Maxent overview

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Based on:

Maximum Entropy (Maxent) method

Precise mathematical definition
Continuous and categorical environmental data
Continuous output
Interpretability in ecological dimensions
Maximum Entropy (Maxent) method

**Features:** environmental variables or functions thereof

Maxent has various classes of features
Maximum Entropy (Maxent) method

Classes of features:

Linear features ... variable itself
Quadratic features ... square of variable
Product features ... product of two variables

Discrete features (categorical) ... variable itself
Maximum Entropy (Maxent) method

Estimates target probability distribution
by finding probability distribution (statistical model) of maximum entropy (i.e., most spread out, closest to uniform)
subject to constraints
Maximum Entropy (Maxent) method

**Constraints:** what we know about the features

Data from the sample points (the known occurrence localities, in our case)
Maximum Entropy (Maxent) method

Constraints:

Linear features  ...  ...  mean
Quadratic features  ...  ...  variance
Product features  ...  ...  covariance

Discrete features (categorical)  ...  proportion
Maximum Entropy (Maxent) method

Constraints:

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear features</td>
<td>... ... mean</td>
</tr>
<tr>
<td>Quadratic features</td>
<td>... ... variance</td>
</tr>
<tr>
<td>Product features</td>
<td>... ... covariance</td>
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<tr>
<td>Threshold/hinge features</td>
<td>... fit an arbitrary response</td>
</tr>
<tr>
<td>Discrete features (categorical)</td>
<td>... proportion</td>
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</tbody>
</table>
Statistical model:

Gibbs probability distribution $q_{\lambda}$ of the form

$$q_{\lambda}(x)$$

Each element $x$ is a pixel of the study region.
**Statistical model:**

Gibbs probability distribution $q_\lambda$ of the form

$$q_\lambda(x) = e^{\lambda \cdot f(x)}$$

Each element $x$ is a pixel of the study region.

$\lambda$ is a vector of $n$ real-valued coefficients (feature weights).
**Statistical model:**

Gibbs probability distribution $q_\lambda$ of the form

$$q_\lambda(x) = e^{\lambda \cdot f(x)}$$

Each element $x$ is a pixel of the study region

$\lambda$ is a vector of $n$ real-valued coefficients (feature weights)

$f$ is the vector of all $n$ features
**Statistical model:**

Gibbs probability distribution $q_\lambda$ of the form

$$q_\lambda(x) = e^{\lambda \cdot f(x)}/Z_\lambda$$

Each element $x$ is a pixel of the study region

$\lambda$ is a vector of $n$ real-valued coefficients (feature weights)

$f$ is the vector of all $n$ features

$Z_\lambda$ is a normalizing constant that ensures that $q_\lambda$ sums to 1
Statistical model:

Gibbs probability distribution $q_\lambda$ of the form

$$q_\lambda(x) = e^{\lambda \cdot f(x)/Z_\lambda}$$

Each element $x$ is a pixel of the study region

The probabilities of all pixels sum to 1
**Statistical model:**

Gibbs probability distribution $q_\lambda$ of the form

$$q_\lambda(x) = e^{\lambda \cdot f(x)}/Z_\lambda$$

Each element $x$ is a pixel of the study region

The probabilities of all pixels sum to 1

These probabilities are *not* probabilities of occurrence, but rather values representing the relative suitability of the environmental conditions in each pixel
Cumulative output:

“raw” probabilities for individual pixels are extremely small

“cumulative” probability is the sum of the probabilities of that particular pixel and all other pixels with equal or lower probability, multiplied by 100 to give a percentage
Cumulative output:

$t\%$ of randomly sampled pixels with have cumulative value of $t$ or less

Expectation: use of a threshold of $t$ to make a binary model from the continuous cumulative output will yield an omission rate of $t\%$

and minimum predicted area among such models

(!!)
Logistic output:

“raw” probabilities for individual pixels are extremely small.

“logistic” probability is probability that the environment is suitable (or probability of occurrence if distribution is at equilibrium with environment).

Ranges from 0 to 1.
Bradypus variegatus

Localities from Anderson and Handley (2001)
Bradypus variegatus

Climatic, topographic, and vegetational variables
*Bradypus variegatus*

Climatic, topographic, and vegetational variables

3 thresholds applied
Thank you
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