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WiseSkin RTD 2013

Automatic Phantom Map Detection

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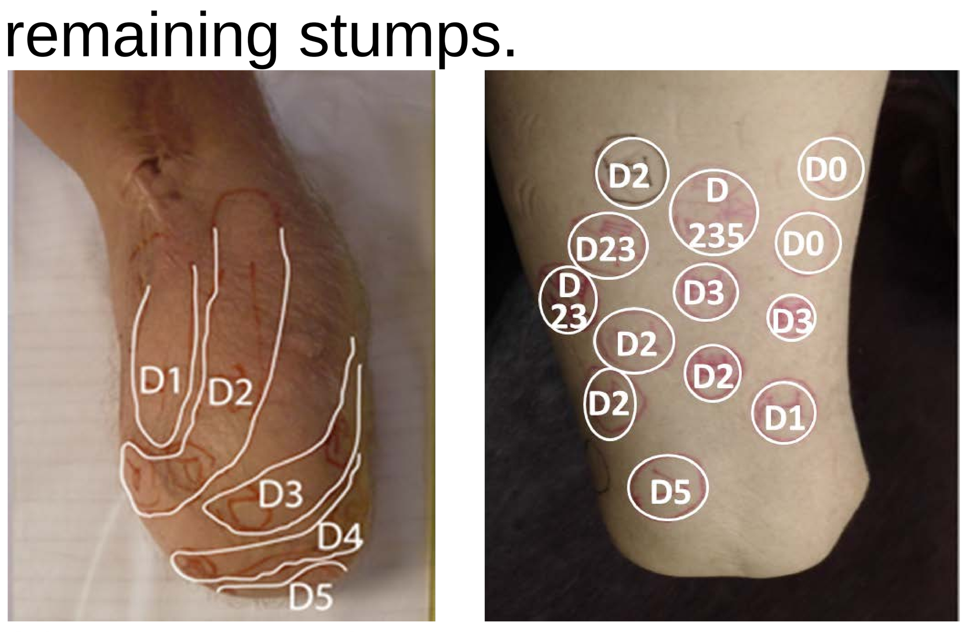
Abstract

There is a need for providing sensory feedback for myoelectric prosthesis users. Providing tactile feedback can improve object manipulation abilities, enhance embodiment of myoelectric prosthetic users and help reduce phantom limb pain. Many amputees have maps of referred sensation from their missing hand on their residual limbs (phantom maps). This skin area can serve as a target for providing amputees with non-invasive tactile sensory feedback. One of the challenges of providing sensory feedback on the phantom map is to determine the accurate boundary of each phantom digit because the distribution of phantom map varies from person to person. In our work, automatic phantom map detection methods based on four decomposition support vector machine algorithms are proposed. The accuracies of proposed algorithms are presented and compared. The results have shown that one-vs-one support vector machine with majority-pooling sampling has the smallest error rate.

Introduction to Phantom Maps

A phantom map is a region on the body that can evoke the sensation of the lost hand. Surveys have shown that 80% to 90% of amputees develop a phantom map immediately after amputation [1]. Most of the time, the hand phantom maps are present on the faces or on the remaining stumps.



(a) A complete phantom map with 5 phantom fingers [3]. (b) An incomplete phantom map with shared phantom finger regions [4].

Fig.1 *Examples of real phantom maps. D1 to D5 represent phantom thumb to phantom little finger, respectively.*

Pressure applied on one area of the phantom map give the sensation that it comes from a specific finger or area of the amputated hand. The shape of phantom maps can also change over time [2].

The dominant theory regarding phantom map formation is the reorganization of the cortical topography. In the Penfield map, the hand area is bordered by the upper arm and the face. When the hand is amputated, these two regions (upper arm and face) invade the area representing the hand, forming the phantom map [2].

The phantom map distribution and sensitivity vary among individuals. To provide efficient stimulation patterns and take full advantage of the high spatial resolution provided by the phantom map, finding the hand phantom map distributions of individual amputees is therefore of great importance.

Automatic Phantom Map Detection

We proposed an automatic phantom map detection method (Fig. 2) based on four decomposition support vector machine (SVM) algorithms: one-vs-one (OVO), one-vs-all (OVA), direct-acyclic-graph (DAG), and binary-tree (BT). Three sampling methods: random sampling (RS), systematic sampling (SS), and majority pooling sampling (MP), were also tested on each algorithm.

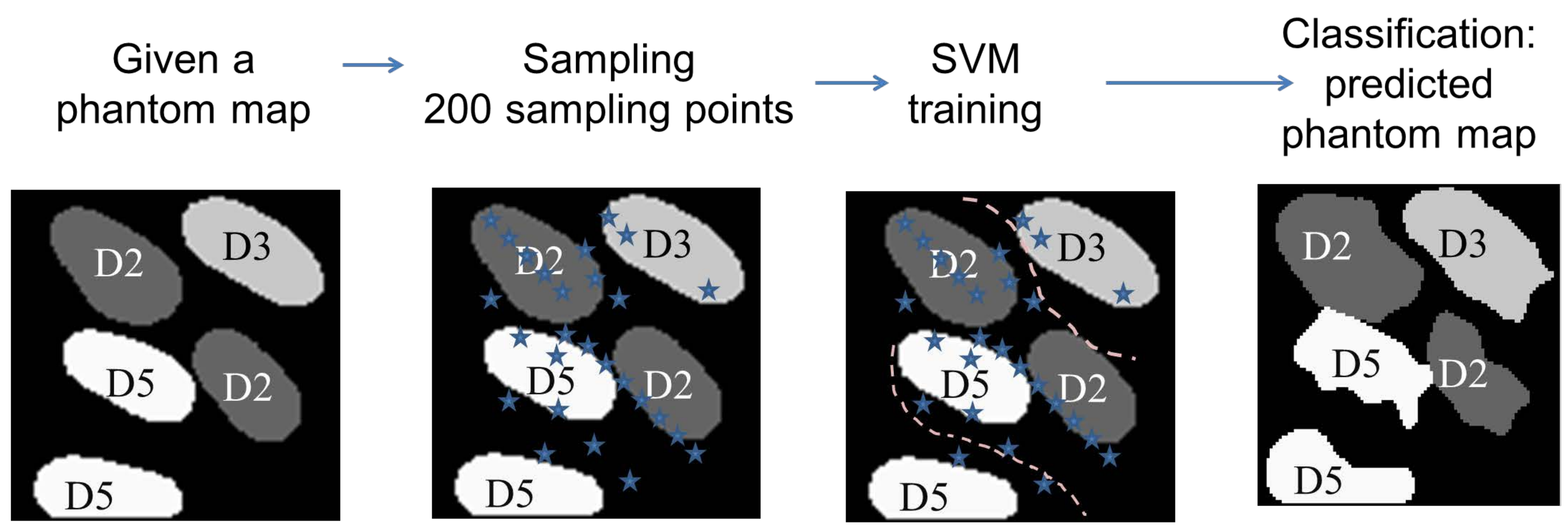


Fig.2 *Automatic phantom map detection method flow diagram using support vector machines (SVMs). D1 to D5 represents phantom fingers from thumb to little finger. Blue stars represent sampling points. Each sampling point represents no phantom sensation , or D1 to D5.*

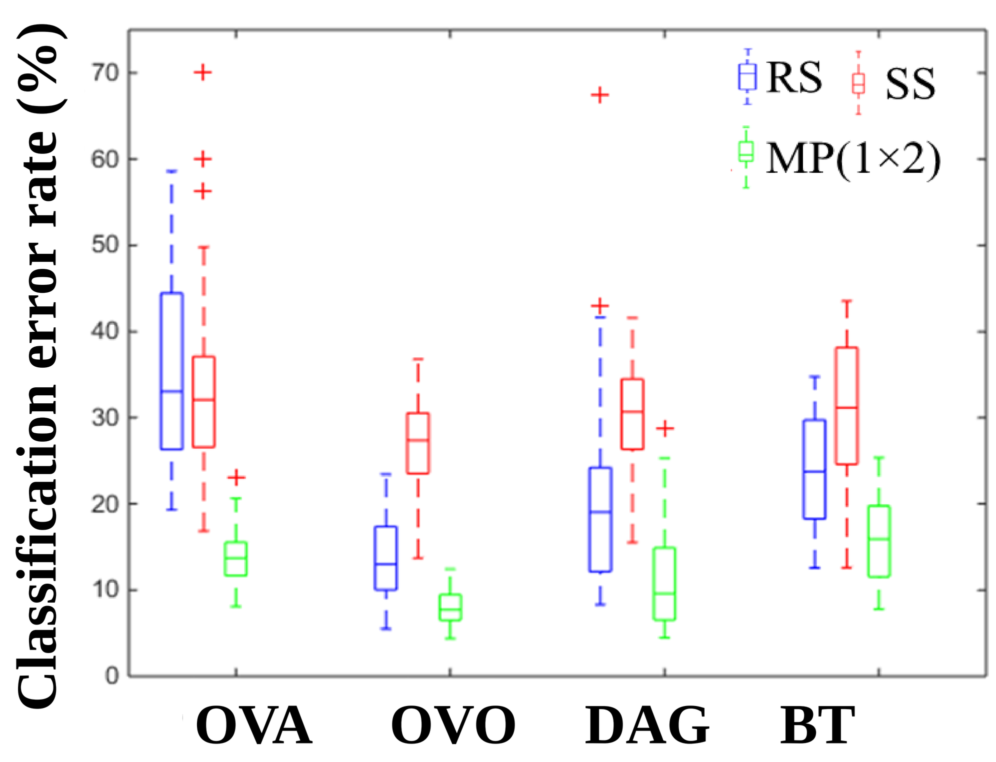


Fig.3 *The box plot of absolute error rate for four SVM algorithms using three sampling methods. Blue represents random sampling (RS). Red represents systematic sampling (SS). Green represents majority pooling (MP) sampling with 1×2 sampling size.*

Each algorithm and each sampling method were tested on 200 generated phantom map models. The sampling time for each method is 200 (8% sampling density).

Their accuracies are compared. The results (Fig.3) show that the combination of OVO-SVM and MP has the smallest absolute error rate (less than 10%).

Conclusion

We have proposed four decomposition multiclass SVMs for automatic phantom map detection and compared the results. To our knowledge, this is the first attempt to apply machine learning algorithms to identify the distribution of phantom maps. The proposed methods provide reliable phantom map shape detection capabilities. They can also be used as a tool to help haptic feedback designers and to track the evolution of phantom maps over time.

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