Outline

- Introduction
- Related Work of ACAF
- ACAF System
  - ACAF Flow Chart
  - ACAF Training Process
  - Main Components
  - Search Mechanism
- Performance of ACAF
- Conclusion & Future Work

Introduction

Find the answer about 「台灣最高的山峰是什麼？」

- Search Engine:
  - Web
  - 台灣、最高、山峰 → Related Docs. of the keywords
- Question Answering System:
  - Web
    - 台灣最高的山峰是什麼？ → 玉山
- Answer-Finding System:
  - QA Set: Question-and-Answer Set
    - 台灣最高的山峰是什麼？ → the Answer Documents

Motivation

- Answer-Finding System
- Concepts: 山、山峰
- Answer Type: 名字、地點位置
Introduction

- Goal: Automatic Concept-Based Answer-Finding System (ACAF)
  - Answer-Finding System: Latent Semantic Analysis (LSA)
  - Question Concepts: LSA
  - Answer-Type Detection: Probabilistic Model

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- Introduction
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- ACAF System
  - ACAF System Architecture
  - Main Components
  - Search Mechanism
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- Conclusion & Future Work

Related Work of ACAF – Outline

- Overview of Related Work
- Answer-Finding System
- Latent Semantic Analysis (LSA)
- The Construction of Conceptual Space
- Answer-Type Detection

Overview of Related Work

Answer Finding
- Berger00
- Dumais02
- Pasca01
- Pinto02

Conceptual Space Construction
- Park96
- Chung99
- Fu01
- Lin01
- Sugumaran02
- Aggarwal01
- Bellegarda96

Answer-Type Detection
- Prager00
- Pasca01
- Zeilikovitz01
- Lin02
- Radev02

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Answer-Finding\cite{Berger00}

- Strategies for Answer-Finding
  - tf-idf
  - Adaptive tf-idf
  - Query Expansion
  - Statistical Translation
  - Latent Variable models

Answer-Finding\textsubscript{2} – IR-Based

- Strategy 1: tf-idf
  - Answer Set is Document Set
  - Who is the first American in the space?
  - Query: first American space.
- Strategy 2: Adaptive tf-idf
  - Similar to Strategy 1.
  - IDF: Increase the weight of a word that occurs in the same Q/A pairs.
- Strategy 3: Query Expansion
  - (Why → because) \& (site → http) \& (windows → Microsoft)
  - Query: (Why, because) \& (site, http) \& (windows, Microsoft)

Answer-Finding\textsubscript{3} – Translation-Based

- Strategy 4: Statistical Translation
  - at, location, place, street, directions → where
- Strategy 5: Latent Variable Models
  - EM algorithm, LSA
  - (Why → because) \& (site → http) \& (windows → Microsoft)
  - Query: (because) \& (http) \& (Microsoft)
Related Work of ACAF – Outline

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LSA [Landauer98] – An Example

An Example of text data: Titles of Some Technical Memos

- HCI: Human Computer Interaction
  - c1: Human machine interface for ABC computer application
  - c2: A survey of user opinion of computer system response time
  - c3: The EPS user interface management system
  - c4: System and human system engineering testing of EPS
  - c5: Relation of user perceived response time to error measurement

- Mathematical Graph Theory
  - m1: The generation of random, binary, ordered trees
  - m2: The intersection graph of paths in trees
  - m3: Graph minors IV: Widths of trees and well-quasi-ordering
  - m4: Graph minors: A survey

Flow chart

<p>| | | | | | | | | |</p>
<table>
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<tr>
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Singular Value Decomposition (SVD) and Dimension Reduction

Dimension Reduction = 2

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<td>0.13</td>
<td>0.19</td>
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</tbody>
</table>

LSA5 – An Example
**LSA6 – Discussion**

- Infer much deeper relations
- Construct synonym sets
- Derive association values between documents.
- Model human conceptual knowledge

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**Related Work of ACAF – Outline**

- Overview of Related Work
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- Answer-Type Detection

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**Overview of Concept Construction**

- Manually construct
  - Ontology: [Sugumaran02]
- Automatically construct by term clustering
  - By Thesaurus (WordNet, HowNet): [Lin01]
  - By Document Set
    - Co-occurrence: [Chung99]
    - Bayesian Network: [Park96]
    - LSA: [Bellegarda’96]
- Automatically construct by document clustering
  - By Self-Organizing Maps (SOM): [Fu01]

---

**Based On LSA [Bellegarda96]**

**Flow Chart**

1. Construct Word-Document Matrix
2. SVD and Dimension Reduction
3. Define a distance measure between the singular vectors of words
4. Cluster the singular vectors (any algorithm)

\[ X = WSP^T \]
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Answer Type Detection

- Document Classification
  - Machine Learning: [Lin02]
- Question Answering
  - Heuristic Rule: [Radev02]
  - Syntax + WordNet: [Pasca01]

Heuristic Rule [Radev02]

List of answer types

<table>
<thead>
<tr>
<th>PERSON</th>
<th>PLACE</th>
<th>DATE</th>
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<tbody>
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<td>DEFINITION</td>
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<td>ABBREVIATION</td>
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<td>RATE</td>
<td>LENGTH</td>
<td>MONEY</td>
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<td>REASON</td>
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Analysis of Wh-words and their corresponding types

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<th>Wh-word</th>
<th>Types</th>
<th>Wh-word</th>
<th>Types</th>
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<td>Who(102)</td>
<td>PER(77) DES(19) ORG(6)</td>
<td>What / which (233)</td>
<td>NOM(78) PLA(27) DEF(26) PER(18) ORG(16) NUM(14) ABB(13) DATE(11) RATE(4) KNO(8) MON(3) PUR(2) REA(1)</td>
</tr>
<tr>
<td>Where(60)</td>
<td>PLA (54) NOM(4), ORG(2)</td>
<td>How(48)</td>
<td>NUM(33) LEN(6) RATE(2), MON(2) DUR(3) REA(1), DES(1)</td>
</tr>
<tr>
<td>When(40)</td>
<td>DATE(40)</td>
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<td></td>
</tr>
<tr>
<td>Why(1)</td>
<td>REA(1)</td>
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</tbody>
</table>

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ACAF System – Outline

- ACAF Flow Chart
- ACAF Training Process
- Main Components
  - Learn the *Relationship* Between Words of Questions and Answers
  - Construct Question Concept
  - *Answer-Type* Detection
- Search Mechanism

ACAF Flow Chart

- Wq-by-Wa Matrix
- Question Concepts
- Find Top N Answer Words
- Find Top M Concepts
- Keywords
- Candidate Answers
- Question Words
- Answer Type Detection
- Answer Type Knowledge
- The Answers

ACAF Training Process

- Preprocessing
- Segmentation

Preprocessing and Segmentation

- Preprocessing
  - Control Term Phrase
    - (台, 臺), (後來, 後來), (體, 體), (我國, 中國 or 台灣), ...
- Segmentation
  - Match Dictionary: Longest matching [Nei99]
    - 我是交通大學資訊科學系的學生 → 我是交通大學、資訊科學系的學生
  - Reduce Stop Word
    - 後來, 但是, 所以, 以後, ...
  - Count word Frequency
Learn the Relationship Between Wq and Wa

- Construct Wq-by-Wa Matrix M:
  - by the co-occurrence of Wq and Wa in same Q/A pairs.

\[
M = \begin{bmatrix}
W_{wq_1} & W_{wq_2} & \ldots & W_{wq_n} \\
W_{wa_1} & m_{a1} & \ldots & m_{a_n} \\
W_{wa_2} & m_{a2} & \ldots & m_{a_n} \\
\vdots & \vdots & \ddots & \vdots \\
W_{wa_n} & m_{a1} & \ldots & m_{a_n}
\end{bmatrix}
\]

\[
w_{q_i} = [q_1, q_2, \ldots, q_n]
\]

\[
w_{a_j} = [a_1, a_2, \ldots, a_n]
\]

\[
m_{q_ia_j} = \sum_{k=1}^{n} q_k x a_k / |kth\ answer|
\]
Construct Question Concept

- Search Engine
- Segmentation & Indexing
- Related Documents
- Question Keywords

Word-by-Doc Matrix X

Construct Question Concept 2

- SVD & Dimension Reduction
- Word-by-Doc Matrix X'
- Word Clustering

Concept 1
Concept 2
Concept 3

Construct Question Concept 3

- Word Clustering:
  - Representation: row vectors of the new word-by-doc Matrix.
  - The similarity:
    \[ \text{sim}_{w_i,w_j} = \frac{w_i \cdot w_j}{|w_i||w_j|} \]
  - Average-Link Clustering [Gose96]
    - One Term \rightarrow one cluster
    - For each term and each cluster,
      a term joins a cluster
      if the average similarity of the term and all terms of the cluster
      is not less than a threshold.

Construct Question Concept 4 – Average-Link Clustering Algorithm

1. Input: word vectors and threshold \( T \): Output Variable: \( \text{Clusters} = \emptyset \)
2. Count Similarities between words.
3. \( \text{Sims}[i] \leftarrow \text{Sort the Similarities bigger than } T \).
4. for \( i=0 \) To Size-of \( \text{Sims}[i] \)
   (1) Let \( \text{Sims}[i] \) is the similarity of \( w_i \) and \( w_k \).
   (2) \( \text{NewCluster} \leftarrow -1 : \text{Changes} \leftarrow 0 \)
   (3) \( \forall \text{cluster } c \) in \( \text{Clusters} \) and \( w_k \) in \( c \),
     \( \text{AVE} \leftarrow \text{the average of the similarities of } w_k \) and all words in \( c \)
     if \( (\text{AVE} \geq T) \) then \( w_j \) joins \( c \) and \( \text{Changes} \leftarrow \text{Changes} + 1 \)
     if \( (\text{Changes} > 0) \) then \( \text{NewCluster} \leftarrow \text{NewCluster} + 1 \) and \( \text{Changes} \leftarrow 0 \)
   (4) \( \forall \text{cluster } c \) in \( \text{Clusters} \) and \( w_j \) in \( c \),
     \( \text{AVE} \leftarrow \text{the average of the similarities of } w_j \) and all words in \( c \)
     if \( (\text{AVE} \geq T) \) then \( w_j \) joins \( c \) and \( \text{Changes} \leftarrow \text{Changes} + 1 \)
     if \( (\text{Changes} > 0) \) then \( \text{NewCluster} \leftarrow \text{NewCluster} + 1 \)
   (5) if \( (\text{NewCluster} < 2) \) then
     \( \text{New cluster } c = \{ w_j, w_k \} \)
     \( c \) joins \( \text{Clusters} \)
**Construct Question Concept \(5 \) – An Example**

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Threshold=0.5

- **Step 1:** \((A, F)\)
- **Step 2:** consider \(AE\)
  - \(\text{Ave}(\text{sim}_{AE},\text{sim}_{EF})=0.55\)
  - \((A, E, F)\)
- **Step 3:** consider \(BF\)
  - \(\text{Ave}(\text{sim}_{AB},\text{sim}_{BE},\text{sim}_{BF})=0.4\)
  - \((A, E, F)\)
  - \((B, F)\)
- **Step 4:** consider \(AD\)
  - \(\text{Ave}(\text{sim}_{AD},\text{sim}_{DE},\text{sim}_{DF})=0.367\)
  - \((A, E, F)\)
  - \((B, F)\)
  - \((A, D)\)
  - \((A, C)\)
- **Step 5:** consider \(AC\)
  - \((A, E, F)\)
  - \((B, F)\)
  - \((A, D)\)
  - \((A, C)\)
  - \((B, D)\)
- **Step 6:** consider \(BD\)
  - \((A, E, F)\)
  - \((B, F)\)
  - \((A, D)\)
  - \((A, C)\)
  - \((B, D)\)
  - \((A, C)\)
  - \((B, D)\)

**ACAF Training Process**

**Answer Type Detection**

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<tr>
<td>數字</td>
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<tr>
<td>描述性</td>
</tr>
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<tr>
<td>人名</td>
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**Answer Type Detection_2**

The probability of a question term \(t_j\) in a answer type \(AT_i\):

\[
P(t_j, AT_i) = \frac{freq(t_j \in AT_i)}{\text{totfreq}(t_j)}
\]

- **Example**
  - **Question Term:** 為何
  - **Answer Type:** 原因(2)、描述性(3)、人名(3)、專有名詞(2)
  - **Total Frequency of 為何:** 10
  - **The probability of a question term \(t_j\) in a answer type \(AT_i\):**
    - \(P(\text{為何}, \text{原因})=0.2\)
    - \(P(\text{為何}, \text{描述性})=0.3\)
    - \(P(\text{為何}, \text{人名})=0.3\)
    - \(P(\text{為何}, \text{專有名詞})=0.2\)
ACAF Flow Chart

Candidate Answers

Search Mechanism – Word and Concept

- For each answer word $w_a$, calculate the significance of $w_a$ for the question $q$.
  \[ \text{score}_{wa} = \sum_{w_q \in q} m_{w_qw_a} \]
  
- Calculate the similarity of a question $q$ and a concept $c$.
  \[ \text{Sim}_{qc} = \text{Ave} \left( \text{weight}_{we} \right) \]
  \[ \text{weight}_{we} = \text{Ave} \left( \text{Sim}_{we} \right) \]

Search Mechanism – SimW and SimC

- The similarity of question $q$ and answer $a$ according to word relationship.
  \[ \text{SimW}_{qa} = p(a \mid q) = \sum_{w_c \in a} p(w_a \mid q) = \sum_{w_c \in a} \text{score}_{wa} \times \text{weight}_{wa} \]

- The similarity of question $q$ and answer $a$ according to concept.
  - Find the top $M$ concepts of $q$ and $a$.
  - $C_q = (C_{q1}, C_{q2}, ..., C_{qM})$ and $C_a = (C_{a1}, C_{a2}, ..., C_{aM})$
  \[ \text{SimC}_{qa} = \sum_{c \in C_q, c \in C_a} \text{Sim}_{qc} \cdot \text{Sim}_{wc} \]

Search Mechanism – Candidate Answers

- Consider all answers in QA set.
  \[ \text{SimWC}_{qa} = w_w \times \text{SimW}_{qa} + w_c \times \text{SimC}_{qa} \]
- Candidate Answers: $\text{SimWC}_{qa} > \text{Threshold}$
ACAF Flow Chart

ACAF Flow Chart

Search Mechanism – Answer Type

- Calculate the similarity of a question q and an answer type t.

\[ Sim_{qt} = \sum_{w \in q} P_{wt} \]

- Candidate Answer Types: \( T = \{ t_1, t_2, \ldots, t_k \} \)
- The similarity of question q and answer a according to answer type.
  - If the answer type t of a was descriptive:
    \[ Sim_{qa} = P_{aq} + 0.5 \times \sum_{t' \in T, t' \neq t} P_{t'a} \]
  - Otherwise
    \[ Sim_{qa} = P_{aq} + 0.3 \times P_{aq'}, \text{ where } t' \text{ is descriptive.} \]

Search Mechanism – Combined

- The total Similarity of a question q and an answer a.

\[ Sim_{qa} = w_w \times SimW_{qa} + w_C \times SimC_{qa} + w_T \times SimT_{qa} \]

Outline

- Introduction
- Related Works of ACAF
- ACAF System
  - ACAF Flow Chart
  - ACAF Training Process
  - Main Components
  - Search Mechanism
- Performance of ACAF
- Conclusions & Future Works
Performance of ACAF - Outline

- System Overview
- Evaluation Metrics
- The Experiment Design
- The Experiment Result
  - Search Result – Sport Rules
  - Search Result – Library Question

System Overview – QA Set

System Overview – ACAF system

System Overview – Search Result
Evaluation Metrics

- TRDR: Total Reciprocal Document Rank [Radev02]
  - The sum of the reciprocal values of the rank of all correct answers among returned N documents
  - \( TRDR = \sum_{i=1}^{N} \frac{1}{\text{rank}_i} \)
- Precision: [Ricardo99]
  - The number of correct answers among returned N documents: \( n \)
  - \( \text{precision} = \frac{n}{N} \)
- Recall: [Ricardo99]
  - The number of correct answer among QA set: \( |R| \)
  - \( \text{Recall} = \frac{n}{|R|} \)

The Experiment Design

- QA Set
  - Sport Rules
  - Library Questions
- Search Result
  - Base Line: IR
  - Word Relationship: ACAF_w
  - Word Relationship + Concept: ACAF_w_c
  - Word Relationship + Concept + Answer Type: ACAF

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Outline

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Conclusion

- Combine 3 kinds of knowledge
  - Relationship between Wqs and Was
  - Conceptual Space
  - Answer-Type Knowledge
- Promoted to the semantic level
- Suitable for the reference desk of library

Future Work

- Segmentation
- LSA – Dimension Reduction
- Answer-Type Detection

References

References


