Optical Music Recognition – Program Design

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January 18, 2013

Outline

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  - Reference Lengths
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- Staff Line Processing
  - Identification
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- Symbol Recognition
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  - Classification
- Musical Semantics
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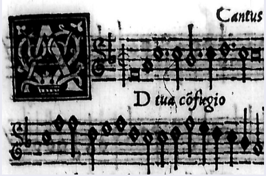
Preprocessing

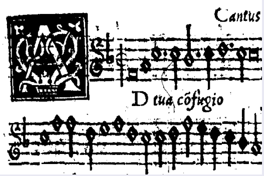
- **Input**: scanned, grey-scale or color image.
- **Output**: binary (black and white) image.

Input



(from [3])

Output



(from [3])

Preprocessing – Binarization

- First, convert the image in grey-scale using the following formula for each pixel[10]:

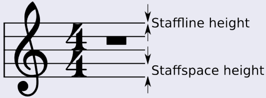
$$Grey = 0.3\ R + 0.59\ G + 0.11\ B$$

- **Otsu**'s method[13] is the most commonly and one of the fastest *global thresholding* method, according to [16].
- **Niblack**'s method[12] is the most commonly used *adaptive binarization* method, according to [16].
- The methods performing the best on degraded music sources are[3]:
  - **Brink and Pendock**, 1996[2].
  - **Pugin**, 2007, but the corresponding article couldn't be found.
  - **Gatos et al.**, 2004[8].

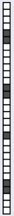
Preprocessing – Reference Lengths

- Also, extract reference lengths needed by the rest of the process (**staffspace height** and **staffline height**).
- Found using *Run-Length Encoding*[16][1]:
  - Encode each column of the binary image using RLE.
  - The most common black-run is the **staffline height**.
  - The most common white-run is the **staffspace height**.

Reference lengths



RLE for reference lengths



$$RLE = (4, 2, 6, 2, 5, 1, 6, 2, 3)$$

□ ■ □ ■ □ ■ □ ■ □

$\Longrightarrow$ Staffline height $= 2$
Staffspace height $= 6$

Preprocessing – Optional Techniques

- Noise reduction:
    - Eliminate isolated black pixels
    - Fill-in isolated white pixels
- Skew detection and correction[6]
    - The image can be skewed if the scan was not done perfectly horizontally.
- Less common[9]: enhancement, blurring, morphological operations.

Preprocessing – Choice

- To implement:
  1. **Otsu**'s method: simple and widely documented.
  2. The RLE-based algorithm to identify reference lengths.
- No other preprocessing.
- Should be enough for most (non-degraded) musical scores. If needed, a better binarization or other noise-reduction methods can be easily added afterwards.

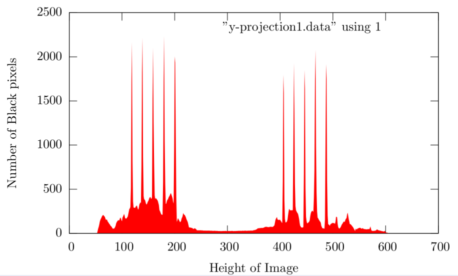
Staff Line Processing

- **Input**: binary image
- **Output**: binary image and staves positions
- **Identify** the positions of the staff
  - Needed to interpret the semantics of the symbols during the generation step.
- **Remove** the staff lines (optional)
  - Isolate the musical symbols (simplify segmentation step).
  - Reduces noise (simplify classification step).
  - Only a few OMR systems don't do this step.
- Challenging step if the staff lines are distorted.
  - We can improve results by adding a **skew correction** step in the preprocessing of the image.

Staff Line Identification

- Use vertical projections
- 5 maxima spaced of the staffspace height = a staff
- Store the position of each staff

Vertical projections



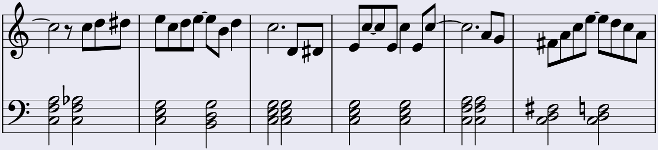
(from [6])

Staff Line Removal

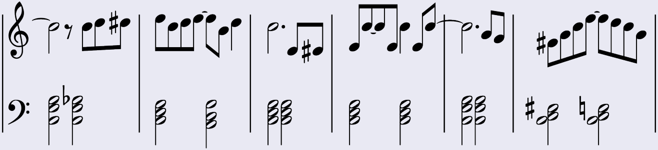
- Lots of algorithms:
  - Linetracking Runlength[14]
  - Linetracking Chord[11]
  - Carter[4]
  - Fujinaga[7]
  - Roach and Tatem[17]
  - Skeleton[5]
- No best algorithm according to [5], but for undeformed images, Roach and Tatem perform better than the others.

Staff Line Removal

Input



Output



Staff Line Processing – Choice

- To implement:
  1. Identification using vertical projections.
  2. Removal using **Roach and Tatem** algorithm (Open Source implementation of multiple staff line removal algorithms available[1]).

[1] http://music-staves.sf.net/

Symbol Recognition

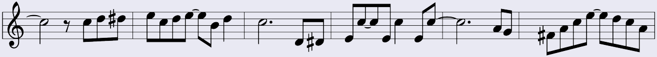
- **Input**: binary image (and staves positions)
- **Output**: list of musical symbols with their positions within the staff
- Done in two steps:
  1. Segmentation
  2. Classification

Symbol Recognition – Segmentation

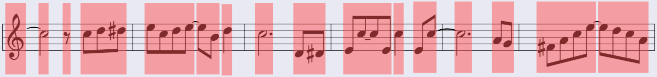
- **Input**: binary image
- **Output**: small binary images with their positions
- Not really described in the litterature, except for OpenOMR[6].
- OpenOMR's method:
  1. **Level 0 image segmentation** (L0) using horizontal projection: find groups of symbols.
  2. **Note head detection** using vertical projection: find which L0 segments contains note heads.
  3. **Symbol segmentation** (L1): separate symbols in L0 segments that contains note heads.
  4. **Note processing** (L2): seperate note heads from other symbols by doing:
     - Stem removal, using vertical projection
     - Staff line removal

Symbol Recognition – Segmentation (OpenOMR)

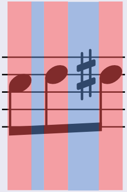
Input



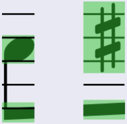
Level 0



Level 1



Level 2



Symbol Recognition – Classification

- **Input**: small binary image
- **Output**: corresponding musical symbol
- Uses well-known classification algorithms: **Neural Networks** (NN), **k-Nearest Neighbors** (kNN), **Support Vector Machines** (SVM), **Hidden Markov Models** (HMM).
- According to [15]:
  - The two best methods are SVM and kNN.
  - For handwritten music, SVM performs better than kNN.
  - For typesetted music, kNN performs better than SVM.
- Training sets:
  - OpenOMR: training set for methods without staffline removal, 727 files.
  - Audiveris: stored in `xml` files describing vertical runs representing the symbol, 4918 files.
  - No others publicly available training set found.

Symbol Recognition – Choice

- To implement:
  1. Segmentation in a similar way than OpenOMR[6].
  2. Classification using **kNN**, trained with Audiveris' training set.

Musical Semantics

- **Input**: musical symbols and their position relative to the staff
- **Output**: MusicXML
- No specific method
- Rules and heuristics
  - For example, for a **note**:
    - **Duration**: note head type? note flag type?
    - **Pitch**: note head vertical position? accidental?

Design Choices

- Select a set of scores for tests and evaluation of the system
- Each stage takes input from a file and outputs to a file
- Preprocessing:
  1. **Binarization**: Otsu's method
  2. **Reference lengths**: RLE-based algorithm
- Staff line processing:
  1. **Identification**: horizontal projections
  2. **Removal**: Roach and Tatem
- Symbol Recognition:
  1. **Segmentation**: horizontal/vertical projections
  2. **Classification**: k-Nearest-Neighbor with Audiveris training set
- Musical Semantics: rule-based

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