Acceleration of Tear Film Map Definition on Multicore Systems

Jorge González-Domínguez*, Beatriz Remeseiro**,
María J. Martín*

*Computer Architecture Group, University of A Coruña, Spain
{jgonzalezd,mariam}@udc.es
**INESC TEC - INESC Technology and Science
bremeseiro@fe.up.pt

International Conference on Computational Science
ICCS 2016

UNIVERSIDADE DA CORUÑA

INESCTEC

1. Introduction
   - Motivation
   - Background
2. Parallel Implementation
3. Experimental Results
4. Conclusions

UNIVERSIDADE DA CORUÑA

INESCTEC

Dry eye syndrome

- Multifactorial disease of the tears and the ocular surface
- Common complaint among middle-aged and older adults
- It affects a wide range of population:
  - Between 10 % and 20 % of the population
  - May be raised up to 33 % in Asian populations
- Cause of great discomfort and frustration
- Require treatment with a significant potential cost

Diagnosis of dry eye syndrome

1. Acquiring an input image of the tear film lipid layer with the Tearscope Plus
2. Definition of tear film map
   - Illustrate the distribution of different patterns in the image
   - Five possible interference patterns
   - Different regions of the image might be associated to different patterns
3. Medical experts analyze the tear film map and provide a diagnosis

State of the art

- *B. Remeseiro, A. Mosquera, and M. G. Penedo. CASDES: a Computer-Aided System to Support Dry Eye Diagnosis Based on Tear Film Maps. IEEE Journal of Biomedical and Health Informatics, 2015.*
- Clinics in Spain, Portugal and UK
- Accuracy over 90 %
  - Comparison with manual annotations by four experts
- Runtime around tens of minutes
  - Medical doctors require shorter times

Goal of this work

- Acceleration of the definition of tear film maps
- Exploitation of multicore systems → Very popular
- Increase adoption of the method among medical doctors

State of the art

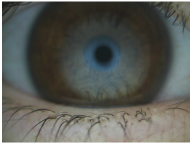
- *B. Remeseiro, A. Mosquera, and M. G. Penedo. CASDES: a Computer-Aided System to Support Dry Eye Diagnosis Based on Tear Film Maps. IEEE Journal of Biomedical and Health Informatics, 2015.*
- Clinics in Spain, Portugal and UK
- Accuracy over 90 %
  - Comparison with manual annotations by four experts
- Runtime around tens of minutes
  - Medical doctors require shorter times

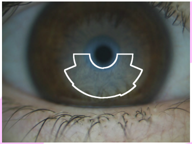
Goal of this work

- Acceleration of the definition of tear film maps
- Exploitation of multicore systems → Very popular
- Increase adoption of the method among medical doctors

General algorithm

1. Determine the relevant areas of the image to analyze
   - Region of interest (ROI)
   - Area around the pupil
2. Preprocessing and obtain parameters for region growing
   - Feature vectors
   - Homogeneity criterion
3. Seeded region growing
   - 95 % of the total time
4. Print the final output with one color for each region





Seeded region growing

1. Automatic generation of the initial seeds
   - Using the feature vectors and class-membership probabilities
   - Each seed is labeled with a predominant pattern
   - First points of the regions
2. For each seed (initial region) calculate the points that belong to that region
   - Analyzing the neighbors of a growing region
   - For each new point analyzed we must calculate several properties
   - Different cost depending on the final region size (number of analyzed points)

Additional information in the manuscript

1. Introduction
2. Parallel Implementation
   - Full Implementation
   - On-demand Implementation
3. Experimental Results
4. Conclusions

Parallel versions

- Full implementation
- On-demand implementation
    - Static distribution
    - Dynamic distribution

Characteristics overview

- Multithreaded support of C++11 standard
- Inputs: Tear film image and number of threads
- Output: Image with tear film map
    - Same accuracy as original algorithm

- Cost of original region growing: calculation of feature vectors and probabilities for all neighbors
- Additional initial step that calculates properties of all points
  - Parallel $\rightarrow$ Threads work over different points
- Region growing very fast
  - Sequential
  - Properties directly obtained from memory
- Strength: No dependencies among threads
- Drawback: Work over not necessary points (do not belong to any region and seed)

Modified general algorithm

1. Determine the relevant areas of the image to analyze
   - Region of interest (ROI)
   - Area around the pupil
2. Preprocessing and obtain parameters for region growing
   - Feature vectors
   - Homogeneity criterion
3. Calculate properties of all points
4. Seeded region growing
5. Print the final output with one color for each region

- Cost of original region growing: calculation of feature vectors and probabilities for all neighbors
- Additional initial step that calculates properties of all points
  - Parallel $\rightarrow$ Threads work over different points
- Region growing very fast
  - Sequential
  - Properties directly obtained from memory
- Strength: No dependencies among threads
- Drawback: Work over not necessary points (do not belong to any region and seed)

- No additional step
- Parallelism included in the region growing itself
- Initial seeds assigned to threads
  - Whole computation of the seed performed by one thread
- Strength: Only work with interesting points (within any region)
- Drawback: Unbalanced workload as seeds involve different number of points (region size)

Static distribution

- State of the art for mutithreaded region growing
- Known at the beginning of the execution
- Similar number of seeds per thread
- Bad workload balance

Dynamic distribution

- Only one seed initially assigned to each thread
- Seed finished $\rightarrow$ Look for the next not computed seed
- Shared variable to indicate the next seed to compute
- Better workload balance
- Synchronization among threads to access the shared variable

UNIVERSIDADE DA CORUÑA

INESCTEC TECHNOLOGY & SCIENCE ASSOCIATE LABORATORY PORTUGAL

Sandy-Bridge platform

- Two 8-core Intel Xeon E5-2660 Sandy-Bridge processors
- 16 cores at 2.20GHz
- 64GB RAM
- GCC version 4.9.2 (-O3)

Opteron platform

- Four 16-core AMD Opteron 6272 processors
- 64 cores at 2.10GHz
- 128GB RAM
- GCC version 4.8.1 (-O3)

VOPTICAL_R dataset

- 50 images of 1024x768 pixels
- Variable runtime
  - How much do the regions grow?
  - How large is the ROI?

Sandy-Bridge platform (time in minutes)

	Full			On-demand static			On-demand dynamic		
Th ↓	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
1	52.10	87.98	25.68	12.73	36.73	2.98	12.73	36.73	2.98
2	26.16	44.55	12.79	7.08	18.75	1.56	6.50	18.56	1.53
4	13.21	22.71	6.38	4.09	11.00	0.97	3.51	10.51	0.87
8	6.72	11.85	3.21	2.57	7.06	0.78	2.01	5.85	0.59
16	3.73	6.70	1.79	1.64	4.18	0.75	1.28	3.17	0.42

Opteron platform (time in minutes)

	Full			On-demand static			On-demand dynamic		
Th ↓	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
1	96.07	163.75	46.70	20.26	58.32	4.60	20.26	58.32	4.60
2	47.90	82.21	23.16	11.08	29.96	2.29	10.17	28.94	2.33
4	23.88	41.66	11.27	6.24	19.68	1.52	5.29	15.44	1.32
8	11.67	21.45	5.42	3.67	9.54	1.14	2.93	9.25	0.86
16	5.67	10.72	2.68	2.26	6.09	0.64	1.71	4.52	0.63
32	2.90	5.51	1.39	1.53	3.48	0.60	1.20	2.80	0.60
64	2.65	5.06	1.28	1.42	3.43	0.60	1.20	2.79	0.60

UNIVERSIDADE DA CORUÑA

INESCTEC
TECHNOLOGY & SCIENCE
ASSOCIATE LABORATORY
PORTUGAL

Contributions

- First parallel algorithm for generating tear film maps
- Use of multiple threads for region growing step
- First experimental evaluation of multithreaded region growing with up to 64 cores
- On-demand approach with dynamic distribution obtains best performance
  - Previous parallel region growing algorithms always static
- Average time reduced from 12.73 and 20.26 to less than two minutes
- Heaviest images only need 3.17 and 2.79 minutes (36.73 and 58.32 the original)
- Future work: extension for multicore clusters (MPI)

Acceleration of Tear Film Map Definition on Multicore Systems

Jorge González-Domínguez*, Beatriz Remeseiro**, María J. Martín*

*Computer Architecture Group, University of A Coruña, Spain
{jgonzalezd,mariam}@udc.es
**INESC TEC - INESC Technology and Science
bremeseiro@fe.up.pt

International Conference on Computational Science
ICCS 2016

COMPUTER ARCHITECTURE GROUP
UNIVERSITY OF A CORUÑA
GAC.UDC.ES
UNIVERSIDADE DA CORUÑA

INESCTEC
TECHNOLOGY & SCIENCE
ASSOCIATE LABORATORY
PORTUGAL