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-TECHNICAL NOTE-

An Intelligent Software for Measurements of Biological Materials: BioMorph

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Abstract

Morphological characters have commonly been used in analysis of biological contexts. Researchers often use the arrangements of morphological landmarks in their studies to extract shape information from any biological materials and need to get bio-measurements using any computer aided tools. Getting landmarks and measurements from biological materials are a time-consuming process. Hence, this study is to provide an intelligent integrated software called BioMorph for morphological measurements. With the BioMorph, Family and species identification of a studied bio-object are automatically be determined using artificial neural network and k-nearest neighbor. The landmarks for discrimination of the bio-objects are automatically found from the given image using artificial neural network. In addition, network analysis methods such as the Euclid network distances, Truss network distances, Triangular network distances, some statistical measures such as mean, standard deviation, minimum and maximum values, etc. and image processing techniques such as image editing, image filtering, image segmentation, etc. are also integrated to the BioMorph.

Keywords:

BioMorph, morphological landmarks, morphological measurements, Family and species identification, image processing.

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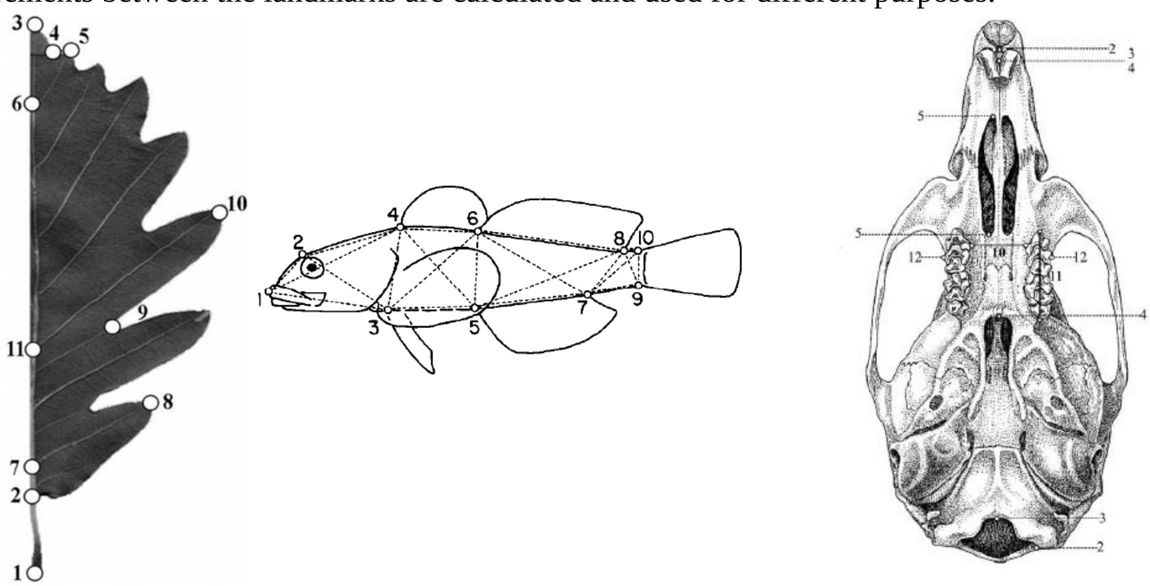
Introduction

Biological researches related to the shape of the object are most common area of applied science. For example, what is the average shape of a bone or organ structure in a population? Morphometry is an area of multivariate statistical analysis which hosts required methods for these questions (Slice, 2007).

Taxonomic classification of an organisms and understanding the biological diversity of species were based on morphological description of the forms. In recent years, the field of analysis of biological objects has undergone a major change. Most of these changes are caused by the improvement and adoption of the anatomical landmarks of Cartesian coordinate analysis methods (Slice, 2007). It is also defined as a new branch that is a techniques used to analyze the diversity of biological shapes combining biometry, computer graphics and statistics tools of geometry (Bookstein, 1997). In biometric methods, the characteristics of biological structures such as landmarks were determined on the surface of objects. These landmarks are determined by the biological properties of objects and are used in the analysis by taking morphological measurements (Hockaday et al. 2000; Parsons et al. 2003; Strauss and Bookstein, 1982; Zelditch et al. 1989; Hossain et al. 2010).

Nowadays, binary distance methods are used for biometrics measurements between identified points on the organism (Parsons et al. 2003). Landmarks for identification of family, species, populations and individuals for different biological substrates as shown in Figure 1. These landmarks are determined according to the biological properties of bio-objects. Morphological measurements between the landmarks are calculated and used for different purposes.



a) b) c)

Figure 1. Biometric measurements for biological objects as leaf from Viscosi and Cardini (2011) (a), and fish from Strauss and Bookstein (1982) (b) and skull from Matteo Breno et al. (2011).

In order to determine the biometric distances, some software are available for biometric measurements such as Matlab or R, which need programming skills, or MorphoJ (Klingenberg, 2011) and MorFISH (Turan and Oral, 2005) which don not need programming skills for user.

The aim of this study is to provide an intelligent integrated software for morphological measurements by which family and species identification of a studied bio-object can automatically be performed and landmarks for discrimination of the bio-objects can automatically be found from the given image. In addition, network analysis methods such as the Euclid network distances, Truss network distances, Triangular network distances and some statistical measures such as mean, standard deviation, minimum and maximum values, etc. are integrated to the software, BioMorph.

In order to determine the biometric measurements, digital photographs from the bio-objects are taken first, then these images are transferred to the computer from which measurements are made using computer aided software. The landmarks were determined on the bio-object surface on digital photo. In order to eliminate the process of marking manual landmarks by scientist for any analysis, an intelligent integrated software for geometric morphometric measurement are developed which help to use in morphological analysis such as biodiversity, systematic, population identification and medical purposes. While using this kind of software with graphical user interfaces, quick and convenient analyses are provided, and the system become flexible to the users to offer automated predictions of landmark of any bio-object. Moreover, the software identify the family or/and species of the bio-object. These two features are the intelligent part of this software, BioMorph.

This study introduces new developed software, BioMorph which is an intelligent tool for biometric measurements to provide user-friendly platform. BioMorph was developed as an application which use the image processing methods, machine learning techniques (Kutlu et al. 2017a, 2017b, 2017c; İşçimen et al. 2014, 2015, 2017a, 2017b, 2017c, 2017d), some statistical methods, etc. k-Nearest Neighbor (k-NN) Classifier and Artificial Neural Network as machine learning techniques were used for classification of family and species of the Bio-objects. Artificial Neural Network was also used for prediction of landmark on the bio-objects (Kutlu and Turan, 2017). The image processing methods were used to apply on images to find objects and extract features of bio-objects developed previously (Kutlu et al. 2017a, 2017b, 2017c; İşçimen et al. 2014, 2015, 2017a, 2017b, 2017c, 2017d). BioMorph is built within the .NET Windows platform, which has wide range of usage in the world.

Machine Learning Techniques

Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is one of the most used machine learning models. It is used for prediction and classification. ANN has input and output layers. The weights of each neuron unit of these layers are trained and produces an output value which is calculated via a function of the sum of its inputs. The output value of each neuron is calculated as

$$y_i = \varphi(\sum x_i w_i)$$

where y_i refers the output, $\varphi(\ \ )$ refers to activation function, w_i refers to weight and x_i refers to input of the ith unit.

The ANN consist of various number of hidden layers with different number of units besides input and output layers. The first layer receives the inputs from outside and transmits to hidden layers. Hidden layers process the data in their turns and transmit to the output layer. Figure 2 shows the basic architecture of an ANN network (Duda et al. 1973; Kutlu et al. 2009).

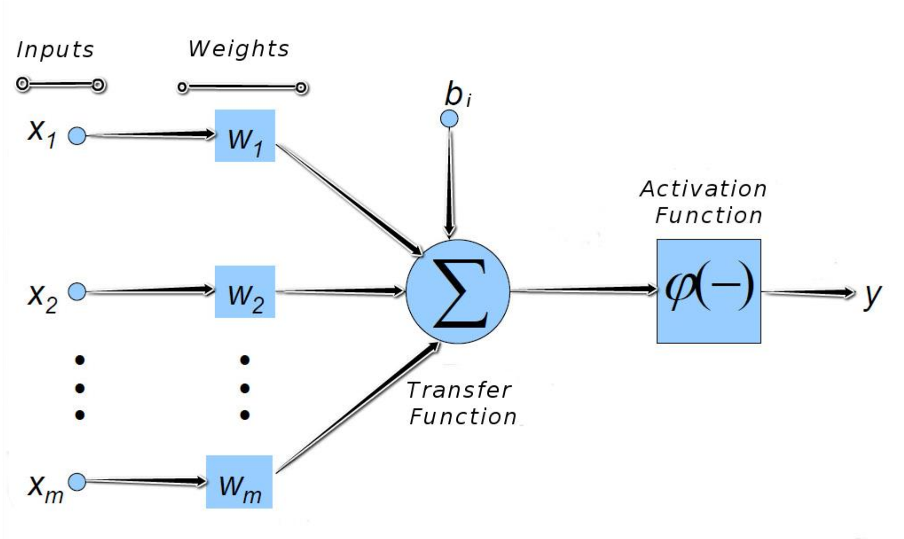


Figure 2. Architecture of the ANN network

k-Nearest Neighbor (k-NN) Classifier

The k-nearest neighbor algorithm (k-NN) is one of the non-parametric technique of machine learning. It is generally used for classifying classes according to nearest training examples in all extracted features. It is a type of sample-based learning. An object is classified by a plurality vote of its neighbors, with the features being assigned to the class most common amongst its k nearest neighbors (Duda et al. 1973).

Image Processing Techniques

Image processing methods are applied on acquired images from which bio-objects are detected. The integrated image processing methods such as noise filter, edge detection, filling operation, opening, closing etc. were applied on the images. In this module, the bio-objects were detected called region of interest (ROI). Then, some features were extracted from the ROI on the images. The extracted features (centroid, area, orientation and extreme points of object are used as input parameter for machine learning techniques.

Statistical Measures

There are different biological measurement methods that can be preferred according to shape of the biological object. Network distance measure is one of the mostly used methods (Kutlu et al. 2017a, 2017b, 2017c) which include the Euclid network distances, Truss network distances, Triangular network distances. In addition, some statistical measure such as mean, standard deviation, minimum and maximum values, etc. can be obtained from the analysis.

Structure of BioMorph

The structure of the BioMorph is shown in Figure 3. It was written in Windows programming environment. The BioMorph has useful modules that have project creation, information entry, image data, image editor, landmark module, recognition module, calculate distance, reporting modules. Each module has many sub-modules.

The module of project creation and information entry use to manage present project or to create new project and to complete information of project. Image file can be loaded form file or captured from camera in image data module. Loaded image can be edited such as cutting, resizing, measuring distance, etc on the bases of user preference. The landmark module is used for pointing landmark over image and adjusting calibration. The BioMorph was gained intelligence to make automatic landmark prediction of some bio-objects (Kutlu and Turan, 2017). The recognition module is used for automatic recognition of family or/and species of bio-object then filling information of object automatically. Some statistical measurement methods were included in modules of Calculation. Different geometric measurement techniques were used in determining the points. The most common ones were the Euclidean Matrix Distance Analysis, truss method and triangulation method, centroid-contour distance (Kutlu et al. 2017a, 2017b, 2017c; İşçimen et al. 2014, 2015, 2017a, 2017b, 2017c, 2017d), According to the properties of biological structure in biometric methods, measurements were calculated by using distance information between landmarks (Hockaday et al. 2000; Parsons et al. 2003; Strauss and Bookstein, 1982; Zelditch et al. 1989; Hossain et al. 2010).

While making calculation, it is important to eliminate any variation resulting from allometric growth (Turan, 1999) by which the allometric transformations were automatically made by BioMorph to eliminate the allometric growth effect. The final module is reporting modules that shows results of all calculations. The researchers can export data as a file such as xls, txt, etc.

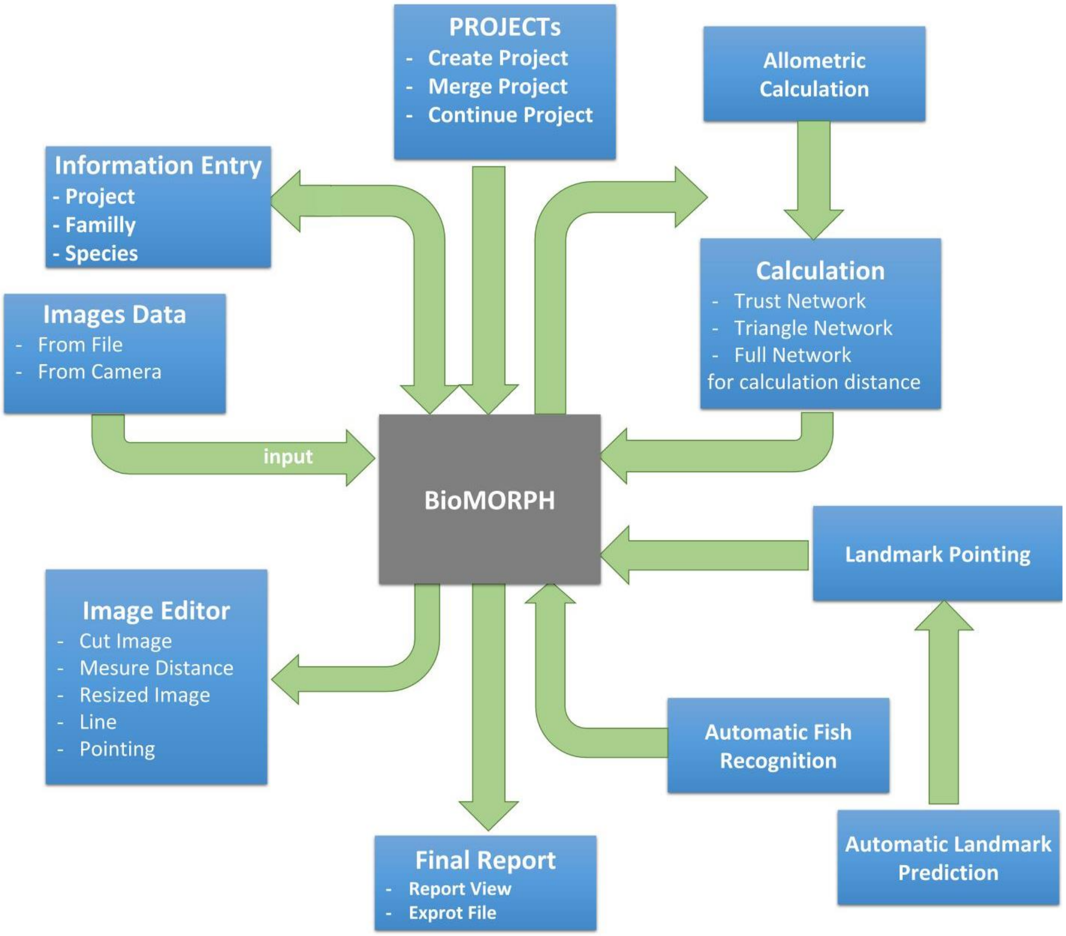
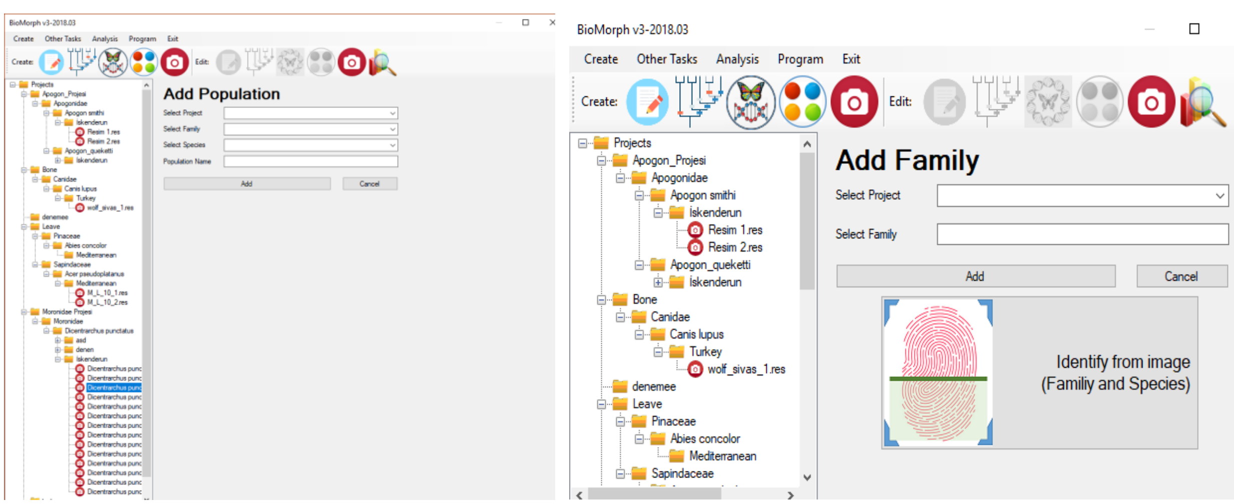
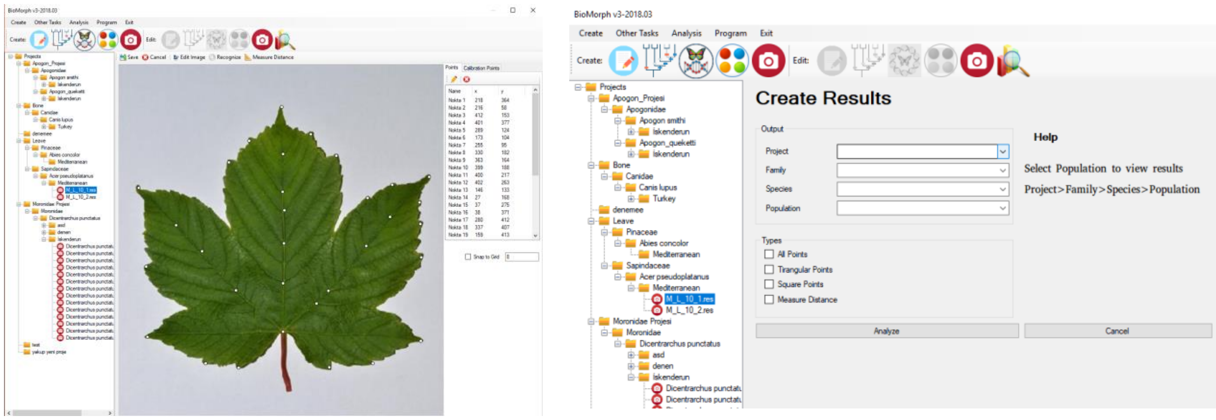


Figure 3. The Modular Structure of the BioMorph.

BioMorph has a user friendly graphical user interfaces which is shown in Figure 4. The researchers can see all created project list at the left side of the interface.



a) **b)**



c) d)

Figure 4. Screen snapshot of user interface of the software BioMorph.

The user interface of the software consist of two sides: left side is the Project Tree tab showing the project and its contents as a tree structure. Right side of the interface display the processed section.

A sample view of the software is shown in Figure 4.a as the list of projects (left side) and view of processed project (right side). The tool bar section of the software is used to create new project and add new family, new species, new population and new sample bio-object. The last button is used to show result of calculation. Moreover, any information on the processed project can be updated. The new process such as adding new family, new population or new sample can be done any time in any project. While adding new family, the software has ability of automatic identification module that is shown in Figure 4.b. Before adding the family, one of sample of bio-object is loaded to identify family and species name using the machine learning techniques as described formerly. The pointing module is used to determine the landmarks of objects (as shown Figure 4.c). It has also some more ability to edit loaded image, measure distance on image and auto-detection of landmarks of object using image processing techniques and machine learning techniques. The report module shows all statistical measurements of any given project as shown Figure 4.d.

In this work, a new intelligent software called BioMorph was developed. It has several advanced tools for analyzing morphological measurements of biologic objects. Using attributes obtained biometric measurements, statistical analysis can be done quickly and save time for the researcher. As a major future work is that it will be transformed into a self-learning system while using BioMorph in any project.

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