Comparison of performance of features and mask size in thermographic images of Chiari dogs for syrinx identification (CLMS/COMS)

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Thesis Generic Outlines Submitted

in Partial Fulfilment of the Requirements

for the Degree of Master of Science

in the field of Electrical and Computer Engineering

Graduate School

Southern Illinois University Edwardsville

April, 2018

**ABSTRACT**

Thermographic imaging techniques produce images whose pixel values represent the temperature distribution of an object. This research focuses on the possibilities of features than can be utilized for the classification of syrinx identification (CLMS/COMS). The thermographic image data from 19º C to 40º C was linearly remapped to create images with 256 gray level values. Further, a single band (green band) from these remapped images was extracted to avoid the out of range temperature value in a few images as well as for the fast processing of results. Features were extracted from these images, including histogram and texture features. Various pattern classiﬁcation algorithms have performed well in thermographic image classiﬁcation problems such as k-nearest neighbor, nearest neighbor, softmax scaling, standard normal density normalization and the distance metrics such as Euclidean distance and normalized vector inner product. Experiments with these features are conducted to determine the best set for syrinx identification in canines. Results indicate that…

**ACKNOWLEDGEMENT**

I would like to express my sincere gratitude to Dr. Scott E Umbaugh, who has provided me with guidance, support, advice and help throughout the research work. Also would like to thank Lakshmi Gorantla, Akhila Karlapalem; members of Computer Vision and Image Processing Lab, Southern Illinois University Edwardsville for their continuous help and advice they provided in times of need.

**Gita Pant**

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# INTRODUCTION

Chiari malformation is a condition where the cerebellum of the brain is structurally defective and has highly heritable neurological disorders. These neurological disorders result from different malformations of the occipital bone of the canine skull. For this reseach Chiari malformation was identified in the breed of Cavalier King Charles Spaniels. According to the resources, almost 95% of Cavalier King Charles Spaniels have Chiari malformation, however any type of symptoms can be found in only one quarter of these dogs. The cause of Chiari-like malformation is not fully understood, but it is thought to be hereditary in some breeds. A Chiari-like malformation (caudal occipital malformation syndrome) is a condition that retards the growth of the hollow places in dog’s skull, making the posterior fossa too small or deformed. This causes syringomyelia, which is the compression of the brain. Researchers estimate that more than 50% of cavaliers may have syringomyelia. The severity and extent of syringomyelia also appears to get worse in each succeeding generation of cavaliers. It is worldwide in scope and not limited to any country, breeding line, or kennel, and experts report that it is believed to be inherited in this breed of dog. This disease not only affects thousands of dogs, but over three hundred thousand children are affected yearly with a similar condition. Therefore, canines are an appropriate model for the treatment of the human condition. In the veterinary field, the thermographic images of canines of the breed Cavalier King Charles Spaniel are taken into consideration to investigate the extent of Chiari malformation or COMS pathology. Several patterns of the images are used to develop pattern classification algorithm to classify absent, mild, moderate and severe classes of the pathology which makes it easier to identify the normal and abnormal dogs. In this study, the thermographic images of canines of the breed Cavalier King Charles Spaniel are used to investigate syringomyelia pathology.

# LITERATURE REVIEW

## Motivation and Background

Veterinary medical practice uses several imaging techniques such as radiology, computed tomography (CT), and magnetic resonance imaging (MRI) for diagnosis. But, harmful radiation involved during imaging, expensive equipment setup and excessive time consumption are major drawbacks of these techniques [1]. Medical science considers temperature as one of the major health indicators. As per medical thermography, the presence of disease may alter the thermal patterns of the skin surface [2] and here we investigate the potential correlation between skin temperature patterns and certain pathological conditions. Thermographic imaging captures infrared radiation to produce images whose pixel values are mapped into appropriate colors that represent the temperature distribution. It will capture the thermal patterns on the body surface which can indicate various underlying pathologies. With thermography, the imaging process is similar to taking a photograph with a standard camera, which alleviates the time and sedation issue. Also, it addresses the shortcomings of the existing imaging systems as it is a noninvasive technique that avoids harmful radiation and is less expensive in terms of cost and time [3].

Because of its noninvasive and inexpensive nature, the use of thermographic imaging, or infrared imaging, has been increasing as a clinical diagnostic tool in both veterinary and human medicine in recent years. Several research and development was continuously done in thermographic images of canines to investigate Chiari malformation, or COMS pathology. In the past, pattern classification algorithm was developed for severe, moderate and mild classes of the pathology for cerebellar herniation and kinking of medulla. The front of head (A1), and top of head (A1D) images were used. After an initial set of experiments, K-nearest neighbor with K=3, distance metric: Euclidean for classification method and distance metric, histogram and texture features and soft-max with r=1 for data normalization method was determined to be the most useful for the final experiments. With this set of parameters, it was determined that the 89% and 97% classification success indicates that the top and front of head are the most useful for differentiation of the two classes, and similarly the texture correlation and histogram energy features appear the most predictive [4].

For this particular research, unlike the number and type of classes used in previous research studies, the image set is classified into *syrinx* and *no syrinx* classes to investigate the extent of syringomyelia in canines. For the previous research the images were mapped to only 18 colors, corresponding to human visual temperature perception – red is hot, blue is cold, etc. Here, the actual temperature information is extracted, and the range from 19° C to 40° C are linearly remapped into 256-gray levels, with the help of COMPIX software.

# MATERIALS AND METHODS

## Materials

### Thermographic Images

The Meditherm thermographic images are used for the research for analysis of syringomyelia in canines. These images are provided by the Long Island Veterinary Specialists (LIVS). The images are divided into two categories: *Syrinx* and *NoSyrinx* classes for the pathology. Masks for all the images to mark the region of interest have been also collected from LIVS.

### Compix WINTES2 software

The Compix WINTES2 software has been used which allowed us to save the captured image with different color maps: 18-color image, 256-level grayscale image, 256-color image, isotherm map and medical map. For this particular study, the 18 color Meditherm images are remapped to 256-graylevel image from 19° C to 40° C, as this temperature range covers the entire range of the body temperature of canines.

### Computer Vision and Image Processing Tools (CVIPtools)

CVIPtools was developed at the Computer Vision and Image Processing (CVIP) laboratory at Southern Illinois University Edwardsville (SIUE) which consists of image processing libraries with a large number of CVIP functions. The CVIPtools feature functions such as histogram, spectral and texture features were used in this research.

### CVIP-FEPC (Feature Extraction and Pattern Classification)

CVIP-FEPC [CVIP-FEPC; 2018] is used to develop algorithms for feature extraction and classification. CVIP-FEPC allows these algorithms to be saved as eXtensible Markup Language (XML) algorithm file which includes features, data normalization methods, and classification methods. After an algorithm has been setup and saved in an XML file, it can be used as input to the clinical application software.

## 3.2 Experimental Methods

The goal of this research is to find the methods and features which give the best results for identifying syringomyelia in Chiari dogs. The initial masks used included peripheral areas such as muzzle, ears, etc., and a number of experiments were performed using these masks, later referred to as the large masks. During discussion of these results with the domain experts from LIVS a question arose regarding the inclusion of the peripheral areas and how that may affect the experimental outcome. Therefore, it was decided that we should generate smaller masks that did not include the peripheral areas and perform experiments comparing results with the small and large masks. A series of experiments were defined to help find the best way to identify syrinx in the Chiari dogs; now including not just various features and pattern classification methods, but also two types of masks – small and large. The entire process consists of numerous individual steps and procedures to follow.

### Compare results from different set features with large mask

The first experiment for this research was to find the features which provide the best result. To compare combinations of features, a total of 195 images with top of head (A1D) view and the initial (large) masks were used. The images are divided into two classes: Syrinx = 137 and NoSyrinx = 58. A series of experiments was performed with different combination of features, including histogram and Laws texture features, texture and Laws texture features with varying texture distance. The Laws texture features were also selected into two groups to verify which group provided the best result.

### Comparison of small and large mask

The reason to create a smaller mask rather than the initial (large) mask was that it does not include peripheral areas such as muzzle, ears, etc. We considered a total of 93 images divided into two classes; Syrinx = 48 and NoSyrinx = 45.

### Comparison of Laws texture features with small mask

This comparison is done to find out the best set of Laws texture features. The total 15 Laws texture features are selected based on previous experiments and divided into three categories [5]. We considered total 93 images dividing into two classes; Syrinx = 48 and NoSyrinx = 45.

# RESULTS AND DISCUSSION

## Comparison of small and large mask

The first phase of the experiments was to compare the mask size of those thermographic images. The smaller masks were created by LIVS research coordinator Joseph Sackman and the images were randomly picked. We considered the same images for large and the smaller masks in order to see which of them performs better. The experiments included the following:

Classification Methods

* K-Nearest Neighbor with K = 3
* Nearest Neighbor

Distance Metrics

* Euclidean Distance
* Normalized Vector Inner Product

Features

* Histogram features: Mean. Standard deviation, Skew, Energy and Entropy
* Texture features: Energy, Inertia, Correlation, Inverse difference, and Entropy. The texture distance of 6, 7, 8 and 9.

Data Normalization Method

* Soft-max with r = 1
* Standard Normal Density Normalization

Experiments for the 8,184 parameter combinations were performed. Results are tabulated for the best 10 results and statistics for all 8,184 experiments in the next two sections.

Here, the top 10 best results from each texture distance (6,7,8,9) are selected, and the averages and variances are calculated for those 10.

**Texture distance = 6; the 10 best results**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 63 | 66.67 | 68.75 |
|  | 63 | 66.67 | 68.75 |
|  | 61 | 57.78 | 72.92 |
|  | 61 | 60 | 70.83 |
|  | 61 | 60 | 70.83 |
|  | 61 | 64.44 | 66.67 |
|  | 61 | 64.44 | 66.67 |
|  | 61 | 66.67 | 64.58 |
|  | 61 | 68.89 | 62.5 |
|  | 61 | 68.89 | 62.5 |
| *average* | *61.4* | *64.445* | *67.5* |
| *Std. dev* | *0.843274043* | *3.920122589* | *3.568121199* |
| **Small mask** | | | | |
|  | | | | |
| |  |  |  |  | | --- | --- | --- | --- | |  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** | |  | 65 | 57.78 | 81.25 | |  | 64 | 53.33 | 83.33 | |  | 64 | 68.89 | 68.75 | |  | 64 | 71.11 | 66.67 | |  | 64 | 73.33 | 64.58 | |  | 63 | 53.33 | 81.25 | |  | 63 | 60 | 75 | |  | 63 | 62.22 | 72.92 | |  | 63 | 64.44 | 70.83 | |  | 63 | 66.67 | 68.75 | | *average* | *63.6* | *63.11* | *73.333* | | *Std. dev* | *0.699205899* | *7.043272598* | *6.646056558* | | | | | |
| *For this case, small masks are better because the average of total results are higher with small masks rather than large masks, and the best success rate for the syrinx class is better by over 10%.* | | | | |

**Texture distance = 7; the 10 best results**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 71 | 75.56 | 77.08 |
|  | 65 | 71.11 | 68.75 |
|  | 63 | 71.11 | 64.58 |
|  | 63 | 73.33 | 62.5 |
|  | 62 | 68.89 | 64.58 |
|  | 61 | 60 | 70.83 |
|  | 61 | 64.44 | 66.67 |
|  | 60 | 51.11 | 77.08 |
|  | 60 | 57.78 | 70.83 |
|  | 60 | 57.78 | 70.83 |
| *average* | *62.6* | *65.111* | *69.373* |
| *Std. dev* | *3.373096171* | *8.117731552* | *5.011568949* |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 64 | 60 | 77.08 |
|  | 64 | 64.44 | 72.92 |
|  | 64 | 66.67 | 70.83 |
|  | 64 | 75.56 | 62.5 |
|  | 63 | 57.78 | 77.08 |
|  | 63 | 62.22 | 72.92 |
|  | 63 | 62.22 | 72.92 |
|  | 63 | 68.89 | 66.67 |
|  | 63 | 68.89 | 66.67 |
|  | 62 | 62.22 | 70.83 |
| *average* | *63.3* | *64.889* | *71.042* |
| *Std. dev* | *0.674948558* | *5.218244596* | *4.652119708* |

*For this case, the average values for the small masks are better except for the NoSyrinx class which is more only by about 0.2%. However, overall the #correct results indicate that the small masks work better.*

**Texture distance = 8; the 10 best results**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 61 | 60 | 70.83 |
|  | 61 | 64.44 | 66.67 |
|  | 61 | 66.67 | 64.58 |
|  | 61 | 66.67 | 64.58 |
|  | 60 | 51.11 | 77.08 |
|  | 60 | 57.78 | 70.83 |
|  | 60 | 60 | 68.75 |
|  | 60 | 60 | 68.75 |
|  | 60 | 62.22 | 66.67 |
|  | 59 | 62.22 | 64.58 |
| *average* | *60.3* | *61.111* | *68.332* |
| *Std. dev* | *0.674948558* | *4.596683466* | *3.90318901* |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 64 | 73.33 | 64.58 |
|  | 63 | 62.22 | 72.92 |
|  | 63 | 66.67 | 68.75 |
|  | 63 | 71.11 | 64.58 |
|  | 62 | 57.78 | 75 |
|  | 62 | 60 | 72.92 |
|  | 62 | 62.22 | 70.83 |
|  | 62 | 62.22 | 70.83 |
|  | 62 | 64.44 | 68.75 |
|  | 62 | 64.44 | 68.75 |
| *average* | *62.5* | *64.443* | *69.791* |
| *Std. dev* | *0.707106781* | *4.79986354* | *3.438896625* |

*For this case, the averages are higher for small masks and the variances (comparing small and large) are similar. Overall, the success rate from small masks has slightly better performance than the large masks.*

**Texture distance = 9; the 10 best results**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 65 | 73.33 | 66.67 |
|  | 62 | 66.67 | 66.67 |
|  | 61 | 60 | 70.83 |
|  | 61 | 64.44 | 66.67 |
|  | 60 | 51.11 | 77.08 |
|  | 60 | 57.78 | 70.83 |
|  | 60 | 62.22 | 66.67 |
|  | 60 | 62.22 | 66.67 |
|  | 60 | 64.44 | 64.58 |
|  | 60 | 66.67 | 62.5 |
| *average* | *60.9* | *62.888* | *67.917* |
| *Std. dev* | *1.595131482* | *5.93020292* | *4.071393564* |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **# Correct (out of 93)** | **%Success NoSyrinx Class** | **%Success syrinx Class** |
|  | 64 | 64.44 | 72.92 |
|  | 64 | 68.89 | 68.75 |
|  | 63 | 62.22 | 72.92 |
|  | 63 | 62.22 | 72.92 |
|  | 63 | 64.44 | 70.83 |
|  | 63 | 66.67 | 68.75 |
|  | 63 | 66.67 | 68.75 |
|  | 63 | 73.33 | 62.5 |
|  | 62 | 60 | 72.92 |
|  | 62 | 60 | 72.92 |
| *average* | *63* | *64.888* | *70.418* |
| *Std. dev* | *0.666666667* | *4.164097341* | *3.374926501* |

*For this case, the small mask averages are better than the large mask averages, and standard deviations are smaller. Taken together this indicates the small masks are better.*

Here, we calculated the statistics, average and standard deviation, for all 8,184 permutations of various parameters (each permutation one experiment) to compare the results from both mask types with all four texture distances.

**Texture Distance = 6; statistics for all 8,184 experiments**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 44.87268 | 46.16405547 | 50.20597996 |
| std. deviation | 4.995432 | 7.989716933 | 7.163007577 |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 49.62793 | 49.13213954 | 57.3301063 |
| std. deviation | 5.130963 | 7.686609736 | 7.433693993 |

*The average and the standard deviation for small mask is higher than the large mask.*

**Texture Distance = 7; statistics for all 8,184 experiments**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 43.92399804 | 44.19868891 | 50.07201246 |
| std. deviation | 5.082729091 | 8.47017473 | 7.294041848 |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 48.62536657 | 47.16803152 | 57.08268084 |
| std. deviation | 4.699569715 | 7.166630303 | 7.152635099 |

*The average for small mask is higher than the larger mask. For standard deviation, there is a small difference.*

**Texture Distance = 8; statistics for all 8,184 experiments**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 43.47104106 | 44.38846041 | 48.95039467 |
| std. deviation | 4.865980195 | 7.782756489 | 7.1026793 |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 49.20026882 | 47.14095186 | 58.305815 |
| std. deviation | 4.593812279 | 7.080030163 | 7.016455975 |

*The average values for small mask is better than the large mask and the variances are similar.*

**Texture Distance = 9; statistics for all 8,184 experiments**

**Large mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 43.92302053 | 45.27063661 | 49.06501711 |
| std. deviation | 4.806375645 | 7.140818335 | 7.229278236 |

**Small mask**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Overall out of 93** | **NO syrinx success %** | **Syrinx success %** |
| average | 48.67619746 | 47.52271139 | 56.85611193 |
| std. deviation | 4.666409607 | 6.968170579 | 7.049295129 |

*The average values for small mask is better than the large mask, with similar variances.*

The top 10 best results with texture distances of 6 and 9 indicates the small masks are better than the large masks. With texture distances of 7 and 8, the results are close but the small masks have slightly better results. Comparing the overall 8,184 experiments, the average results indicate the small masks are better than the large masks and the similar variances indicate the validity of the mean comparison.

# SUMMARY AND CONCLUSION

Thermographic imaging techniques produce images whose pixel values represent the temperature distribution of an object. These thermographic images of Chiari dogs provided by Long Island Veterinary Specialists (LIVS) are considered in this study for syringomyelia identification. The primary aim of this study focuses on the performance of combination of features, pattern classification parameters and the mask size that provide optimal results. The results obtained from the experiments comparing mask size suggests that the small masks give better result. Other experiments are ongoing to determine the best features that can be used in further study.

# FUTURE ENHANCEMENT

As the performance of small mask is better than the large mask, the addition of new features should be used for experiments using small mask in future. The current experiments are done on the small set of images. Thus, further investigation can be done in large set of images.

# 7. REFERENCES

|  |  |
| --- | --- |
| [1] | E. Y.-K. Ng, "The review of thermography as promising non-invasive detection modality for breast tumor," *International journal of thermal science, 850-851,* 2008. |
| [2] | D. J. Marino and C. A. Loughin, "Diagnostic imaging of the canine stiﬂe: a review," Veterinary surgery, vol. 39, no. 3, pp. 284–295, 2010. |
| [3] | V. Redaelli, B. Tanzi, F. Luzi, D. Stefanello, D. Proverbio and L. a. D. G. M. Crosta, "Use of thermographic imaging in clinical diagnosis of small animal: preliminary notes," in *Annali dell'Istituto Superiore di Sanità 50(2), 140-146,*, Italy, 2014. |
| [4] | S. E. Umbaugh, P. Solt and H. K. Akkineni, "Veterinary Thermographic Image Analysis," January 22,2010. |
| [5] | K. H. Poudel, "Laws Texture Features Implementation and Integration in CVIP-FEPC," 2014. |