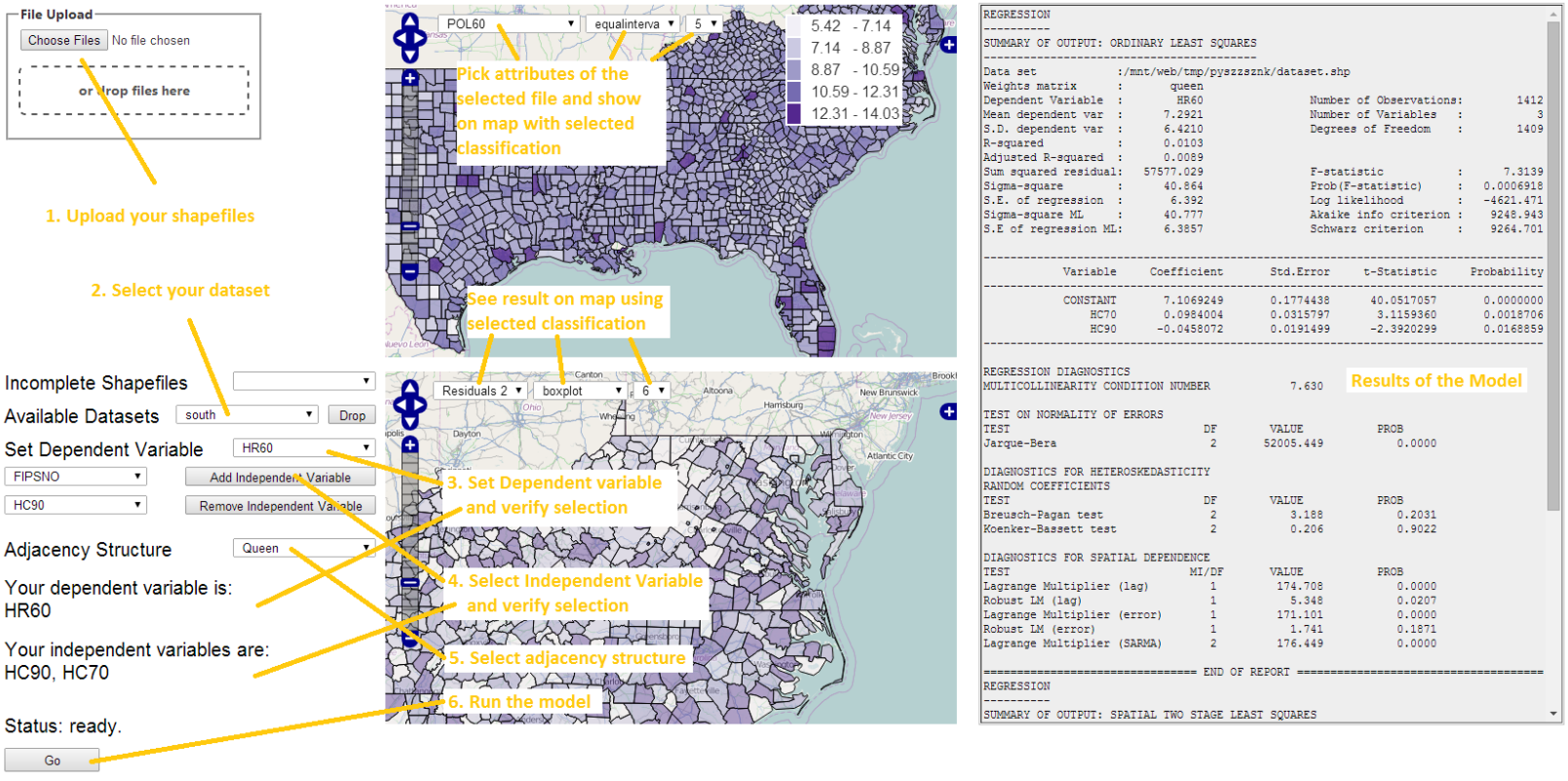
Parallel Strategy

- Speculative Parallelism
  - Solve' all branches of a search tree
  - Leverage an excess computation model
  - No dependency in execution order
  - Synchronization at the completion of all computation
- Implementation
  - Utilize a processing queue
  - One manager, and n workers
  - Workers draw a regression model from the queue, process, and return the result
  - Scales to where n = number of models to compute
  - Potential to extend to variable parameter specification (larger tree)

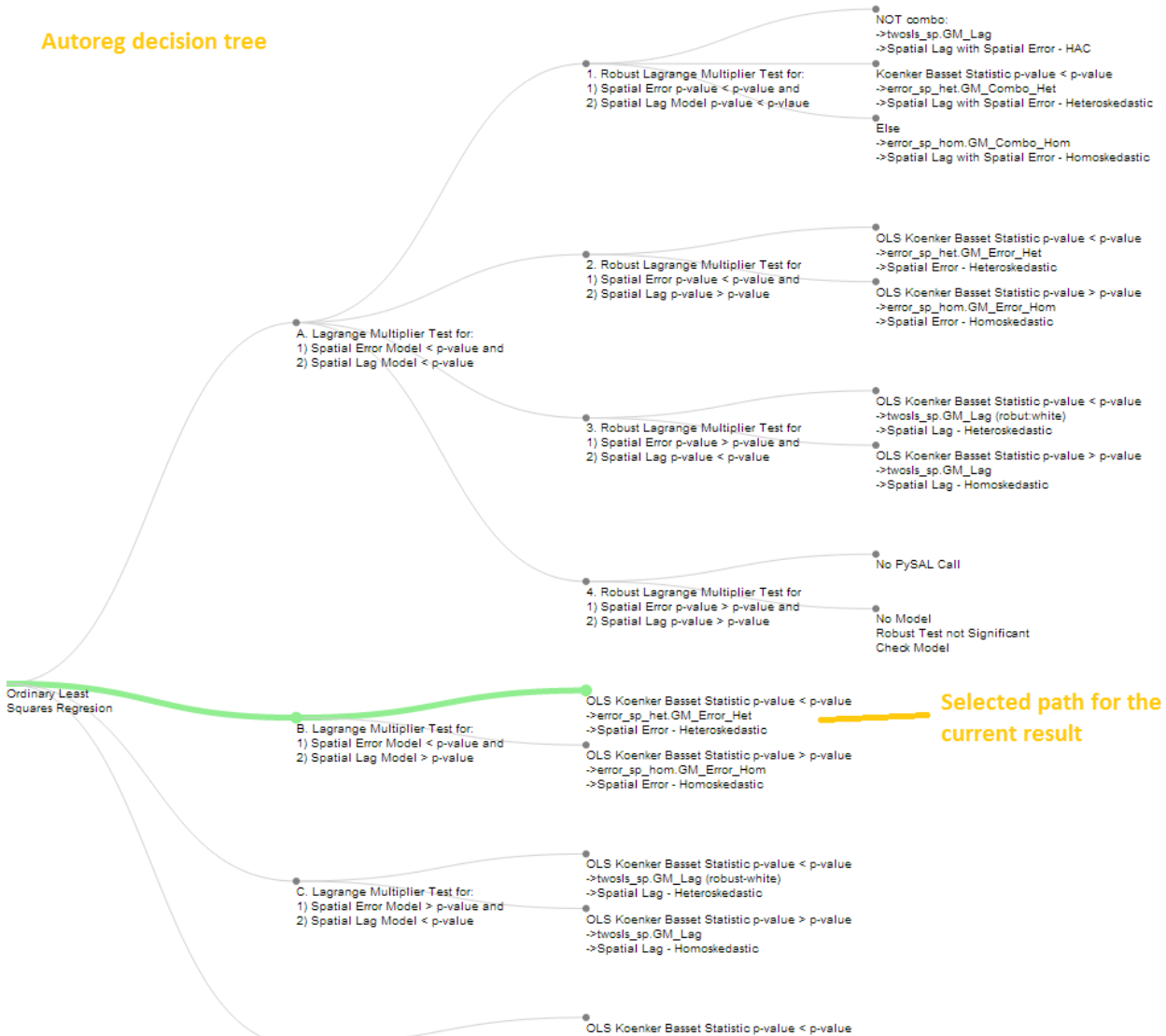
Complex Systems Framework



Autoreg in CSF



Model Path


Autoreg decision tree
Ordinary Least Squares Regresion
A. Lagrange Multiplier Test for:
1) Spatial Error Model < p-value and
2) Spatial Lag Model < p-value
1. Robust Lagrange Multiplier Test for:
1) Spatial Error p-value < p-value and
2) Spatial Lag Model p-value < p-vlaue
NOT combo:
->twosls_sp.GM_Lag
->Spatial Lag with Spatial Error - HAC
Koenker Basset Statistic p-value < p-value
->error_sp_het.GM_Combo_Het
->Spatial Lag with Spatial Error - Heteroskedastic
Else
->error_sp_hom.GM_Combo_Hom
->Spatial Lag with Spatial Error - Homoskedastic
2. Robust Lagrange Multiplier Test for
1) Spatial Error p-value < p-value and
2) Spatial Lag p-value > p-value
OLS Koenker Basset Statistic p-value < p-value
->error_sp_het.GM_Error_Het
->Spatial Error - Heteroskedastic
OLS Koenker Basset Statistic p-value > p-value
->error_sp_hom.GM_Error_Hom
->Spatial Error - Homoskedastic
3. Robust Lagrange Multiplier Test for
1) Spatial Error p-value > p-value and
2) Spatial Lag p-value < p-value
OLS Koenker Basset Statistic p-value < p-value
->twosls_sp.GM_Lag (robut:white)
->Spatial Lag - Heteroskedastic
OLS Koenker Basset Statistic p-value > p-value
->twosls_sp.GM_Lag
->Spatial Lag - Homoskedastic
4. Robust Lagrange Multiplier Test for
1) Spatial Error p-value > p-value and
2) Spatial Lag p-value > p-value
No PySAL Call
No Model
Robust Test not Significant
Check Model
B. Lagrange Multiplier Test for:
1) Spatial Error Model < p-value and
2) Spatial Lag Model > p-value
OLS Koenker Basset Statistic p-value < p-value
->error_sp_het.GM_Error_Het
->Spatial Error - Heteroskedastic
OLS Koenker Basset Statistic p-value > p-value
->error_sp_hom.GM_Error_Hom
->Spatial Error - Homoskedastic
Selected path for the current result
C. Lagrange Multiplier Test for:
1) Spatial Error Model > p-value and
2) Spatial Lag Model < p-value
OLS Koenker Basset Statistic p-value < p-value
->twosls_sp.GM_Lag (robust-white)
->Spatial Lag - Heteroskedastic
OLS Koenker Basset Statistic p-value > p-value
->twosls_sp.GM_Lag
->Spatial Lag - Homoskedastic
OLS Koenker Basset Statistic p-value < p-value

Next Steps

Parallel Autoreg

- Ensemble of search strategies
  - short
  - full
  - hybrid
- Candidate Variables
- Candidate Ws

Integration

- CyberGIS Gateway
- Strategies

Come see the demo!