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Ground-truth creation for end-user trainable machine vision systems

Applied to antibiotic disc print reading

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This research is part of a project for BD Kiestra

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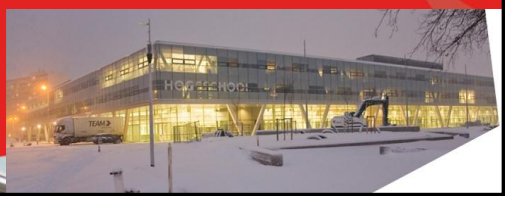
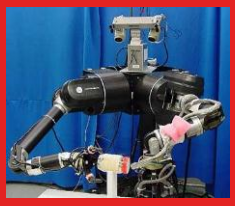
NHL University of Applied Sciences

Institute: Techniek
Department: Engineering
Center of Expertise Computer Vision
Bachelors
Information Science
Technical Information Science
Electrical Engineering
Mechanical Engineering



Computer Vision

Automation of visual inspections



Cameras


Area scan


Thermo


3D / Time Of Flight


3D / Stereo


Intelligent

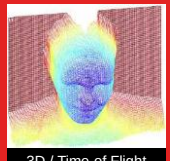

Line scan

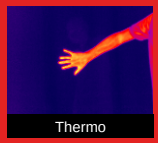

Surround

Images


Surround


3D / Stereo


3D / Time of Flight


Thermo

Illumination

Lenses

Ringlight

Backlight

Dome

NHL COMPUTER VISION

NHL Center of Expertise Computer Vision

Background:
- Founded 1996
- 4,5 FTE
- 170 industrial projects, > 3.000.000 euro
- Course Computer Vision

Goals
- Extending knowledge and expertise
- Professional networks and market exploration
- Transfer of knowledge to companies
- Education

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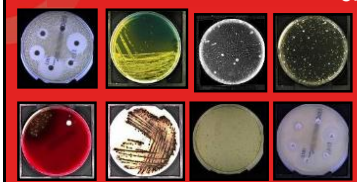
Microbiology



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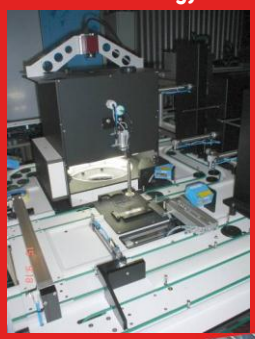
Microbiology



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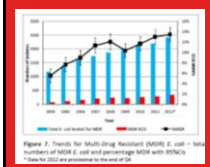
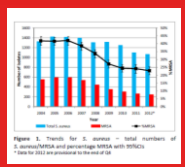
Pilot application

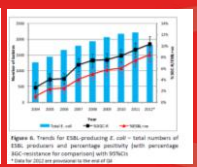
- Antibiotic Susceptibility Testing.
  - EARS-Net Report for Quarter 4 2012 [1]



Multi drug resistant (MDR)
E. coli



Methicillin resistant
Staph. aureus
MRSA



ESBL producing
E. coli

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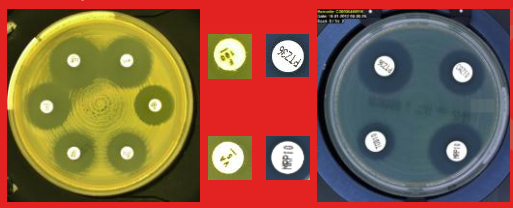
Pilot application

- Antibiotic Susceptibility Testing:
  1. Diameter of circular zone determines antibiotic sensitivity
  2. Disc print determines antibiotic



Disc print reading is used as a pilot application

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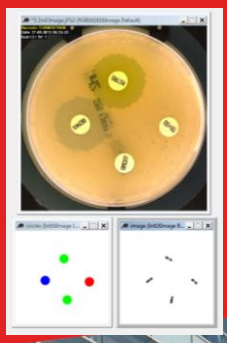
Blob matching demo



Motivation / Problem definition

Domain expert != Technical expert

- Two strategies for automating classification applications:
  1. Domain expert trained in technical knowledge
     - End-user software engineering (EUSE) [2]
       - Application Specific Language
       - Programming by Example
       - Visual Programming
       - Natural Programming
  2. Technical expert trained in domain knowledge
     1. Investigate demands
     2. Software design
     3. Train algorithms on ground-truth input

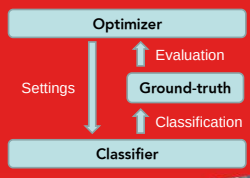
Aims and Objectives

- End-user trainability
  - Minimize domain knowledge needed by technology expert
  - Minimize technical knowledge needed by domain expert
  - Maximize classifier's performance
- Roles
  - Technical expert: Limit the solution space by specifying *which* classification algorithm to use
  - Domain expert: Make a ground-truth to specify *what* the system needs to do
  - Artificial Intelligence: Find technical parameters evaluated using only the ground truth to determine *how* this is done.

Optimization framework

- Classifier is used to classify objects
- Optimizer is used to converge to more optimal classifiers
- Ground-truth is used to evaluate classifiers

General framework:



Rules for an end-user trainable machine vision system

- Steps by the *technical expert*:

1. Choose algorithms using the following criteria:
   a) Few parameters, to limit possible solutions.
   b) Robust, which limits dependence on parameters.
   c) Heuristics, determine rules for setting the parameters.
   d) Prior knowledge, to limit solution space.
2. For remaining parameters choose an optimization method with:
   a) Few parameters and for all others use heuristics.

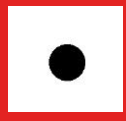
- Steps by the *domain expert*:

1. Create a ground-truth.
   a) Entice the end-user, to minimize errors.

Technical expert: Disc print segmentation

Original image

- Robust



Hough circle Transform [3]

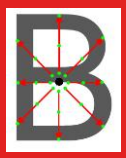
- Few parameters
- Heuristics

Local adaptive threshold [3]

Technical expert: Disc print classification using the Blob Matcher

- Uses a single pattern as a model for the rest
- Exterior matching using the contour (less accurate, faster)
- Interior matching by sampling points (more accurate, slower)
- Matching error $e_{total} = e_{exterior} * f + e_{interior}$

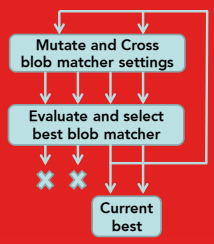
- example: nr of rotations = 8
  fill sample size = 3



- Prior knowledge

Technical expert: Blob Matcher optimization using a Genetic Algorithm

- Optimization algorithm based on natural selection [4]



- Few parameters
- Heuristics

Domain expert: Ground-truth creation using Surprise-Explain-Reward

- Making ground-truth more appealing:
  1. Tedious work
  2. Human error
  3. Inter-operator bias
  4. Intra-operator bias

- EUSE [2]
  1. *Surprise* end-user
  2. *Explain* what this means
  3. *Reward* the end-user

Entice the end-user

Demostration ground tool

Ground-truth creation using Surprise-Explain-Reward

1. End-user specifies disc print annotation
2. Current partial ground-truth is used to propose annotation
   - Surprise
3. Classification becomes better while *in the process* of ground-truth creation
   - Explain
4. Less annotation has to be specified by end-user and ground-truth creation becomes easier
   - Reward

Ground-truth creation using Surprise-Explain-Reward

1. Tedious work
   - Becomes less tedious because end-user is helped
2. Human error
   - Is reduced because blob matcher is able to detect geometrically different disc prints

Prior knowledge

3. Inter-operator bias and intra-operator bias
   - Less prominent in this pilot application, because disc prints are not ambiguous

Ground-truth creation using Surprise-Explain-Reward

- Proposed annotation is accompanied by a confidence from the blob matcher:

1. Proposed annotation has a high confidence
   - Annotation is automatically accepted
2. Proposed annotation has a low confidence and is correct
   - Annotation should be accepted by end-user
3. Proposed annotation is incorrect
   - Annotation is corrected by the end-user and single class optimization is performed on the incorrect class

Ground-truth creation using Surprise-Explain-Reward

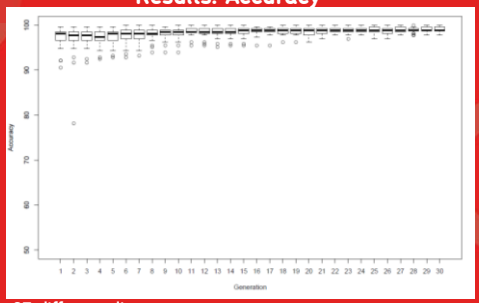
- Single class optimization:

```
min_error_sum = infinity
For a = 0 to count(patterns) - 1
  For b = 0 to count(patterns) - 1
    error_sum += match(patterns[a], patterns[b]).error
  End
  If error_sum < min_error_sum
    best = a
    min_error_sum = error_sum
  End
End
```

Erroneous pattern is never chosen

Demonstration optimization

Results: Accuracy

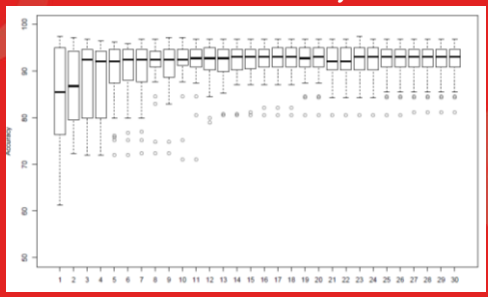


37 different discs
17 samples per class
5 folds 5 repetitions

Results: Precision

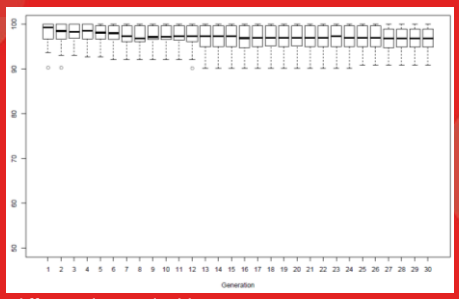
37 different discs
17 samples per class
5 folds 5 repetitions

Results: Accuracy



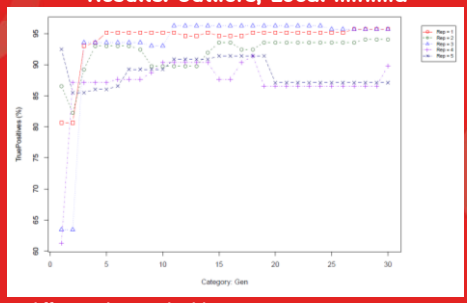
36 different discs and tablets
10 samples per class
5 folds 5 repetitions

Results: Precision



36 different discs and tablets
10 samples per class
5 folds 5 repetitions

Results: Outliers, Local minima



36 different discs and tablets
10 samples per class
5 repetitions

Results: Human error

Class: CN10
Confidence: 0.49

Class: LZD10
Confidence: 0.14

Part of training set

Conclusions

- Ground-truth software using *Surprise-Explain-Reward*
- End-user trainable disc print application
- Optimization framework with rules for deciding on algorithms
- Error correction using prior knowledge

Future work

- End-user trainable basis for future applications
- Extend optimization
- Find heuristics for population size and generations
- Extend classification to regression analysis
- Measure quantitative performance

References

[1] European Antimicrobial Resistance Surveillance Network, 2012. *Report for Quarter 4 2012*. Health Protection Surveillance Center, Available at: <http://www.hpsc.ie/hpsc/A-Z/MicrobiologyAntimicrobialResistance/EuropeanAntimicrobialResistanceSurveillanceSystemEARSS/EARSSSurveillanceReports/2012Reports/File,13921,en.pdf> [Accessed 3 April 2013].

[2] Ko, A. J., Abraham, R., Beckwith, L., Blackwell, A., Burnett, M., Erwig, M., Scaffidi, C., Lawrance, J., Lieberman, H., Myers, B., Rosson, M. B., Rothermel, G., Shaw, M., and Wiedenbeck, S. The state of the art in end-user software engineering. Computing Surveys 43 (2011).

[3] van de Loosdrecht, J. (2013), `Course Computer Vision', Available at: http://www.vlmv.nl/course [Accessed 11 March 2013]. 2013

[4] Eiben, A. E. & Smith, J. E. (2007), Introduction to Evolutionary Computing, 2nd edn, Springer.