Kohonen's self-organizing maps in education
Kohonen önszerveződő térképei az oktatásban

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Abstract: A Kohonen network, also known as a Kohonen action map, is a type of artificial neural network that falls into the category of self-organizing networks. A Kohonen network was developed by Teuvo Kohonen in the 1980s and is one of the most widely used types of self-organizing networks. The goal of a Kohonen network is to group data into a two-dimensional map based on their similarity. In a Kohonen network, data is provided as an input layer, and the output layer forms a two-dimensional grid in which each neuron belongs to a cell. The algorithm feeds data into the network through the input layer and assigns the data to the nearest neuron based on its characteristics. The output neurons then change their activity due to their influence on nearby neurons, causing the network to self-organize and group similar data into the same group. Kohonen networks are widely used for pattern classification, segmentation, and dimensionality reduction, as well as for data visualization. Kohonen networks use unsupervised learning, which allows the network to work efficiently on data without prior knowledge of the output results. This can also be used in education. [2]

Keywords: Kohenen, network, education

1. Kohonen’s Self-Organizing Maps

The Kohonen network, also known as a Self-Organizing Map (SOM), is a type of unsupervised neural network designed to discover hidden structures and patterns in data without using predefined labels. It is particularly effective for visualizing and clustering complex, high-dimensional information.

A Kohonen network consists of a two-dimensional grid of neurons, each associated with a weight vector of the same dimension as the input data. When an input vector is presented, all neurons calculate their distance from it, and the neuron with the smallest distance becomes the Best Matching Unit (BMU). This neuron, along with its neighbors on the grid, updates its weights to become more similar to the input. Over many iterations, the map gradually organizes itself so that similar inputs activate neurons close to each other — preserving the topological relationships of the data.

The learning process is competitive and cooperative at the same time: neurons compete to represent the input, but neighboring neurons cooperate during weight updates. As training progresses, both the learning rate and the neighborhood radius decrease, allowing the map to form a fine-grained, stable representation of the input space.

One of the key advantages of the Kohonen network is its ability to reduce dimensionality while maintaining the original data structure. It converts complex, multidimensional data into a two-dimensional visual map, where clusters and similarities become intuitively visible.

This makes the Self-Organizing Map a valuable tool in fields like pattern recognition, data mining, market analysis, and bioinformatics — bridging the gap between numerical data and intuitive visual understanding.The learning process involves three main steps:

1. **Competition:** When an input vector is presented, all neurons compute their distance from it, and the neuron with the smallest distance is selected as the **Best Matching Unit (BMU)**.

2. **Cooperation:** The BMU’s neighboring neurons on the grid are also activated, forming a **neighborhood**.

3. **Adaptation:** The BMU and its neighbors adjust their weight vectors to move closer to the input vector. Over time, the neighborhood radius and learning rate decrease, leading to a stable, self-organized map.

One of the major strengths of the SOM is its ability to preserve the structure of the input data in a way that is easily interpretable. It can transform complex datasets—such as images, sensor readings, or gene expression data—into two-dimensional visual maps where clusters, patterns, and correlations become visible. This makes SOMs highly valuable in exploratory data analysis, pattern recognition, and data mining.

Kohonen maps are widely used in various fields, including finance (for portfolio analysis), biomedicine (for identifying genetic patterns), marketing (for customer segmentation), and engineering (for fault detection and process monitoring). Their strength lies in their intuitive visualization capability, allowing humans to grasp relationships that might otherwise remain hidden in raw, high-dimensional data.

In summary, Kohonen’s Self-Organizing Maps are a remarkable example of biologically inspired machine learning. They demonstrate how simple, local adaptation rules can produce global organization, offering both practical analytical power and deep insights into how learning and perception might occur in the human brain. [3]

2. Applications of Kohonen's Self-Organizing Maps

Kohonen's Self-Organizing Map (SOM) is widely used across many scientific, industrial, and commercial fields because it helps people visualize, analyze, and cluster complex data in an intuitive way. Its ability to reveal patterns without requiring labeled data makes it a powerful tool in both research and real-world applications.

Data Visualization and Exploration:

SOMs are often used to transform large, high-dimensional datasets into easy-to-interpret two-dimensional maps. This helps researchers discover relationships, clusters, and trends that might not be visible in raw data.

Pattern Recognition and Classification:

In areas like image and speech recognition, SOMs can identify similarities between patterns. For example, they can group handwritten digits, facial features, or voice samples based on their characteristics.

Market and Customer Analysis:

Companies use SOMs in marketing and customer segmentation to identify groups of consumers with similar purchasing behavior or preferences. This supports targeted advertising, product development, and personalized recommendations.

Bioinformatics and Medicine:

In genetics and medical diagnostics, SOMs help analyze gene expression data or classify diseases based on complex biological markers. They are also used to detect patterns in medical imaging or patient monitoring data.

Finance and Economics:

SOMs are applied to credit risk analysis, stock market data, and portfolio management. They can reveal hidden correlations among financial instruments or help detect anomalies in transactions.

Engineering and Process Monitoring:

In industrial systems, SOMs assist in fault detection, quality control, and sensor data analysis. By mapping normal and abnormal conditions, engineers can identify irregular behavior early.

Robotics and Control Systems:

SOMs help robots and autonomous systems learn to interpret sensory inputs and navigate environments. They support adaptive control and decision-making by organizing sensory data efficiently.

Text and Document Analysis:

In natural language processing, SOMs are used to cluster documents by topic or meaning, helping organize large collections of text or improve search and recommendation systems. [4]

I use it in education.

3. Summary

Kohonen's Self-Organizing Map (SOM) is a type of unsupervised neural network developed by Finnish scientist Teuvo Kohonen in the 1980s. It is a powerful tool for data visualization, clustering, and dimensionality reduction, especially useful when dealing with high-dimensional datasets. Unlike traditional neural networks that require labeled data, the SOM learns to organize information based purely on similarities between input patterns.

The central idea of a SOM is to map complex, multidimensional input data onto a two-dimensional grid of neurons, preserving the topological relationships within the data. Each neuron in the grid is associated with a weight vector that has the same dimensionality as the input data. During the learning process, the SOM adjusts these weights so that similar inputs activate neurons that are close to each other on the grid. As a result, the map forms an organized representation of the input space. [1]

4. Conclusion

Globally, Kohonen's Self-Organizing Maps serve as a bridge between complex numerical data and human intuition. They are used wherever large datasets need to be explored, simplified, and understood — from scientific research to business intelligence, from bioinformatics to artificial intelligence.

5. References

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