File Classification Using Sub-Sequence Kernels

By

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File Classification Using Sub-Sequence Kernels

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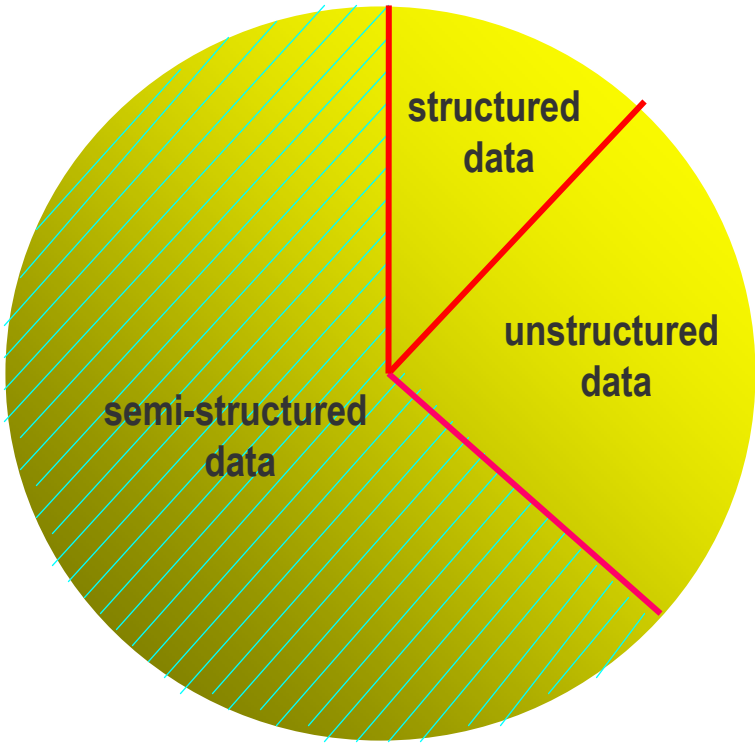
Presentation:

- ✓ Document mining and computer forensics
- ✓ Semi-structured documents
- ✓ Broadband *k*-spectrum kernel
- ✓ Coloured generalized suffix tree representation
- ✓ Experimental methodology
- ✓ Results and Conclusion

Computer Forensics: Focus on Document Mining

Eg, disk surface contents



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Semi-Structured Documents

- May or may not include natural language text
- May be compound documents
- Include low-level, short-range structures. For example:
  - byte block identifiers
  - mark-up tokens

Semi-Structured Documents

⇒ **Traditional text mining techniques generally not appropriate.**

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Broadband *k*-Spectrum Kernel:

Use an extension to the string kernel.

x_i = BOOKOOPERPPO…

(*k*=4)

BOOK
OOKO
OKOO
KOOP
OOPE
etc.…

String (*k*-Spectrum) Kernel:

- Is the set of all k-length contiguous subsequences that a sequence x_i (of alphabet T, size |T|=*l*) contains
- Feature space dimension is up to $|T|^k$ (eg, if *k*=4 and |T| = 256 ⇒ number of dimensions ≈ 10^9)

Vector representation: $(\varphi_{\kappa 1}(x_i), \varphi_{\kappa 1}(x_i), \ldots, \varphi_{\kappa 1}(x_i))$

where $\kappa 1, \kappa 2, \ldots, \kappa l \in T^k$

Broadband *k*-Spectrum Kernel:

Broadband *k*-Spectrum Kernel:

- Is the set of all (0, 1, ..*k*)-length contiguous subsequences that a sequence (of alphabet T) contains
- Feature space dimension is even larger!

BOOKOOPERPPO…

(*k*=4)

B, BO, BOO, BOOK
O, OO, OOK, OOKO
O, OK, OKO, OKOO
K, KO, KOO, KOOP
O, OO, OOP, OOPE
etc….

Broadband *k*-Spectrum Kernel:

Matrix representation, $\varphi_{(BB)}(x_i)$:

$$
\begin{matrix}
(\varphi_{\kappa 1^{(1)}}(x_i) & \varphi_{\kappa 2^{(1)}}(x_i) & \dots & \varphi_{\kappa l^{(1)}}(x_i), \\
\varphi_{\kappa 1^{(2)}}(x_i) & \varphi_{\kappa 2^{(2)}}(x_i) & \dots & \varphi_{\kappa l^{(2)}}(x_i), \\
\vdots & & & \\
\vdots & & & \\
\vdots & & & \\
\varphi_{\kappa 1^{(2)}}(x_i) & \varphi_{\kappa 2^{(2)}}(x_i) & \dots & \varphi_{\kappa l^{(2)}}(x_i))
\end{matrix}
$$

where $\kappa_i^{(j)} \in T^j$ for $i = 1, 2, .. l$

Broadband *k*-Spectrum Kernel: What's the Big Deal?

This allows us to define the inner product between two input sequences, x_r and x_s as:

$$\text{GramMatrix}(x_r, x_s) \equiv \varphi_{(BB)}(x_r) \bullet \varphi_{(BB)}(x_s)$$

and use the "kernel trick" when maximising the margin of separation between two classes. The decision function for the SVM learning algorithm is:

$$f(x) = \text{sign}\left(\sum \alpha_l \, y_i [\varphi_{(BB)}(x_r) \bullet \varphi_{(BB)}(x_s)] + b\right)$$

in the transformed feature space rather than the input feature space.

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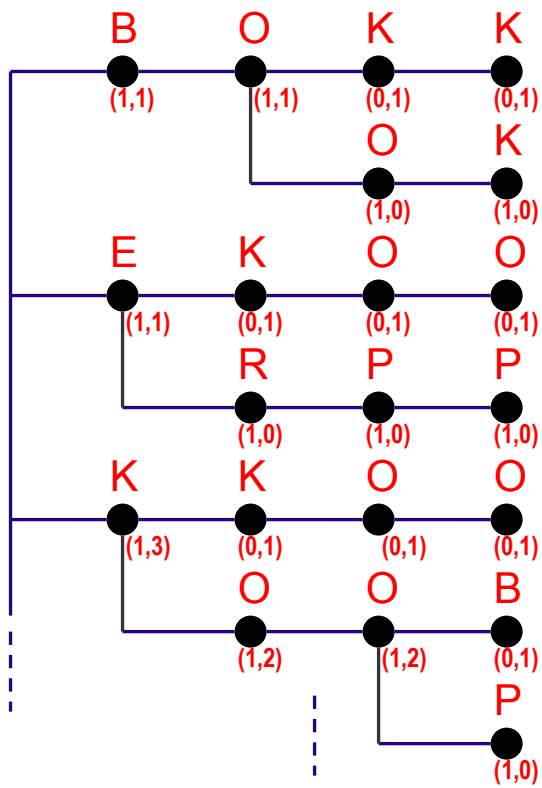
Coloured Generalized Suffix Tree (CGST):

BOOKOOPERPPO PPEKOOBOKKOO

(*k*=4)

The CGST is a labelling of the GST representation of a sequence of symbols:

It stores a count vector to be stored at each node in the GST – each vector element value equals the frequency of the subsequence in the sequence.



CGST: Computing the Kernel (Gram) Matrix

For *N* input sequences, the *NxN* Gram matrix G is computed as follows:

- initialize $G_{r,s} = 0 \quad \forall\ x_r$ and x_s
- traverse the CGST
- at each node, compute the product of each vector element pair and sum to $G_{r,s}$

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Experimental Methodology: Corpus

Document corpus for a controlled experiment :

- 5 document classes (MSWord, JPEG, MSExcel, Java source, Adobe PDF)
- 465 documents (0.11KB min. to 523.3KB max. size)
- data are scaled to unit standard deviation and zero mean

Experimental Methodology: Classifier

- SVM^{light} as the (two-way) classifier,
- Obtain two-way categorisation matrix for each document type category, using 10-fold cross-validation sampling,
- Calculate per-document-type category classification performance statistics – precision, recall and F_1 statistics.

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Experiments: Performance Results

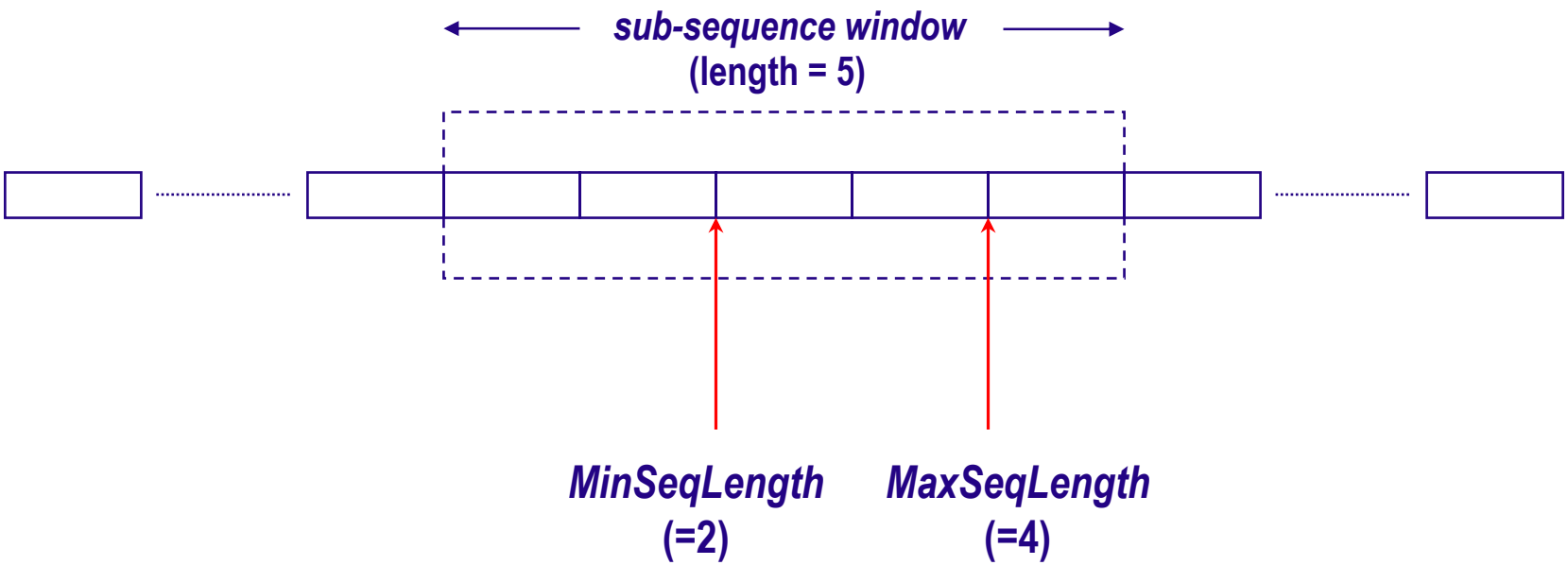
Classification performance was evaluated using the following parameters:

- Minimum and maximum sub-sequence window offset lengths,

Experiments: Performance Results

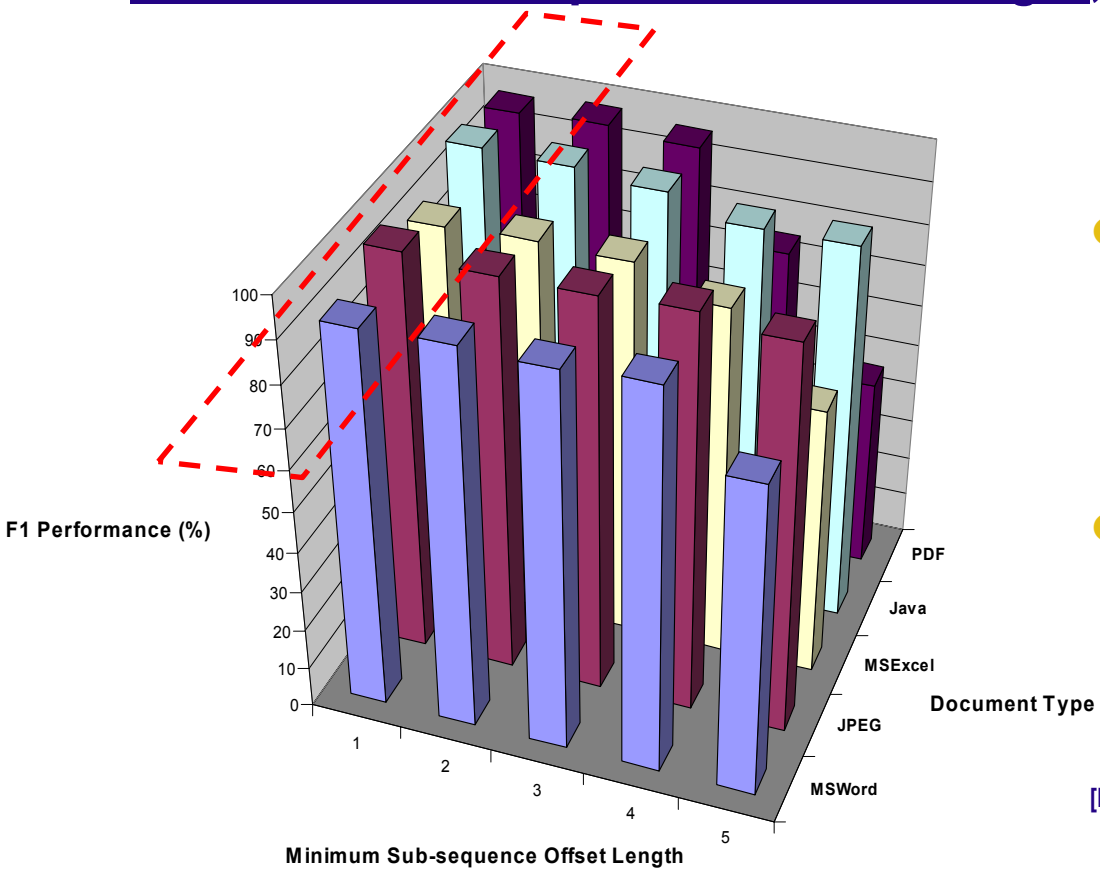
Minimum and Maximum Sub-sequence Window Offset Length:

- Definition: For example;



Experiments: Performance Results

Minimum Sub-sequence Offset Length, *MinSeqLength*:

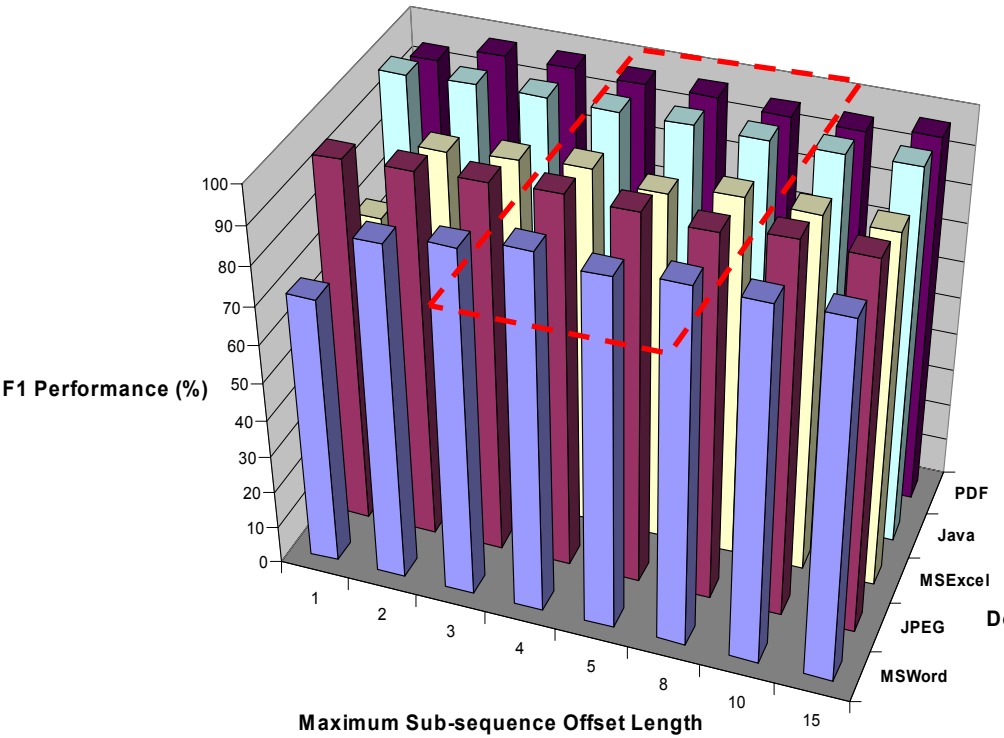


- Optimal *MinSeqLength*=1
  - Use broadband spectrum
- Faster drop-off for non-text documents (except JPEG)

[Parameters: *MaxStringLength*=256 *MaxSeqLength*=5 *MinSeqCount*=10]

Experiments: Performance Results

Maximum Sub-sequence Offset Length, *MaxSeqLength*:



- Optimal value is *4<MaxSeqLength<7*
- No significant improvements for large sub-sequence offset values

Conclusions:

- Promising semi-structured document categorization results using the broadband *k*-spectrum kernel.
- Experiments suggest:
  - use broadband kernels rather than narrow band kernels (ie fixed *k*-length sequence),
  - document length can be small,
  - use a minimum suffix count to achieve improved classification performance and tree compression.
- Extensions:
  - Increase the number of document types
  - Investigate techniques for capturing longer-range data structures in documents

Questions ?

Advertisement:

"*Computer and Intrusion Forensics*"
by *G. Mohay, A. Anderson, B.Collie, O. de Vel* and *R. McKemmish*
Artech House ISBN 1-58053-369-8 (2003)