

Towards modeling implicit feedback with quantum entanglement

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Quantum Interaction
Oxford, UK, 26th – 28th March 2008

- 1 Information Retrieval
- 2 Towards a Model of Implicit Feedback
- 3 Decomposition
- 4 A Methodology for Implicit Feedback
- 5 Concluding Remarks

Information Retrieval

- Concerned with retrieving all and only the documents relevant to any information need of any user
- Intrinsically dependent on
 - the user
 - the task the user is performing
- Difficulty of obtaining queries well designed for retrieval purpose
 - vague information need
 - limited experience in the search environment

Relevance Feedback

- Relevance information explicitly provided by the user used to
 - suggest query expansion terms
 - retrieve new search results
 - dynamically reorder existing results
- Effective but:
 - high user effort
 - benefit not always apparent
- How to remove the burdens of traditional RF?

Implicit Relevance Feedback

Alternative: **Implicit Relevance Feedback** (IRF)

- Using contextual features generated during user-information interaction

Example of contextual features: display time, bookmarking, saving, printing, scrolling

- Requires a software tool which
 - monitors subject behavior
 - uses these interaction data as a source of IRF

Modeling Implicit Feedback

- Abstraction of the software tool to automate the feedback process
- Geometric Framework proposed in [1] to model Implicit Feedback
 - considers multiple source of evidence
 - personalized for each user
 - tailored for each search task
- Framework revisited with some QM concepts according to the proposal originally reported in [2] where QM was proposed for tackling the problem of IR

- [1] M. Melucci and R. W. White.
Utilizing a geometry of context for enhanced implicit feedback.
In *Proceedings of the ACM Conference on Information and Knowledge Management (CIKM)*, pp. 273–282, Lisbon, Portugal, November 2007.
- [2] C.J. van Rijsbergen.
The Geometry of Information Retrieval.
Cambridge University Press, New York, 2004.

Towards a Model of Implicit Feedback

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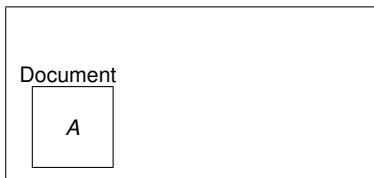
User-document interaction



Information Retrieval

Towards a Model of Implicit Feedback

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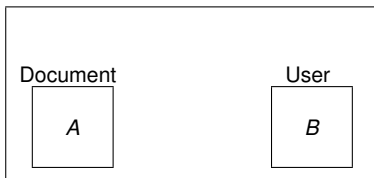


Information Retrieval

A visited document or the visit of the document

Towards a Model of Implicit Feedback

User-document interaction

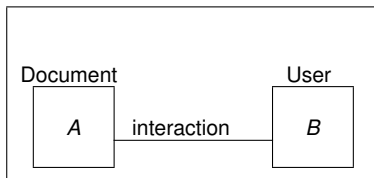


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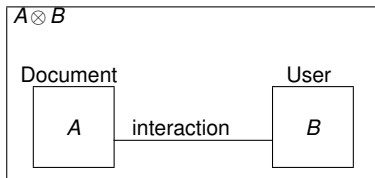


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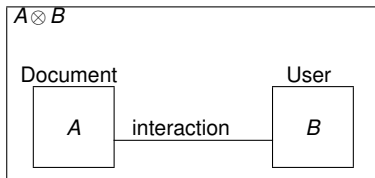


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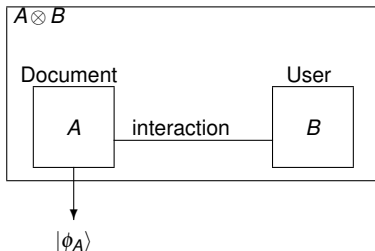
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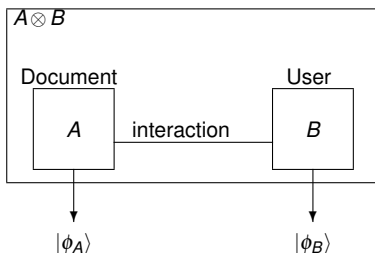
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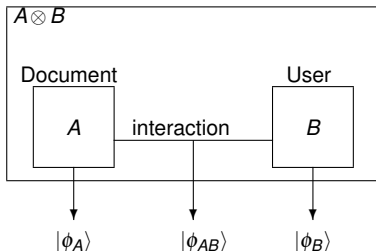
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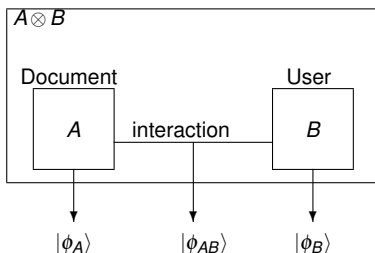
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 - $|\phi_{AB}\rangle$ entangled or separable?

Schmidt Decomposition

Bipartite System AB

- Bipartite pure state $|\phi_{AB}\rangle$ separable iff can be written as

$$|\phi_{AB}\rangle = |\phi_A\rangle \otimes |\phi_B\rangle$$

- In general $|\phi_{AB}\rangle$ is written in any orthonormal product basis $\{|i_A\rangle \otimes |j_B\rangle\}$ as

$$|\phi_{AB}\rangle = \sum_{i=0}^{N_A} \sum_{j=0}^{N_B} C_{ij} |i_A\rangle \otimes |j_B\rangle \quad \text{where } C_{ij} \text{ element of a matrix } C$$

- Schmidt Decomposition Theorem

There always exists a product bi-orthonormal basis $\{|e_A^i\rangle \otimes |e_B^i\rangle\}$

$$|\phi_{AB}\rangle = \sum_i^{\min\{N_A, N_B\}} \lambda_i |e_A^i\rangle \otimes |e_B^i\rangle$$

where λ_i nonzero singular eigenvalues of C .

λ_i : obtained by Singular Value Decomposition of $C \rightarrow C = B\Lambda A \rightarrow \lambda_i = \{\Lambda\}_{i,i}$

Schmidt Number: number of nonzero singular eigenvalues of C

A Methodology for Implicit Feedback

Possible Methodology

- 1 preparation of the interaction data
- 2 computation of a contingency matrix
- 3 decomposition of the contingency matrix
- 4 analysis of entanglement

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- subset of the document features of the dataset

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- usefulness scores assigned to each document

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normalization of the dataset

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computation of the average value of every feature from the tuples of the chosen subject and task identifiers

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normalization of the obtained 2×5 matrix

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Example - All subjects and All tasks

$$\mathbf{C} = \begin{bmatrix} \text{display time} & \text{bookmark} & \text{saving} & \text{frequency} & \text{scrolling} & \text{useless} \\ -0.162 & -0.066 & 0.020 & -0.037 & 0.004 & \\ 0.201 & 0.082 & -0.025 & 0.043 & -0.005 & \text{useful} \end{bmatrix}$$

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Decomposition of the contingency matrix: SVD of $\mathbf{C} \Rightarrow \mathbf{C} = \mathbf{B}\mathbf{\Lambda}\mathbf{A}$

$$\mathbf{\Lambda} = \begin{bmatrix} 0.9999 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0059 & 0.0000 & 0.0000 & 0.0000 \end{bmatrix}$$

$$\mathbf{A} = \begin{bmatrix} \text{display time} & \text{bookmark} & \text{saving} & \text{frequency} & \text{scrolling} \\ 0.902 & 0.182 & 0.108 & -0.375 & 0.023 \\ 0.367 & 0.074 & 0.033 & 0.927 & 0.007 \\ & & \dots & & \end{bmatrix}$$

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Analysis of the Entanglement

- $\lambda_{1,1} = 0.9999 \approx 1 \Rightarrow$ *Schmidt Decomposition* $|\phi_{AB}\rangle \approx |1_A\rangle \otimes |1_B\rangle$
- all the subjects and tasks: $A \otimes B$ is a product state vector
- is entanglement somehow related to the subject or to the task?

Example - Subject 1 and Task 1

$$\mathbf{C} = \begin{bmatrix} \text{display time} & \text{bookmark} & \text{saving} & \text{frequency} & \text{scrolling} & \\ -0.158 & -0.094 & -0.052 & -0.110 & 0.835 & \text{useless} \\ 0.014 & 0.128 & -0.052 & 0.256 & 0.411 & \text{useful} \end{bmatrix}$$

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$$\mathbf{A} = \begin{bmatrix} \text{display time} & \text{bookmark} & \text{saving} & \text{frequency} & \text{scrolling} \\ 0.145 & 0.243 & -0.053 & -0.188 & 0.939 \\ 0.031 & 0.473 & 0.092 & -0.827 & -0.288 \\ & & \dots & & \end{bmatrix}$$

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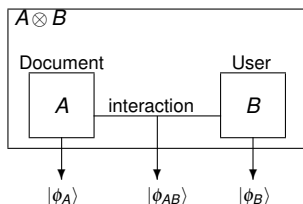
Second singular value is significantly greater than 0

⇒ Schmidt number is significantly greater than 1

⇒ $|\phi_{AB}\rangle$ is entangled

Concluding Remarks and Open Issues

User-document interaction



- User visiting a document
 - ⇒ state of the system (A) is the pure state of the observable which describes the measurement of the style of interaction
- User assessing the usefulness of a document
 - ⇒ the state of the system (B) is to the pure state of the observable that describes the measurement of usefulness
- State of $A \otimes B$ separable
 - ⇒ measurement of a property does not influence the state of the other observable
- What happens if the composite state of $A \otimes B$ is entangled?

Open Issues

- When the composite state of $A \otimes B$ is entangled
 - how does the state of B behave?
 - what pure state of B does it collapse to?
- When does the collapse occur, given that it occurs?
- Entanglement used to verify the existence of a relationship between user and information.

How to use it for retrieval purpose?