Methods for Fitting Data to NURBS Based Surrogate Models

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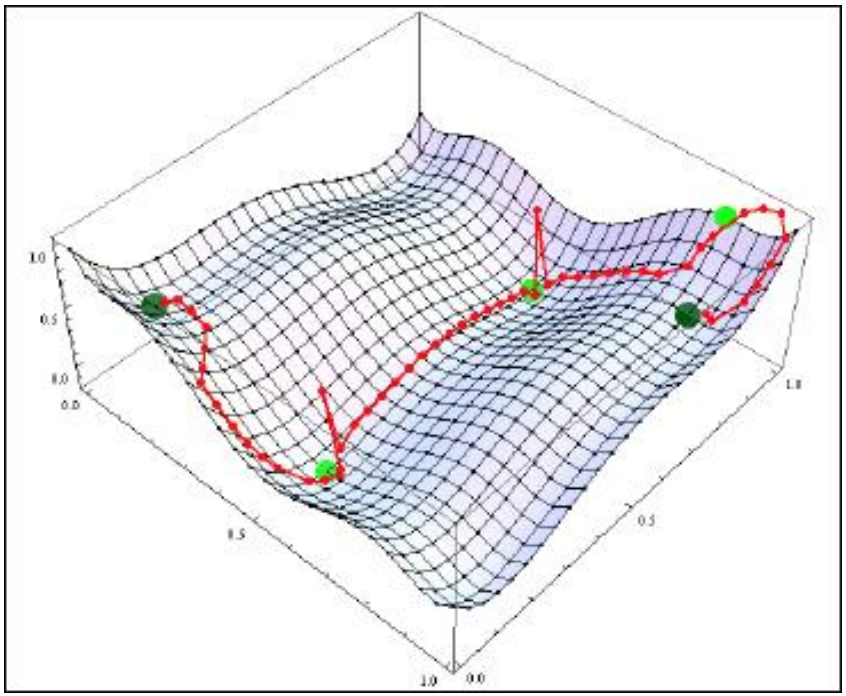
Background

- Previous simulations showed benefits of surrogate-model based decision making for a drone navigating to a target location
- Showed emergent, or unexpected, intelligent behavior



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Research Overview

- **Design statement: Use surrogate model based optimal decision making and data storage to develop more efficient multi-robot collaborative goal-oriented exploration techniques.**
- Design goals:
  - Redundant platforms for a robust system
  - Non-centralized control
  - Intelligent autonomous robot decision making
  - An efficient method for representing the environment, such as a surrogate model
  - Platforms that can gather large amount of environment data during operation
  - Platforms that can easily cross rough terrain

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Applications

- Exploration on other planets
- Terrain mapping
- Search and rescue
- Resource exploration
- Exploring hostile areas

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NURBS Surrogate Models

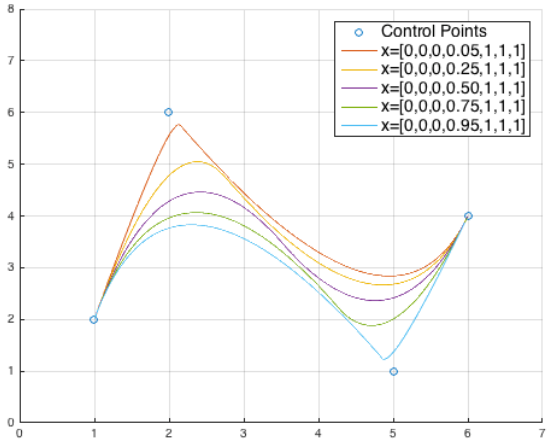
- Non-Uniform Rational B-Splines
- Commonly used in CAD software for representing surfaces
- Can accurately represent any geometry
- Defined by a set of control points, weights, a knot vector, and a curve order

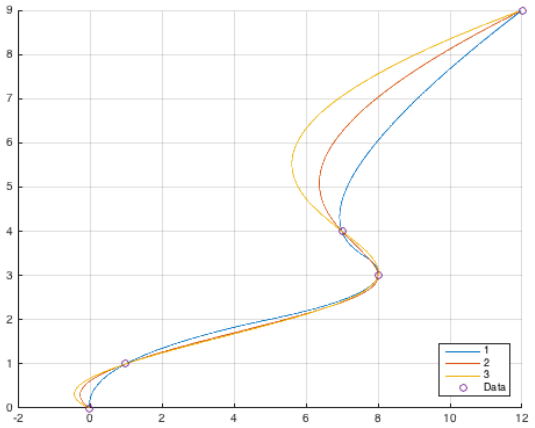
$$\boldsymbol{C}(u) = \frac{\sum_{i=0}^{n} N_{i,k}(u) w_i \boldsymbol{P}_i}{\sum_{i=0}^{n} N_{i,k}(u) w_i}$$

$$\text{for} \quad a \leq u \leq b$$

$$\text{where} \quad N_{i,k}(u) = \left(\frac{u - x_i}{x_{i+k-1} - x_i}\right) N_{i,k-1}(u) + \left(\frac{x_{i+k} - u}{x_{i+k} - x_{i+1}}\right) N_{i+1,k-1}(u)$$

$$N_{i,1}(u) = \begin{cases} 1 & \text{if} \quad x_i \leq u \leq x_{i+1} \\ 0 & \text{otherwise} \end{cases}$$





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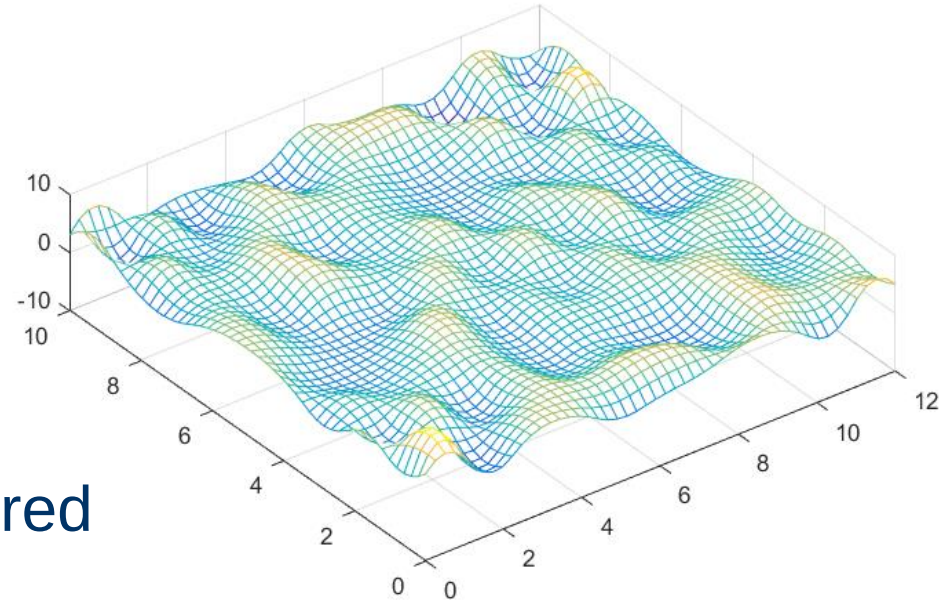
NURBS Surfaces

- Must have a rectangular mesh of control points
- The u and v directions each have
  - A degree
  - A knot vector
- Weights are in a matrix
- u and v parameters are entered for a X,Y,Z coordinate



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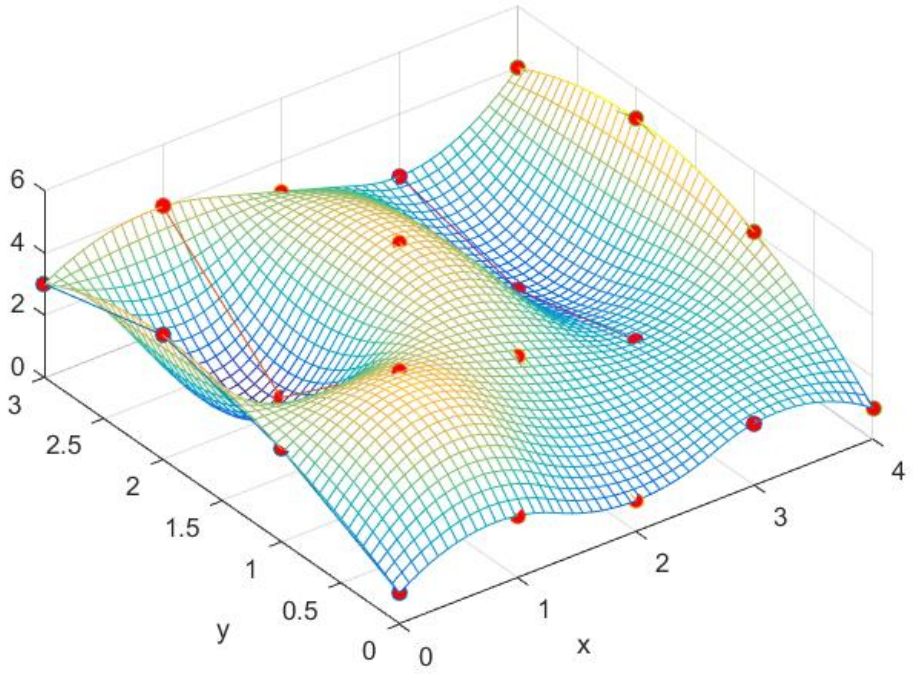
Global Interpolation

- A control point is made for each data point
- Two linear systems of equations are formed from the data points and matrices of basis values
- Parameterized so that X=u and Y=v
  - Easy point referencing



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Squared Error

- Initial control points are added at the most influential data points
- Model is evaluated at the location of the remaining data points
- Squared error is calculated
- If error is not in tolerance, control points are added to data with highest error

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Uncertainty Weighting

- “Weights” are assigned to each control point and kept in a matrix
- Correspond to the level of uncertainty in the data
- These weights will be used in decision making

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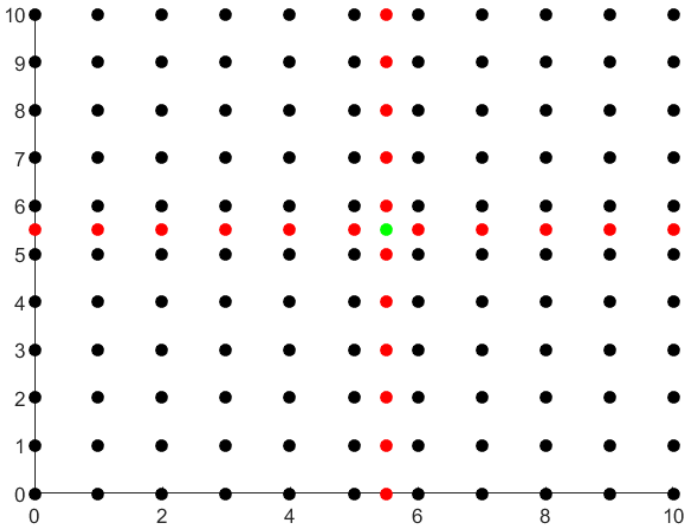
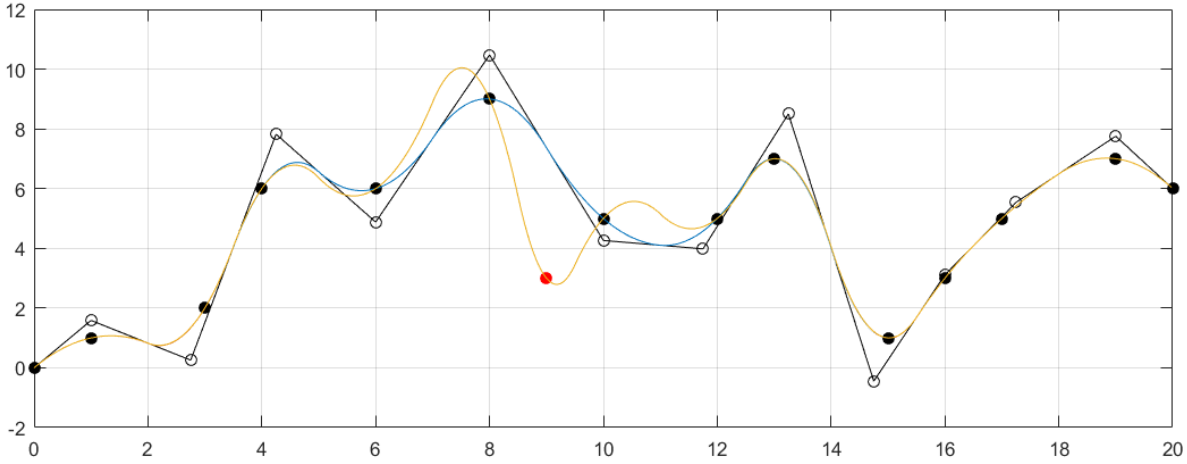
Local Interpolation

- For data points added to the model
- Refit to data near the new point and keep control points further away
- For surfaces, control points must be added to maintain rectangular mesh





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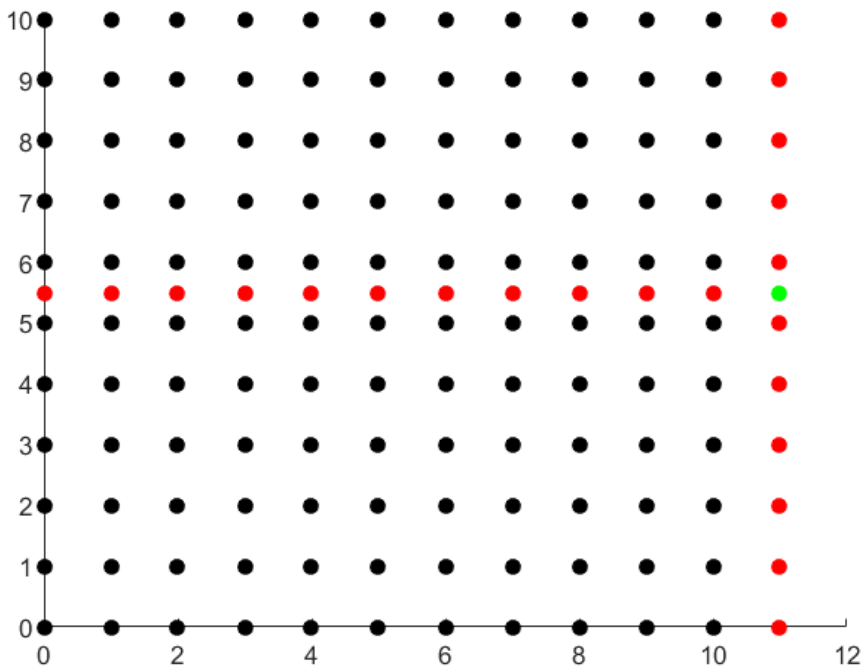
Kriging for Edge Extrapolation

- Control points added on edge cannot be interpolated from the model
- Kriging estimates points as a function of nearby points
- Uncertainty is based on the nearby points



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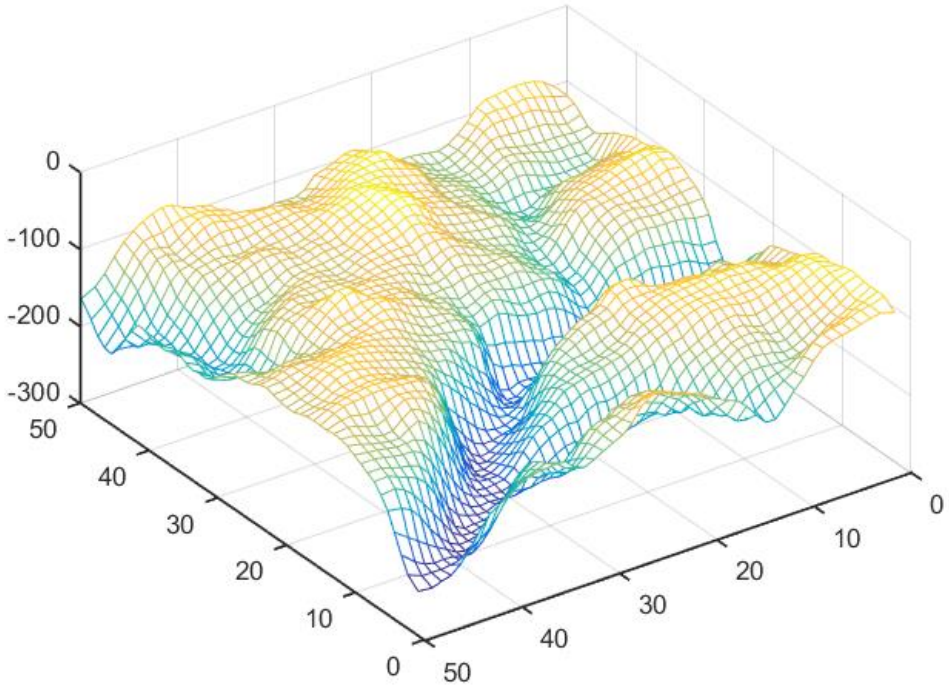
Next Steps

- Combine fitting techniques to simulate a drone collecting data in an environment
- Couple with decision making algorithms



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