Chains of Reasoning over Entities, Relations, and Text using Recurrent Neural Networks

Rajarshi Das, Arvind Neelakantan, David Belanger, Andrew McCallum

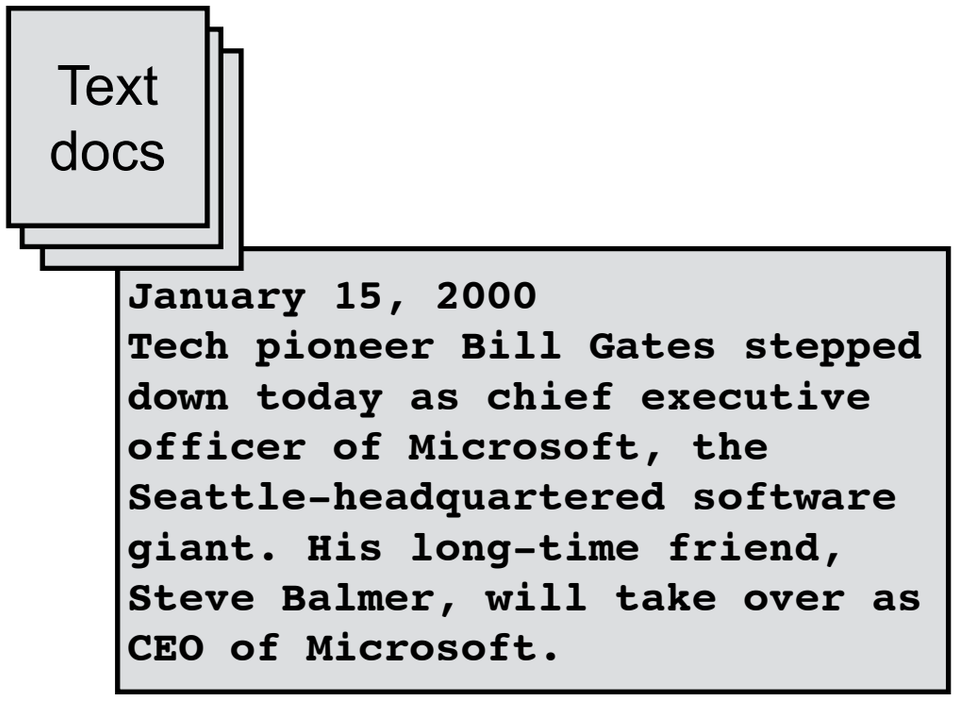



Presentation in Deep Learning Summer School, Montreal
Aug 4 2016

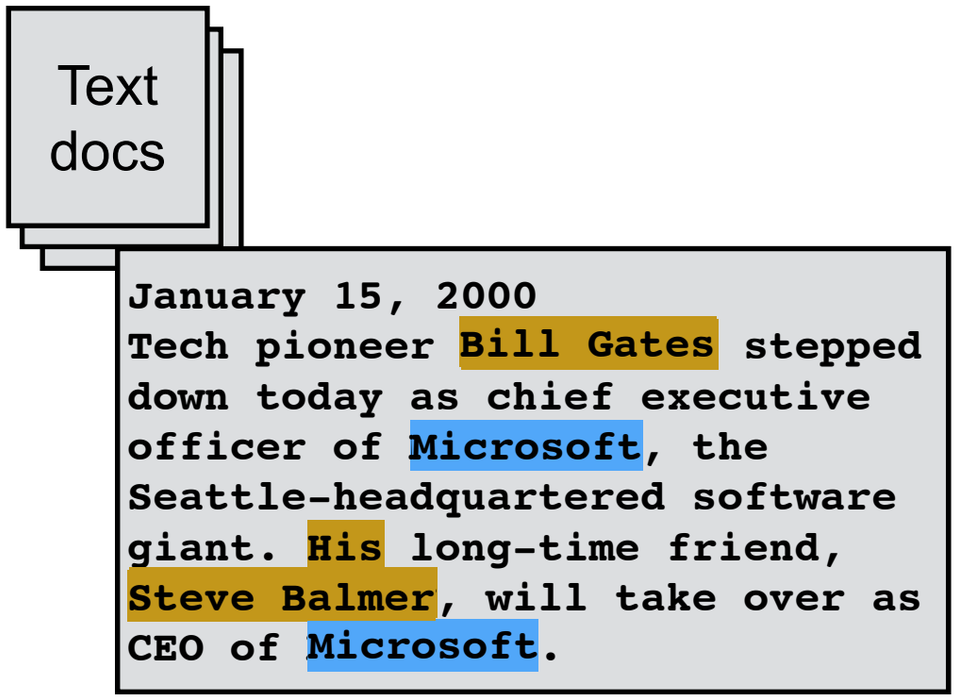
UMassAmherst

IESL

Relation Extraction



Relation Extraction



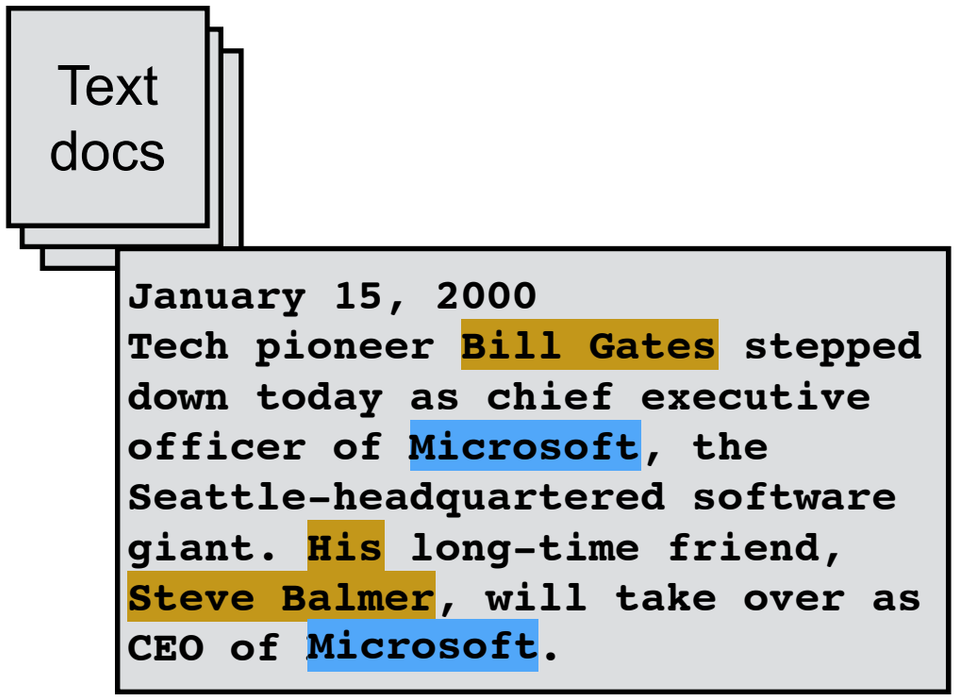
Relation Extraction

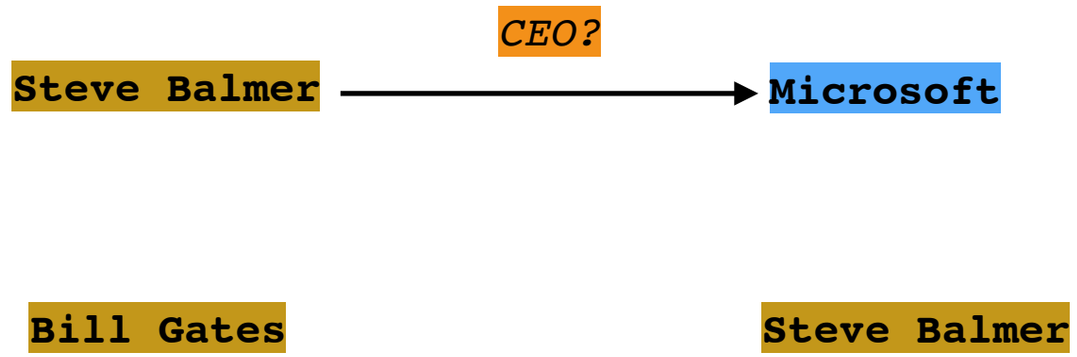
Text docs

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft.

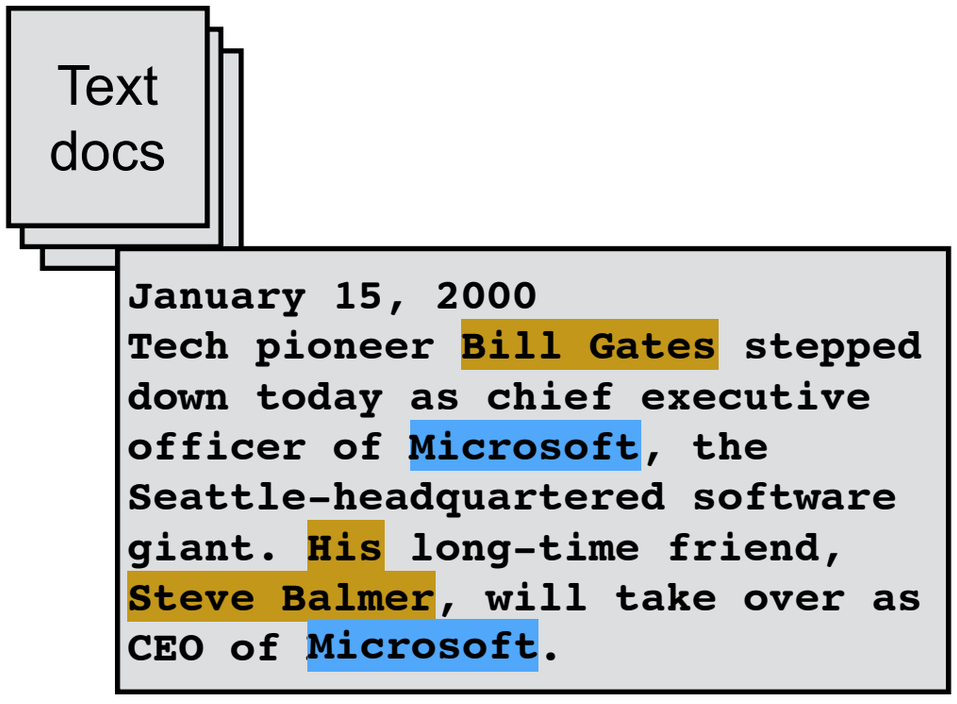
Steve Balmer	Microsoft
Bill Gates	Steve Balmer

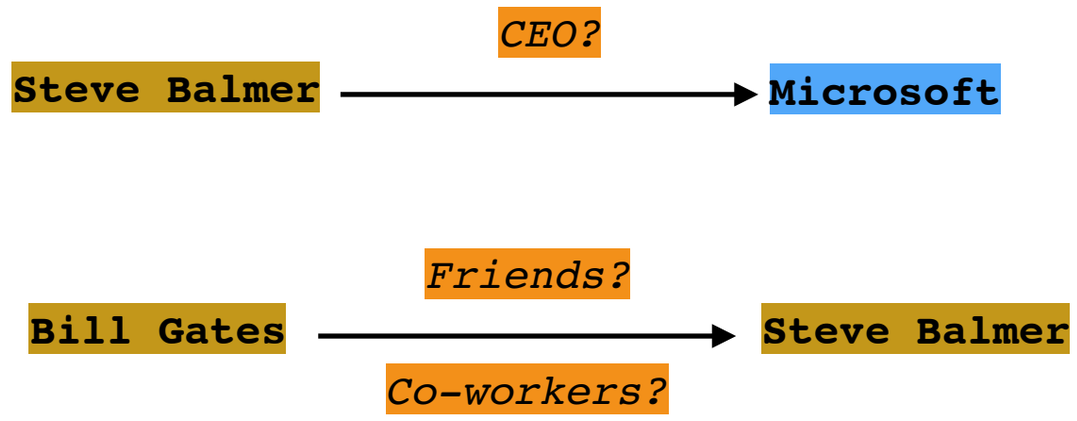
Relation Extraction





Relation Extraction

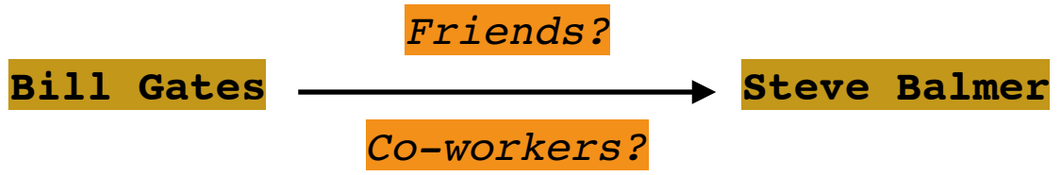




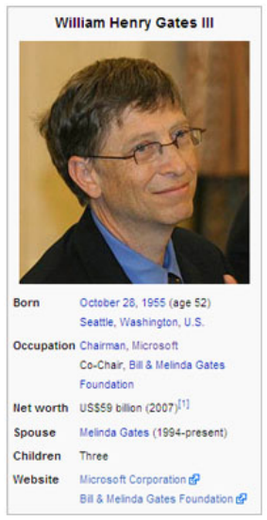
Relation Extraction

Text docs

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the Seattle-headquartered software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**.



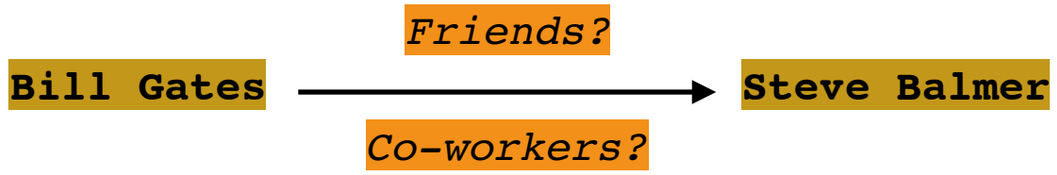
WIKIPEDIA
The Free Encyclopedia



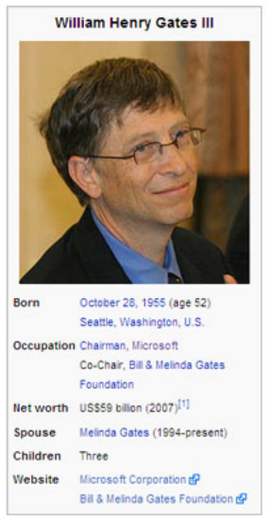
Relation Extraction

Text docs

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the Seattle-headquartered software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**.



WIKIPEDIA
The Free Encyclopedia



Freebase

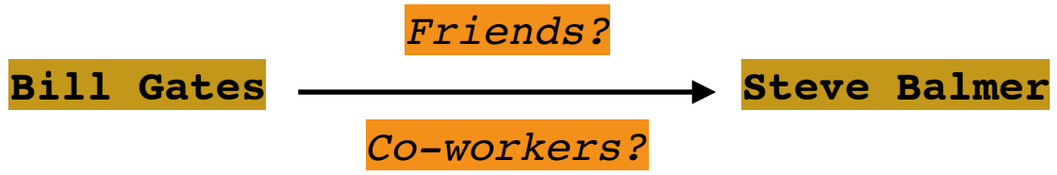
Freebase: ***CEO ?***

Freebase: ***worked_together ?***

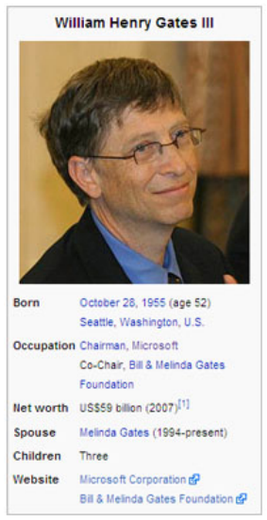
Relation Extraction

Text docs

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the Seattle-headquartered software giant. **His** **long-time friend**, **Steve Balmer**, will **take over as** **CEO** of **Microsoft**.



WIKIPEDIA
The Free Encyclopedia



Freebase

Freebase: ***CEO ?***

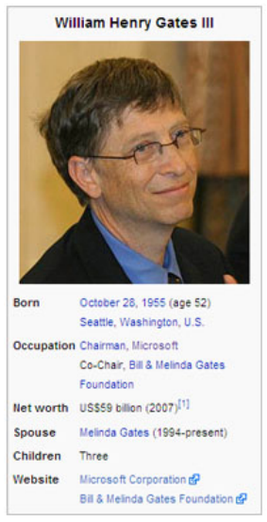
Freebase: ***worked_together ?***

Relation Extraction

Text docs

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the Seattle-headquartered software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**.

WIKIPEDIA
The Free Encyclopedia



Freebase

Freebase: ***CEO ?***

Freebase: ***worked_together ?***

long-time friend

take over as

CEO

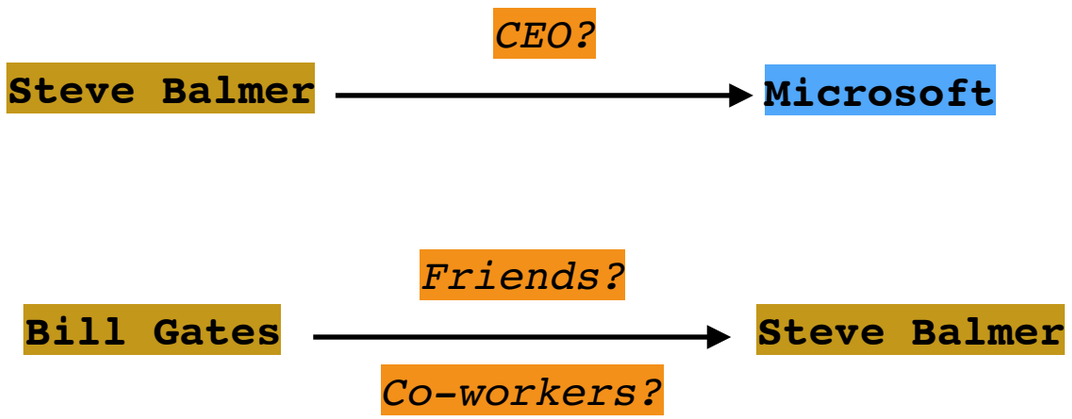
Open IE textual relation types (Banko et al, 2007)

Universal Schema for Relation Extraction

Text docs

Riedel, Yao, McCallum, Marlin, 2013

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the Seattle-headquartered software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**.



Union of all relation types from all structured sources and text

WIKIPEDIA
The Free Encyclopedia

Freebase

Freebase: ***CEO ?***

Freebase: ***worked_together ?***

long-time friend

take over as

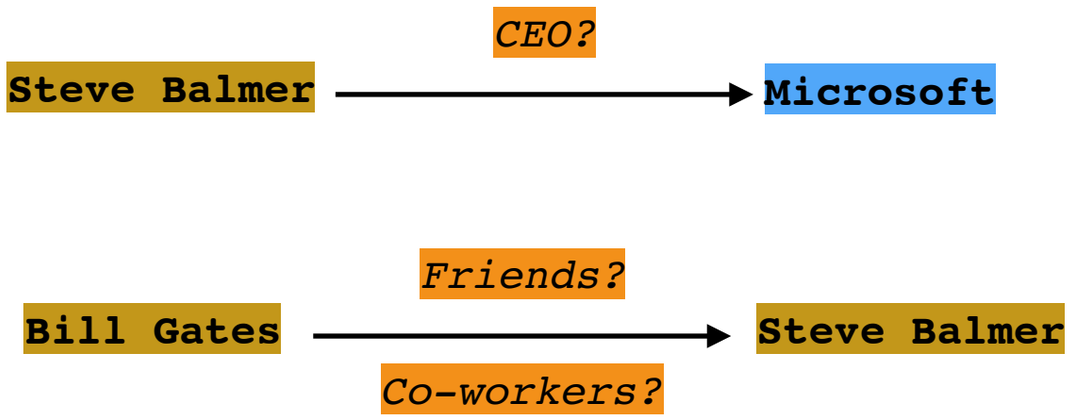
CEO

Open IE textual relation types (Banko et al, 2007)

Universal Schema for Relation Extraction

Text docs

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the Seattle-headquartered software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**.



Union of all relation types from all structured sources and text

WIKIPEDIA
The Free Encyclopedia

Freebase

Freebase: ***CEO ?***

Freebase: ***worked_together ?***

long-time friend

take over as

CEO

Open IE textual relation types (Banko et al, 2007)

Universal Schema for Relation Extraction

Text docs

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft.

Predict **relation** between **entities** based on **mentions** in **text**

Union of all relation types from all structured sources and text

WIKIPEDIA
The Free Encyclopedia

Freebase

Freebase: ***CEO ?***

Freebase: ***worked_together ?***

long-time friend

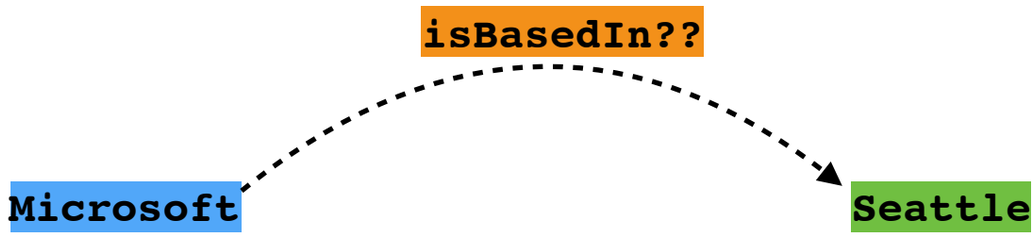
take over as

CEO

Open IE textual relation types (Banko et al, 2007)

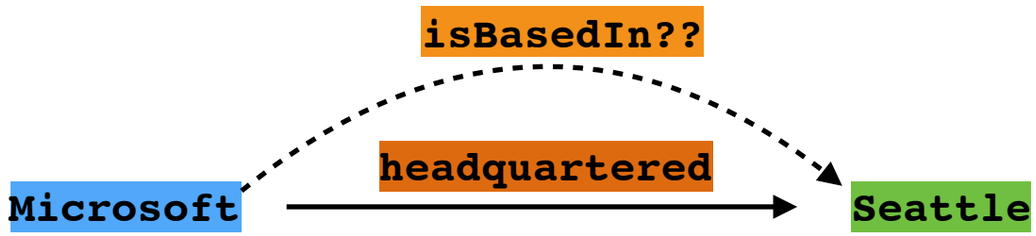
Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft.



Chains of Reasoning for Relation Extraction

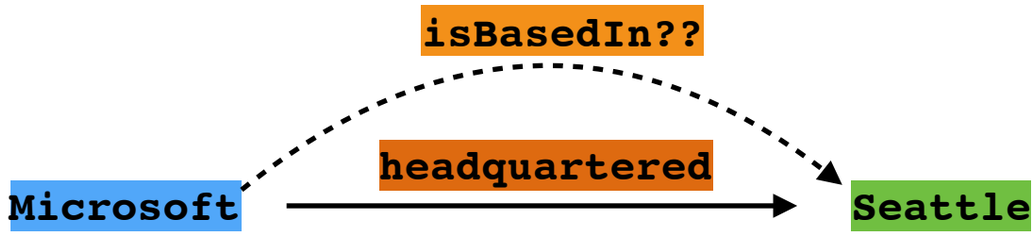
January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft.



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft.

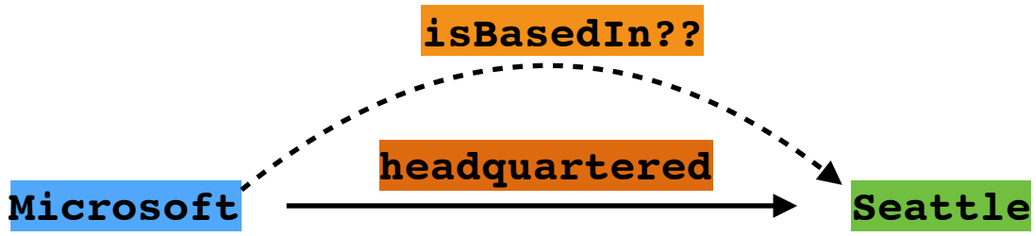
Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. Bill and Melinda were married in a ceremony in Hawaii, rather than her hometown of Dallas.



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft.

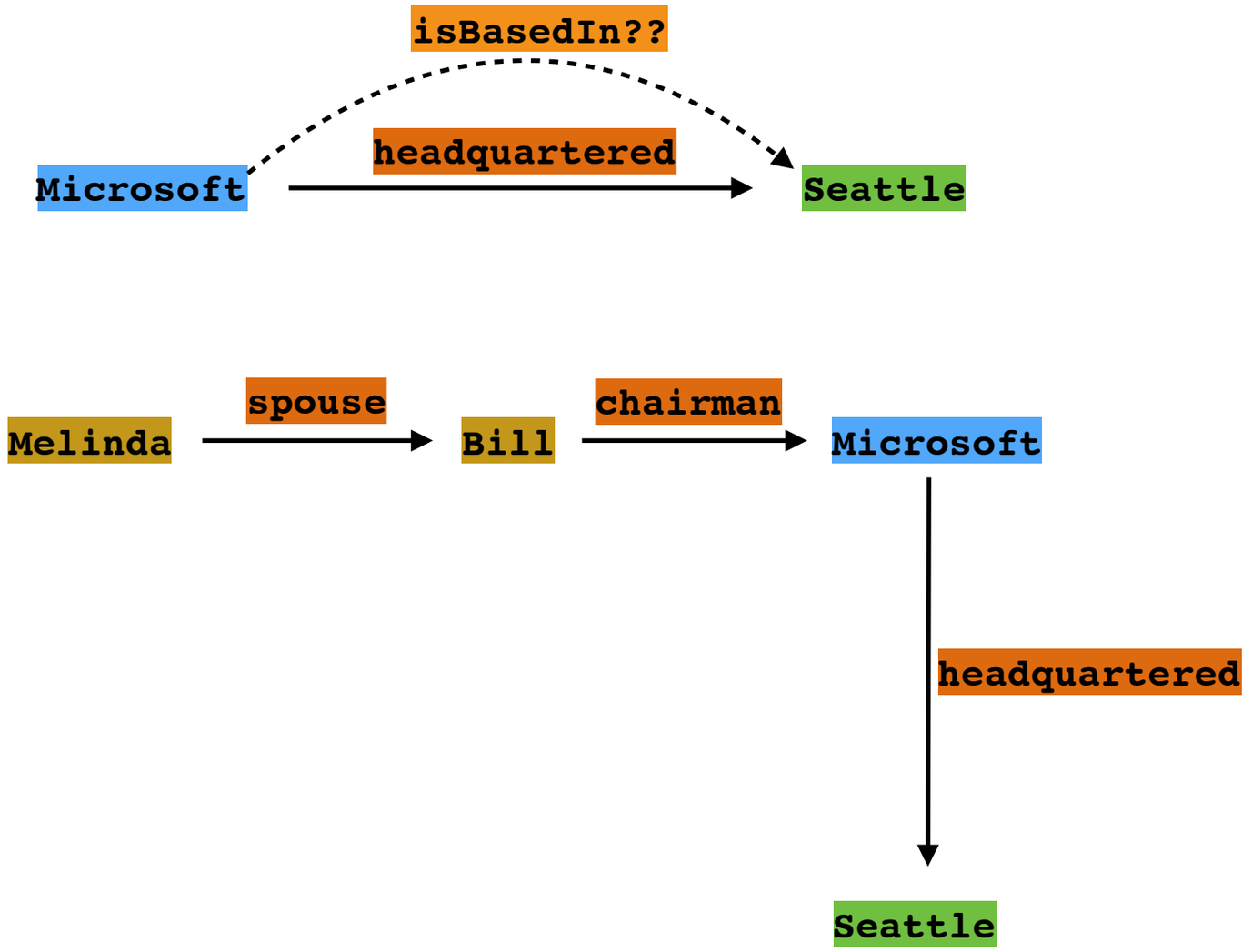
Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. Bill and Melinda were married in a ceremony in Hawaii, rather than her hometown of Dallas.



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the **Seattle**-**headquartered** software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**

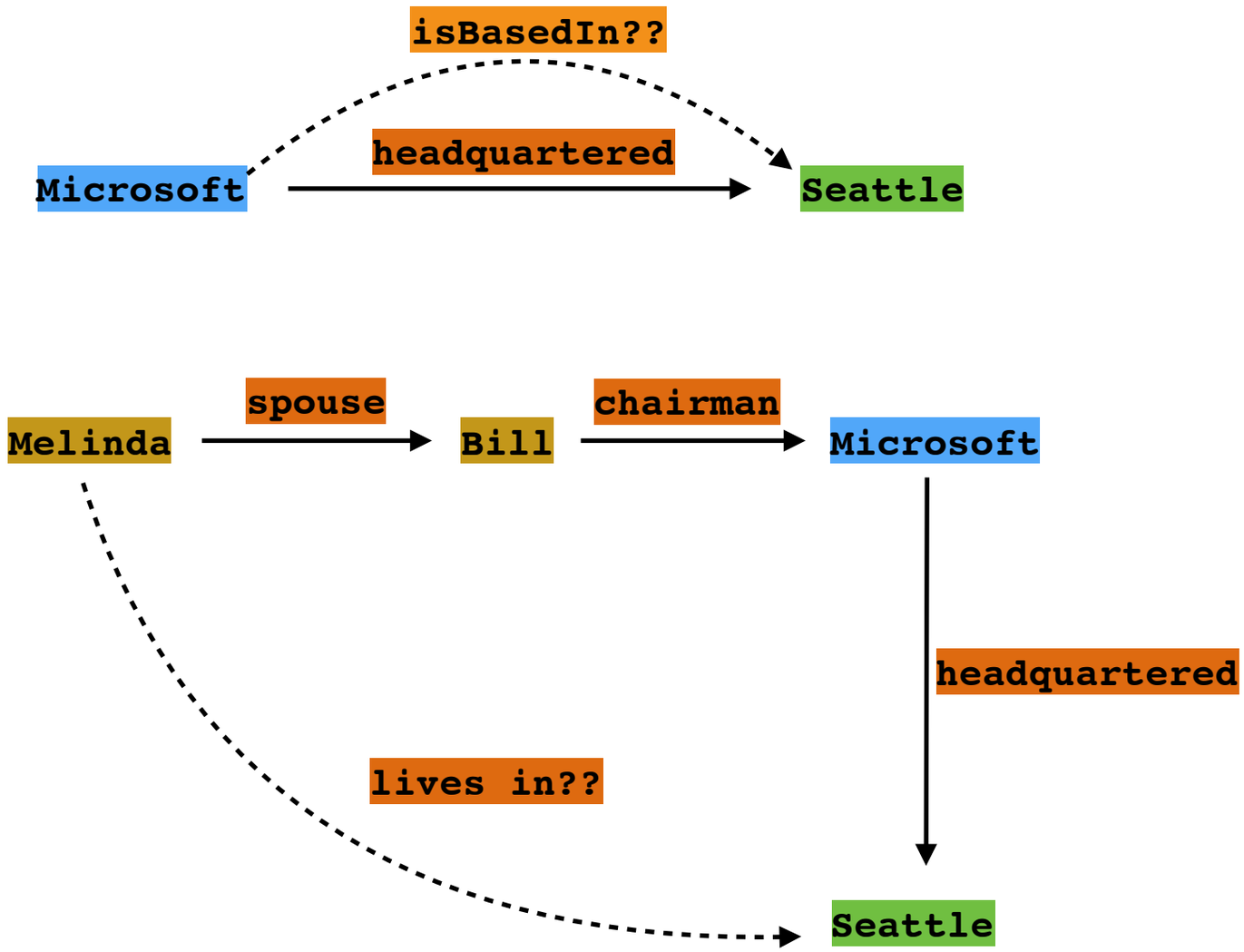
Gates will now focus on the charitable foundation he runs with **his** wife **Melinda French Gates**. He will continue to serve as the chairman of **Microsoft**. **Bill** and **Melinda** were married in a ceremony in **Hawaii**, rather than her



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft

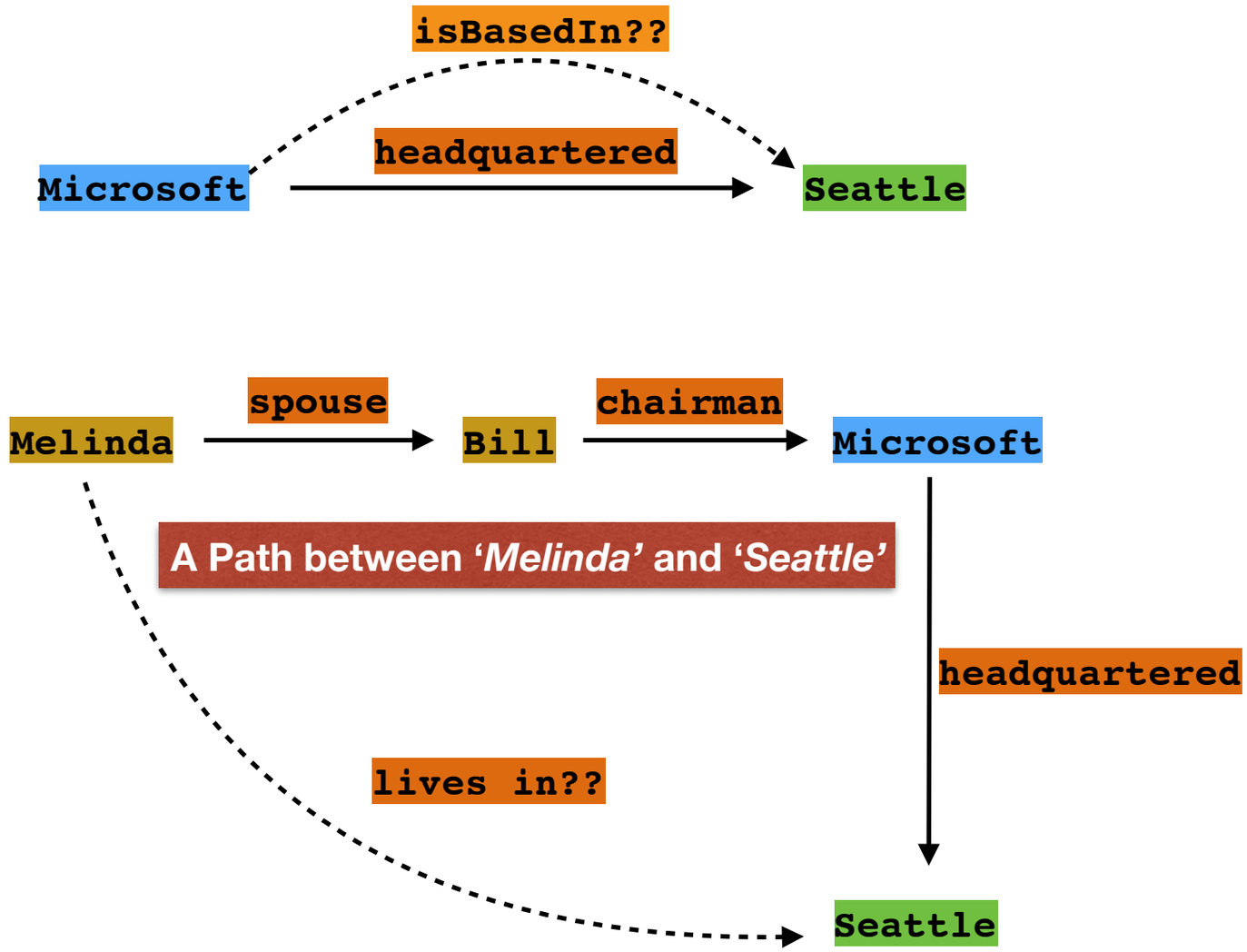
Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. He will continue to serve as the chairman of Microsoft. Bill and Melinda were married in a ceremony in Hawaii, rather than her



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the **Seattle**-**headquartered** software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**

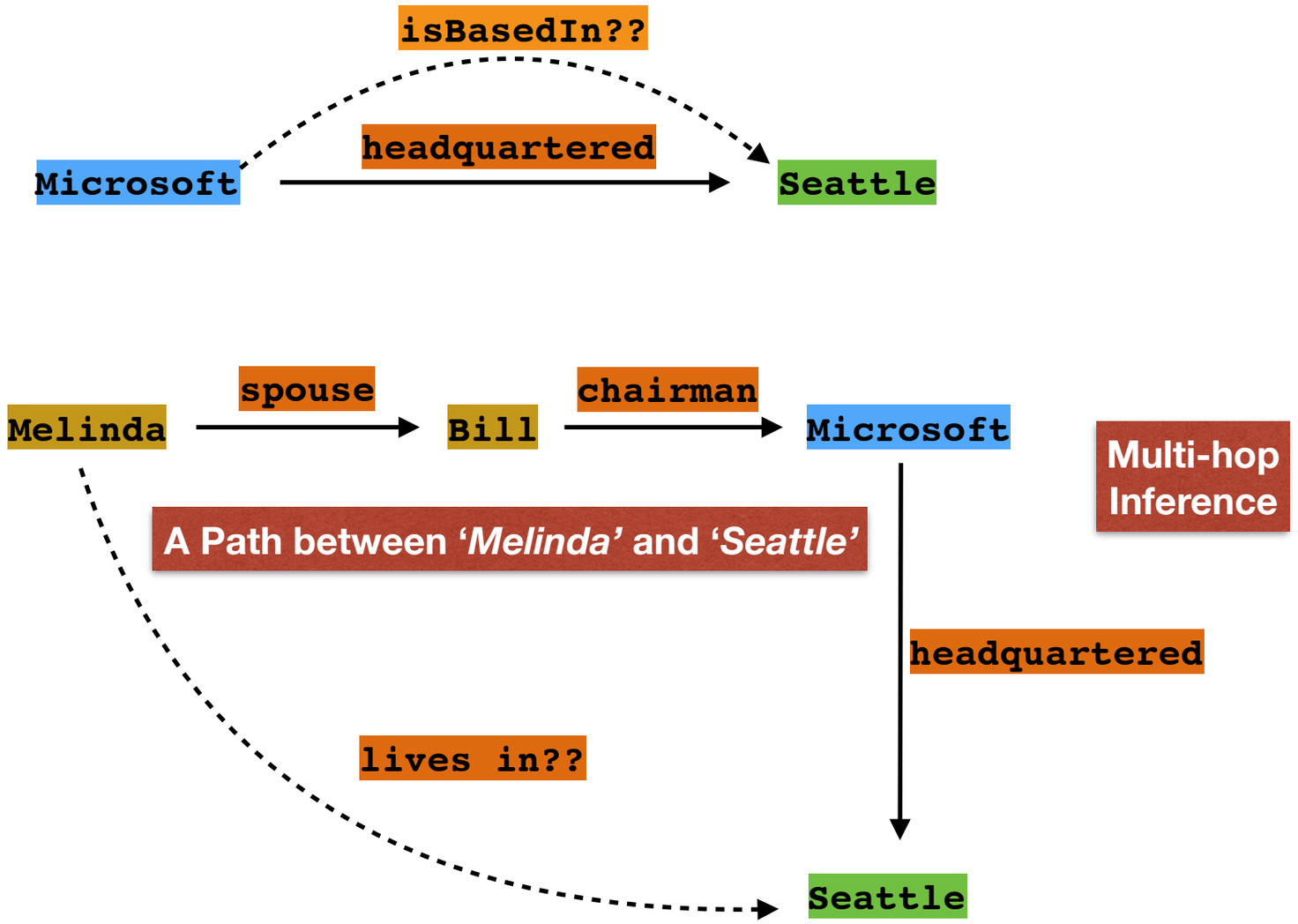
Gates will now focus on the charitable foundation he runs with **his** wife **Melinda French Gates**. He will continue to serve as the chairman of **Microsoft**. **Bill** and **Melinda** were married in a ceremony in **Hawaii**, rather than her



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft

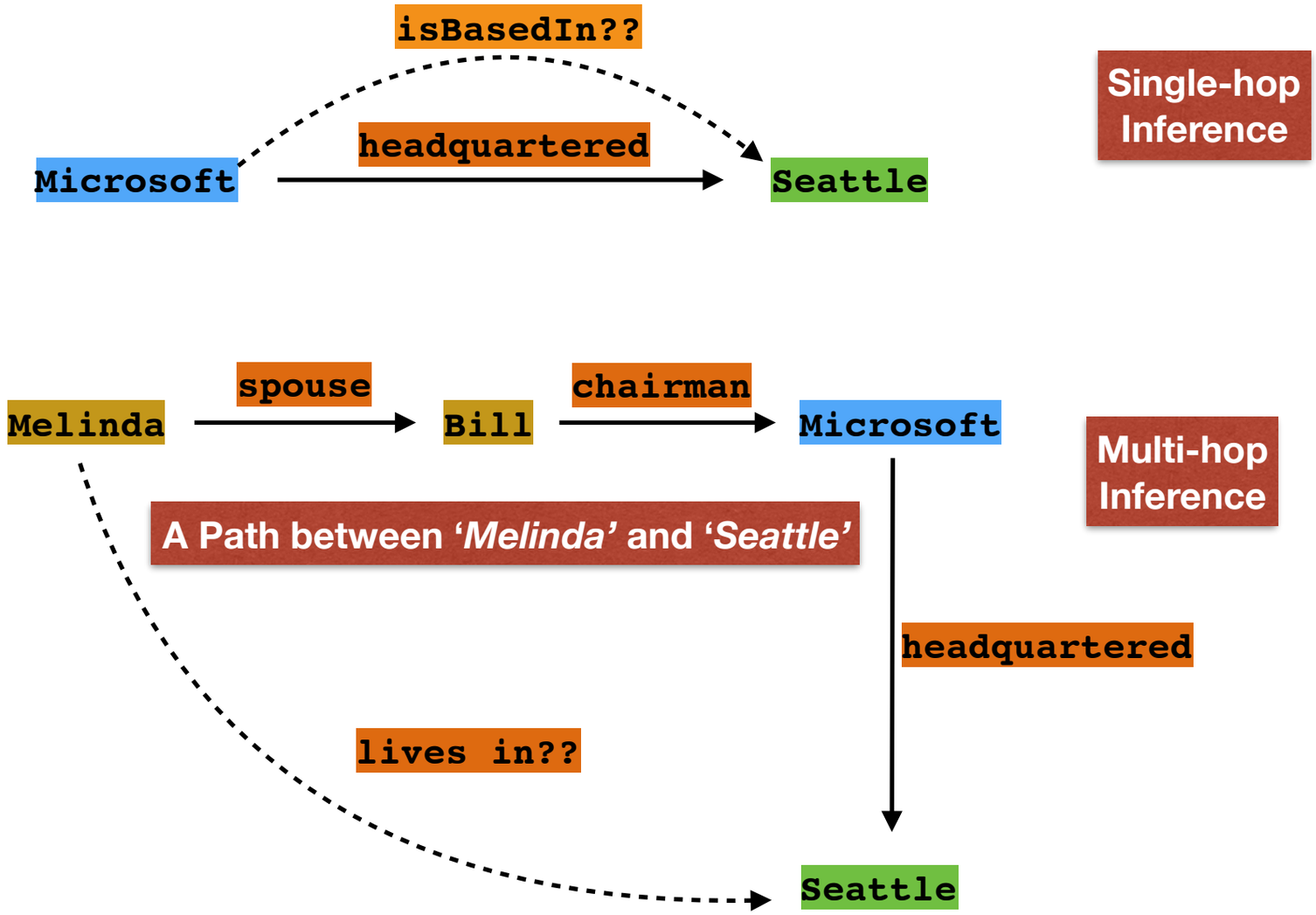
Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. He will continue to serve as the chairman of Microsoft. Bill and Melinda were married in a ceremony in Hawaii, rather than her



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft

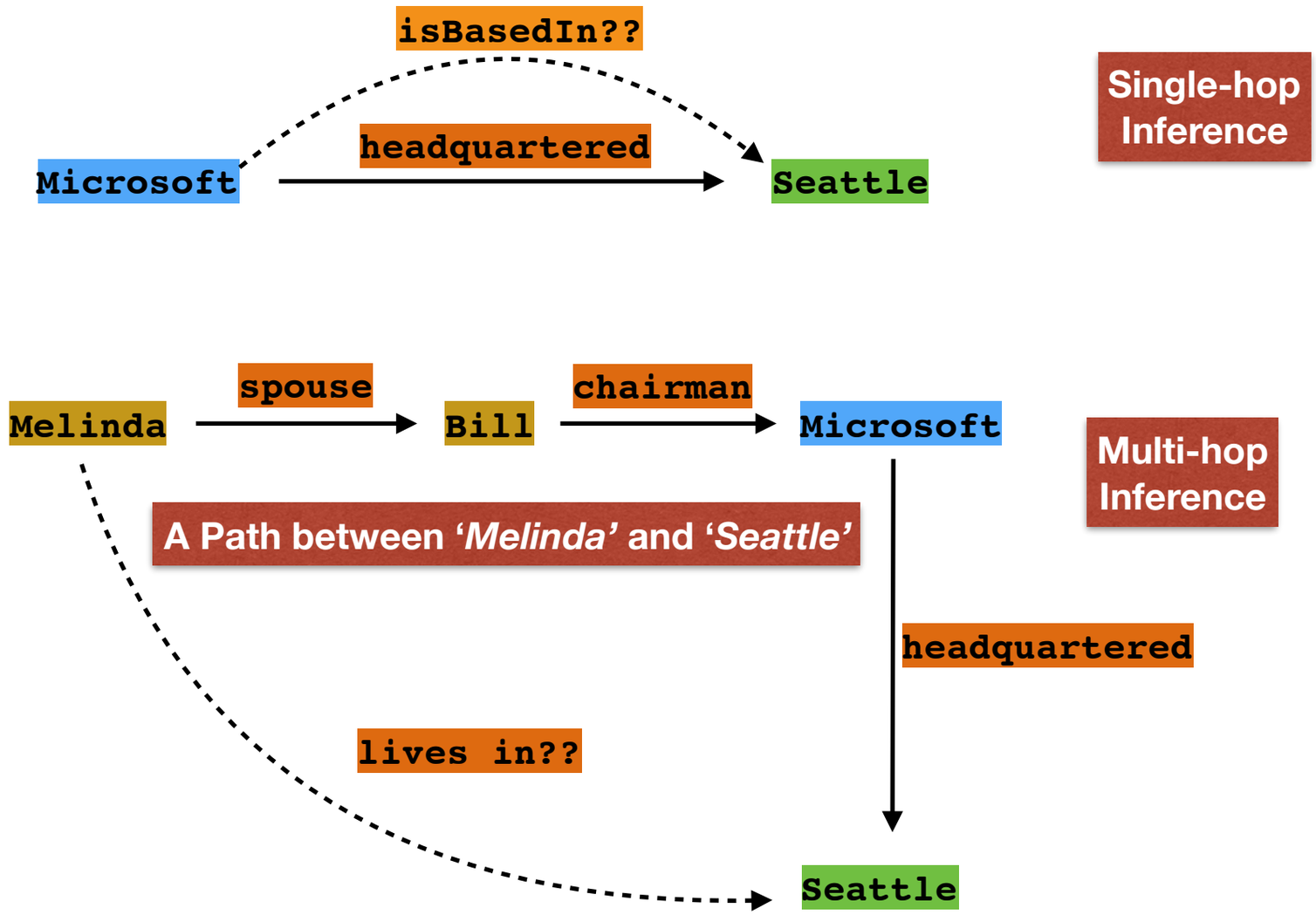
Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. He will continue to serve as the chairman of Microsoft. Bill and Melinda were married in a ceremony in Hawaii, rather than her



Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the **Seattle**-**headquartered** software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**

Gates will now focus on the charitable foundation he runs with **his** wife **Melinda French Gates**. He will continue to serve as the chairman of **Microsoft**. **Bill** and **Melinda** were married in a ceremony in **Hawaii**, rather than her

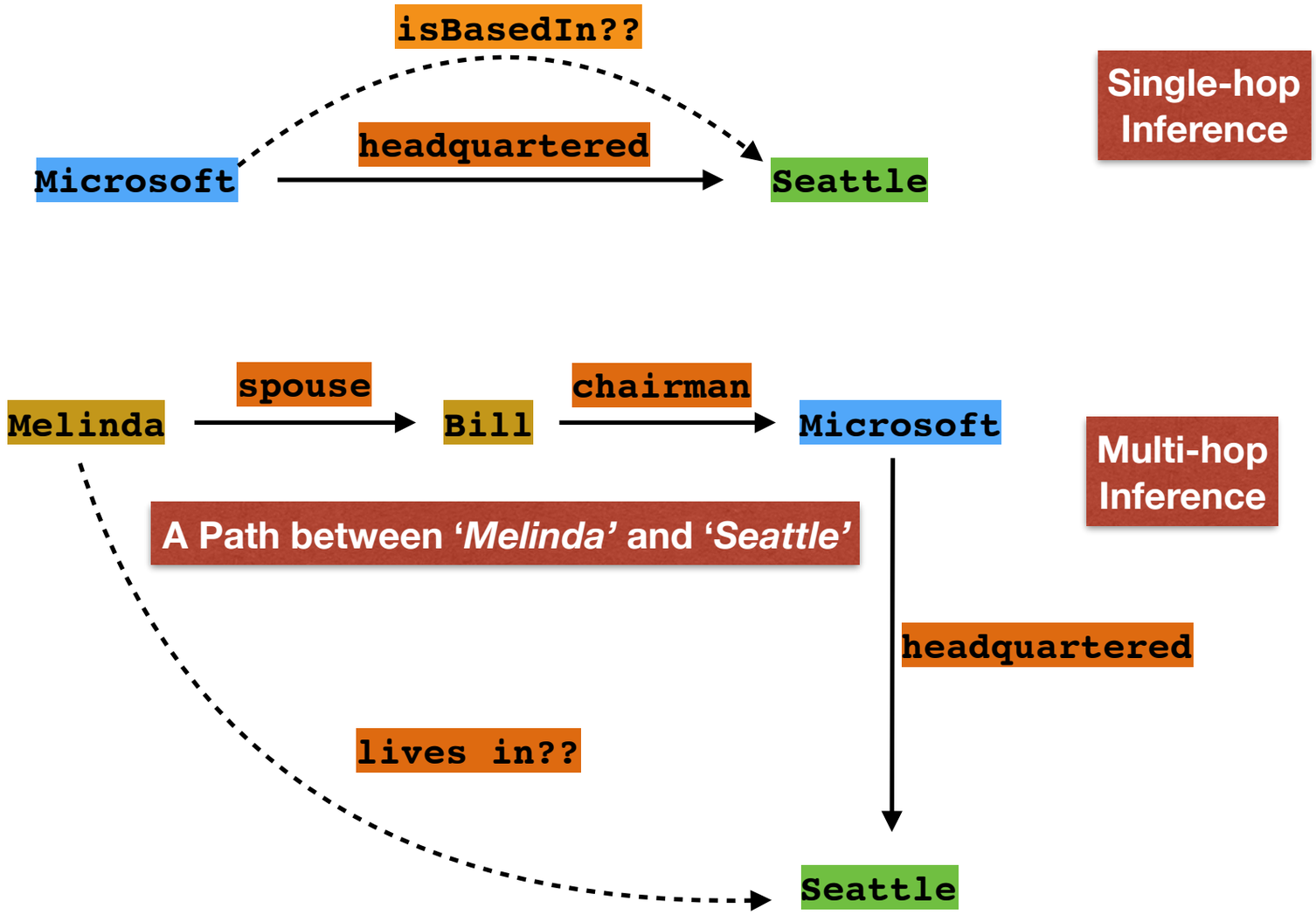


Spouse(A,B) & Chairman(B,C) & HQ-in(C,D) → Lives-in(A,D)

Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the **Seattle**-**headquartered** software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**

Gates will now focus on the charitable foundation he runs with **his** wife **Melinda French Gates**. He will continue to serve as the chairman of **Microsoft**. **Bill** and **Melinda** were married in a ceremony in **Hawaii**, rather than her



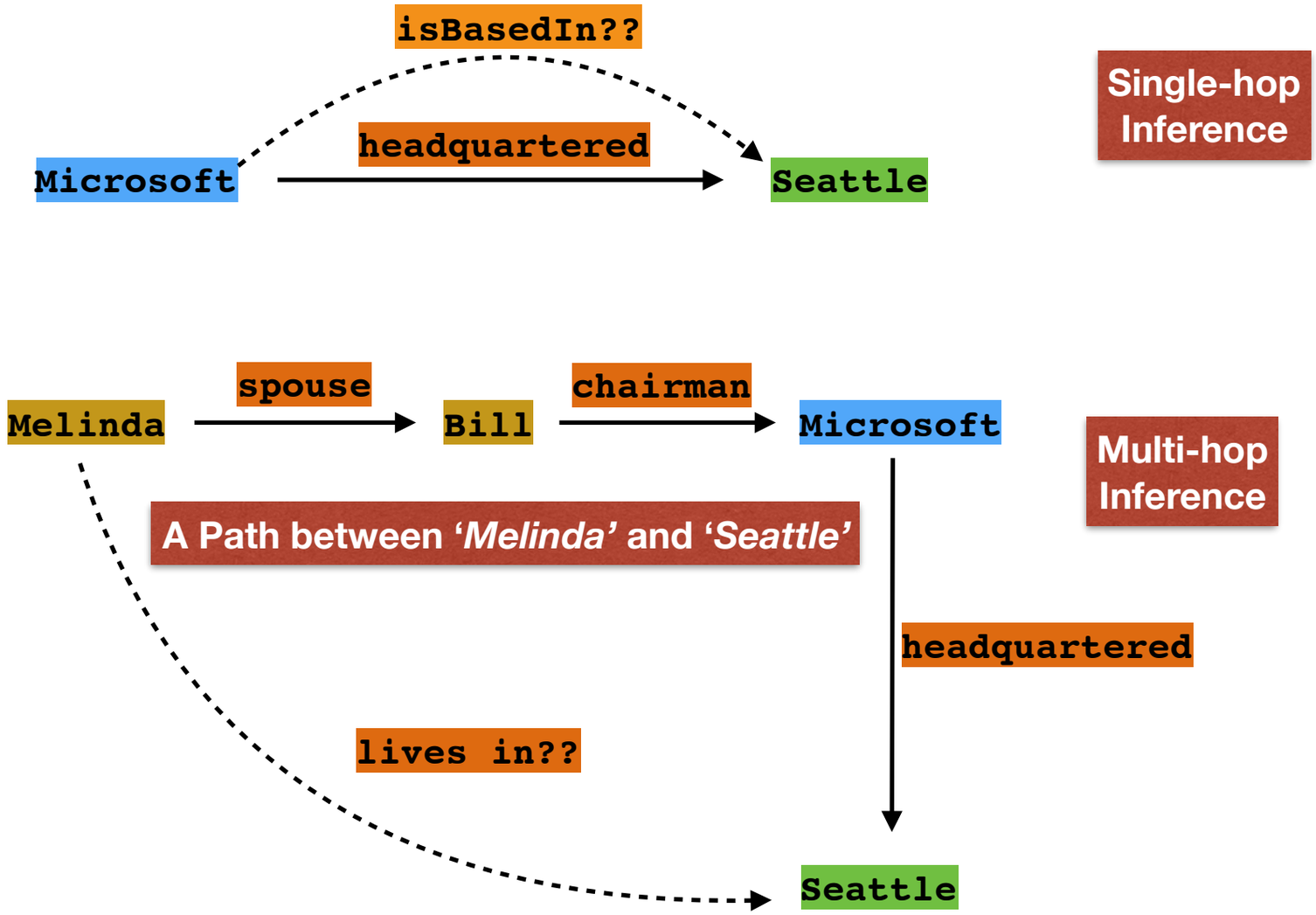
- **Sherlock** (Schoenmackers et al. 2010)
- **Path Ranking Algorithm**(Lao et al, 2011, 2012),

Spouse(A,B) & Chairman(B,C) & HQ-in(C,D) → Lives-in(A,D)

Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft

Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. He will continue to serve as the chairman of Microsoft. Bill and Melinda were married in a ceremony in Hawaii, rather than her



- **Sherlock** (Schoenmackers et al. 2010)
- **Path Ranking Algorithm**(Lao et al, 2011, 2012),

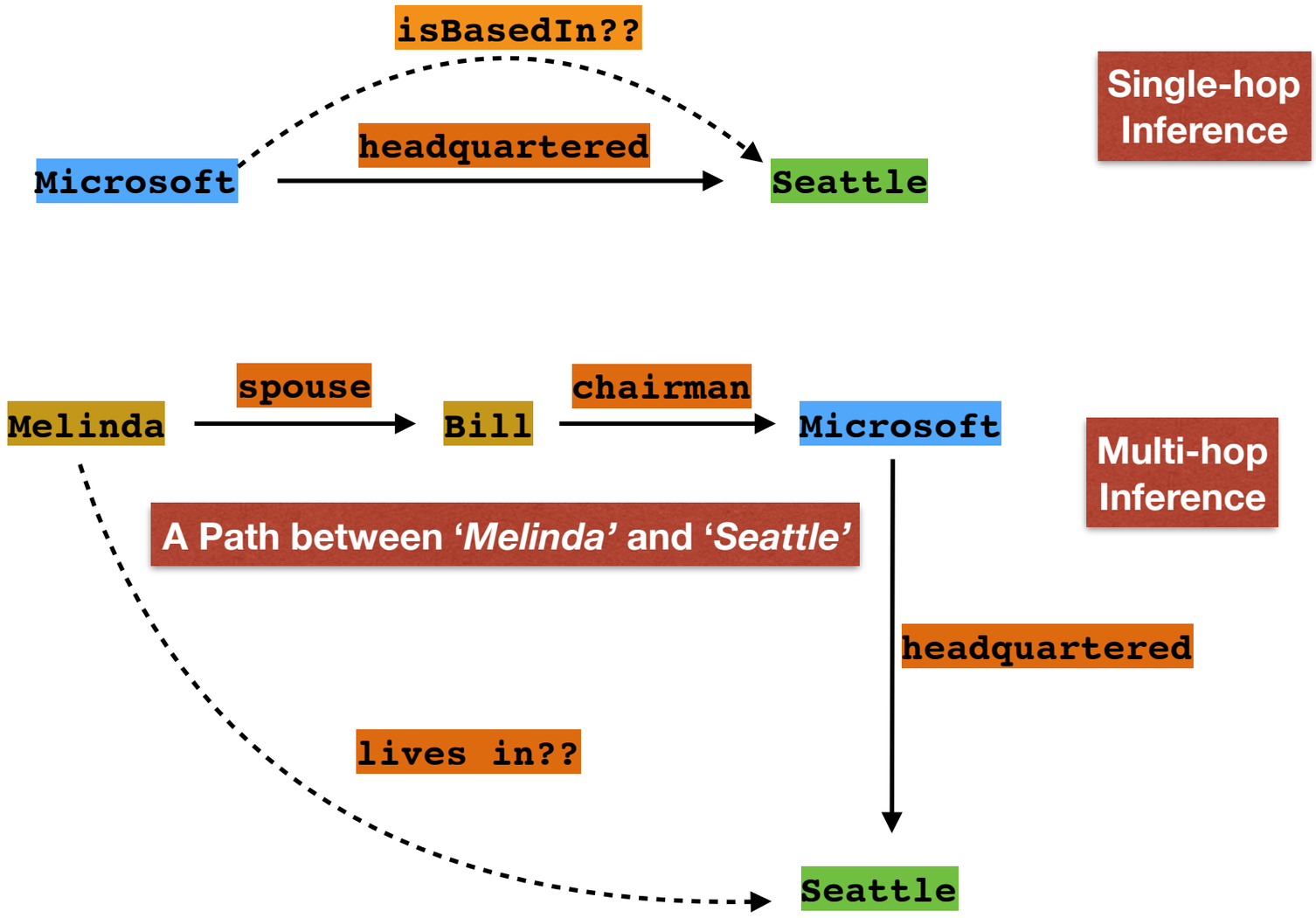
Spouse(A,B) & Chairman(B,C) & HQ-in(C,D) → Lives-in(A,D)

Symbolic;
Doesn't generalize

Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft

Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. He will continue to serve as the chairman of Microsoft. Bill and Melinda were married in a ceremony in Hawaii, rather than her



- **Sherlock** (Schoenmackers et al. 2010)
- **Path Ranking Algorithm**(Lao et al, 2011, 2012),

Spouse(A,B) & Chairman(B,C) & HQ-in(C,D) → Lives-in(A,D)

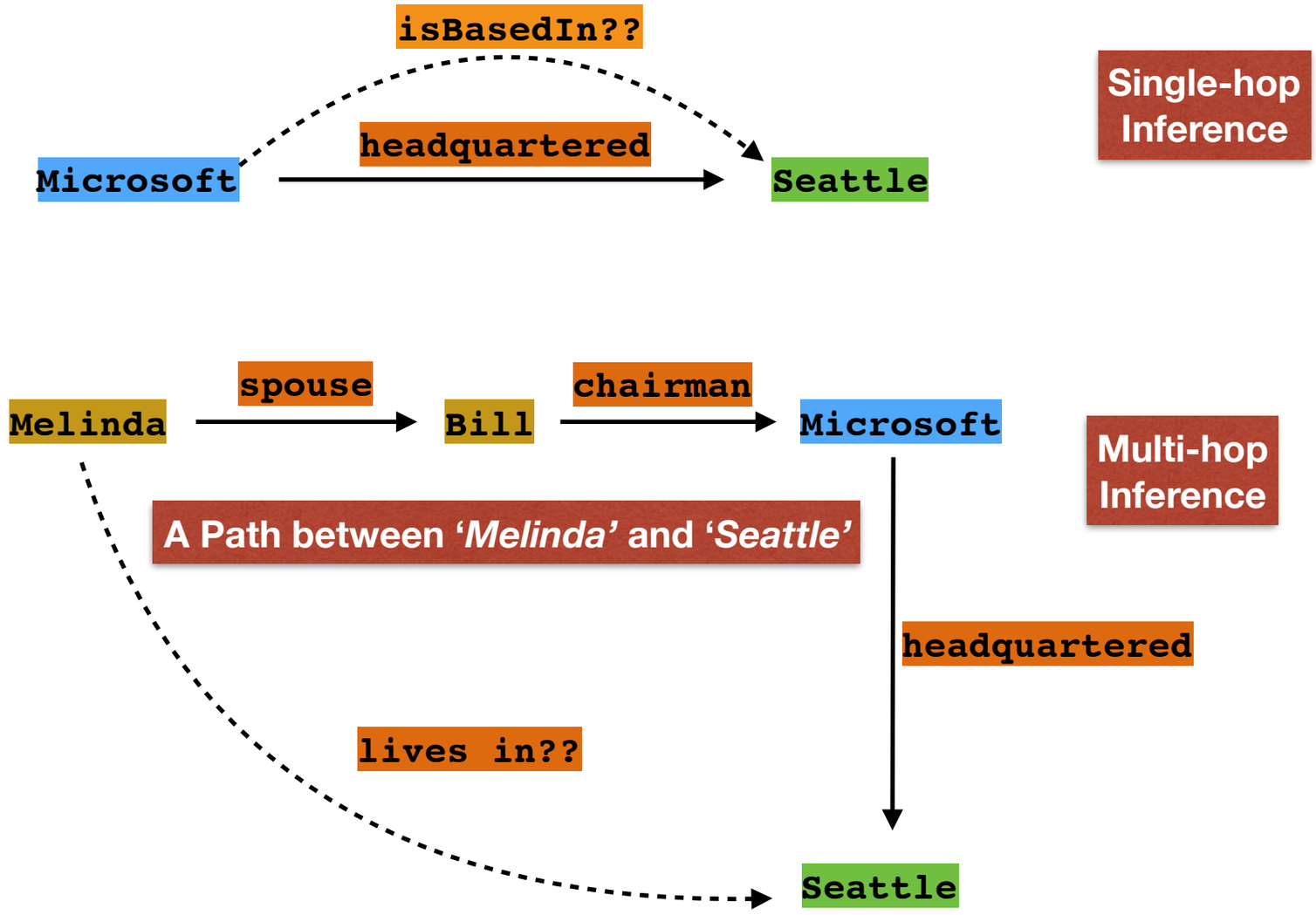
Spouse(A,B) & CEO(B,C) & HQ-in(C,D) → Lives-in(A,D)

Symbolic; Doesn't generalize

Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer **Bill Gates** stepped down today as chief executive officer of **Microsoft**, the **Seattle**-**headquartered** software giant. **His** long-time friend, **Steve Balmer**, will take over as CEO of **Microsoft**

Gates will now focus on the charitable foundation he runs with **his** wife **Melinda French Gates**. He will continue to serve as the chairman of **Microsoft**. **Bill** and **Melinda** were married in a ceremony in **Hawaii**, rather than her



- **Sherlock** (Schoenmackers et al. 2010)
- **Path Ranking Algorithm**(Lao et al, 2011, 2012),

Spouse(A,B) & Chairman(B,C) & HQ-in(C,D) → Lives-in(A,D)

Spouse(A,B) & **CEO(B,C)** & HQ-in(C,D) → Lives-in(A,D)

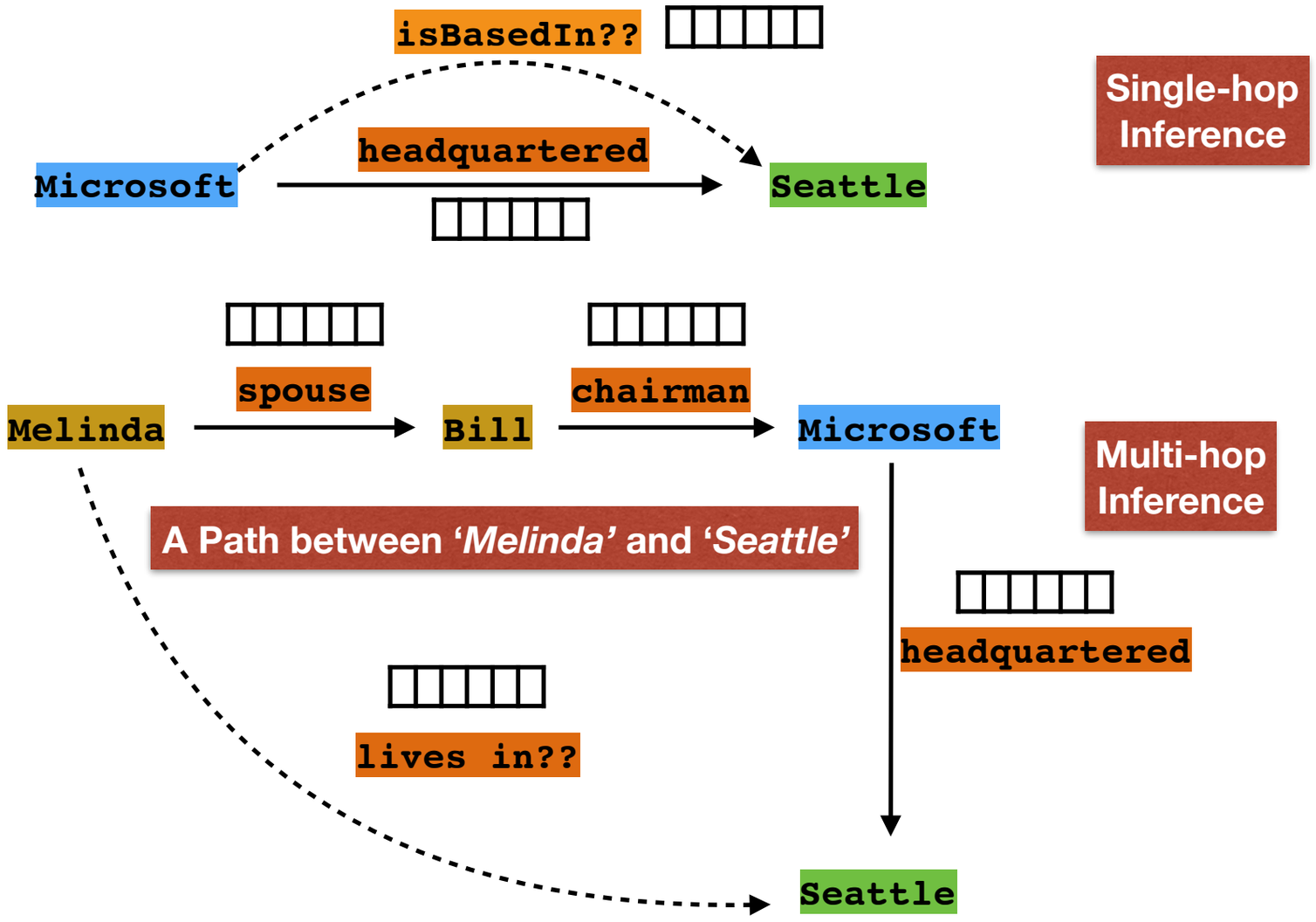
Spouse(A,B) & **COO(B,C)** & HQ-in(C,D) → Lives-in(A,D)

Symbolic;
Doesn't generalize

Chains of Reasoning for Relation Extraction

January 15, 2000
Tech pioneer Bill Gates stepped down today as chief executive officer of Microsoft, the Seattle-headquartered software giant. His long-time friend, Steve Balmer, will take over as CEO of Microsoft

Gates will now focus on the charitable foundation he runs with his wife Melinda French Gates. He will continue to serve as the chairman of Microsoft. Bill and Melinda were married in a ceremony in Hawaii, rather than her



- **Sherlock** (Schoenmackers et al. 2010)
- **Path Ranking Algorithm**(Lao et al, 2011, 2012),

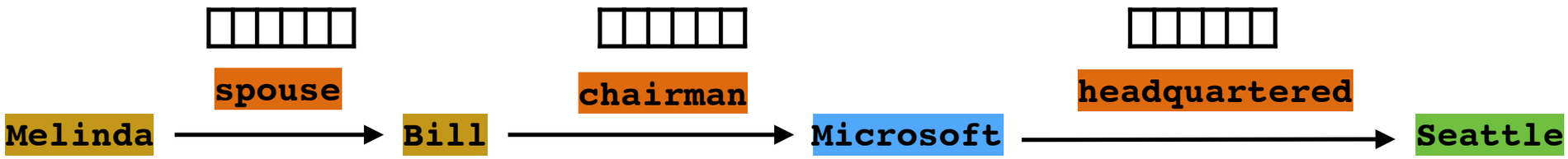
Spouse(A,B) & Chairman(B,C) & HQ-in(C,D) → Lives-in(A,D)

Spouse(A,B) & CEO(B,C) & HQ-in(C,D) → Lives-in(A,D)

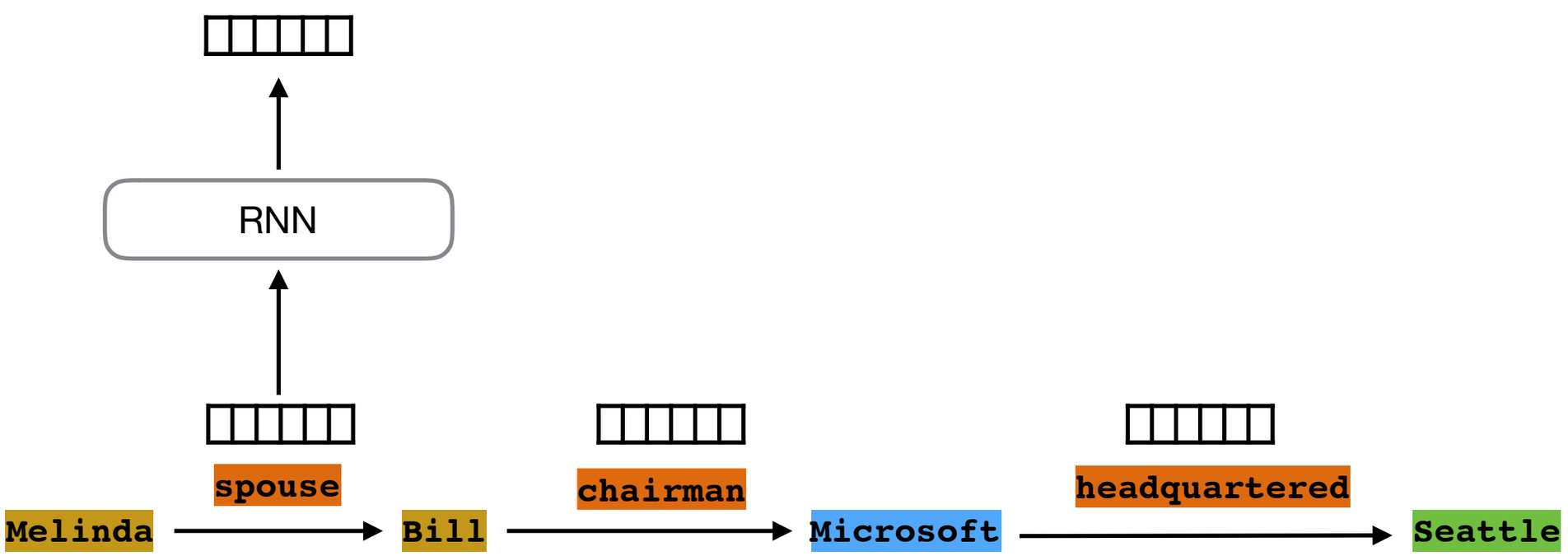
Spouse(A,B) & COO(B,C) & HQ-in(C,D) → Lives-in(A,D)

Symbolic; Doesn't generalize

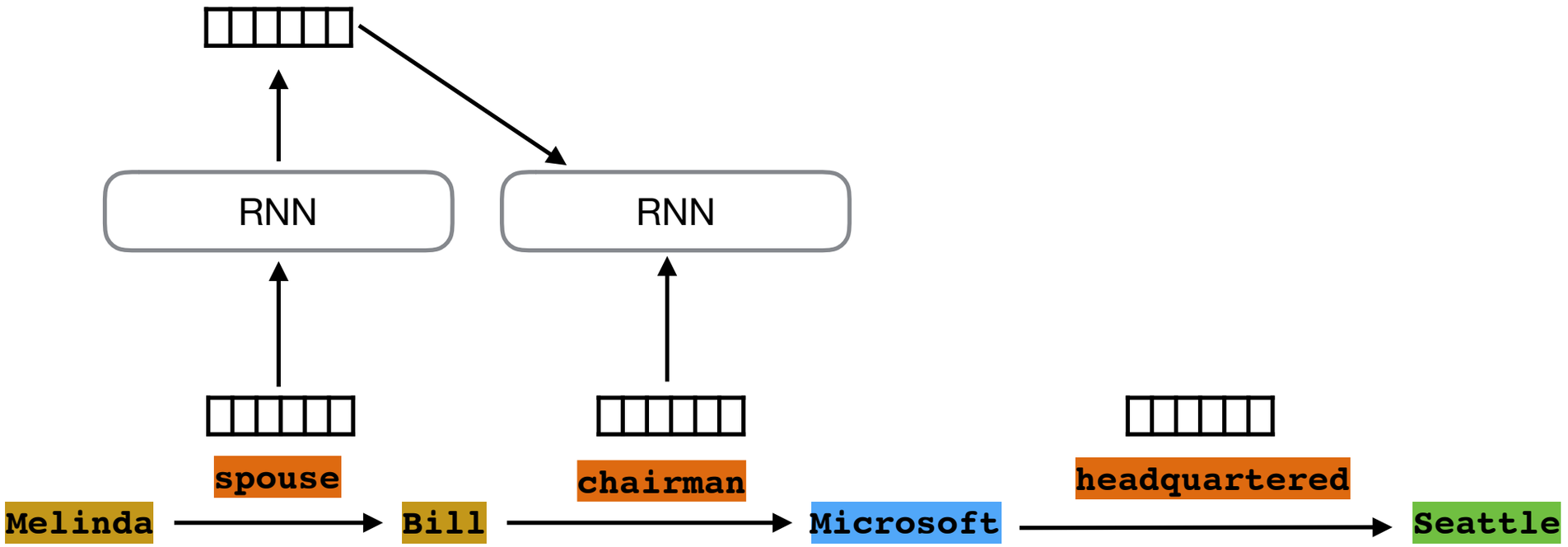
RNNs for Chains of Reasoning



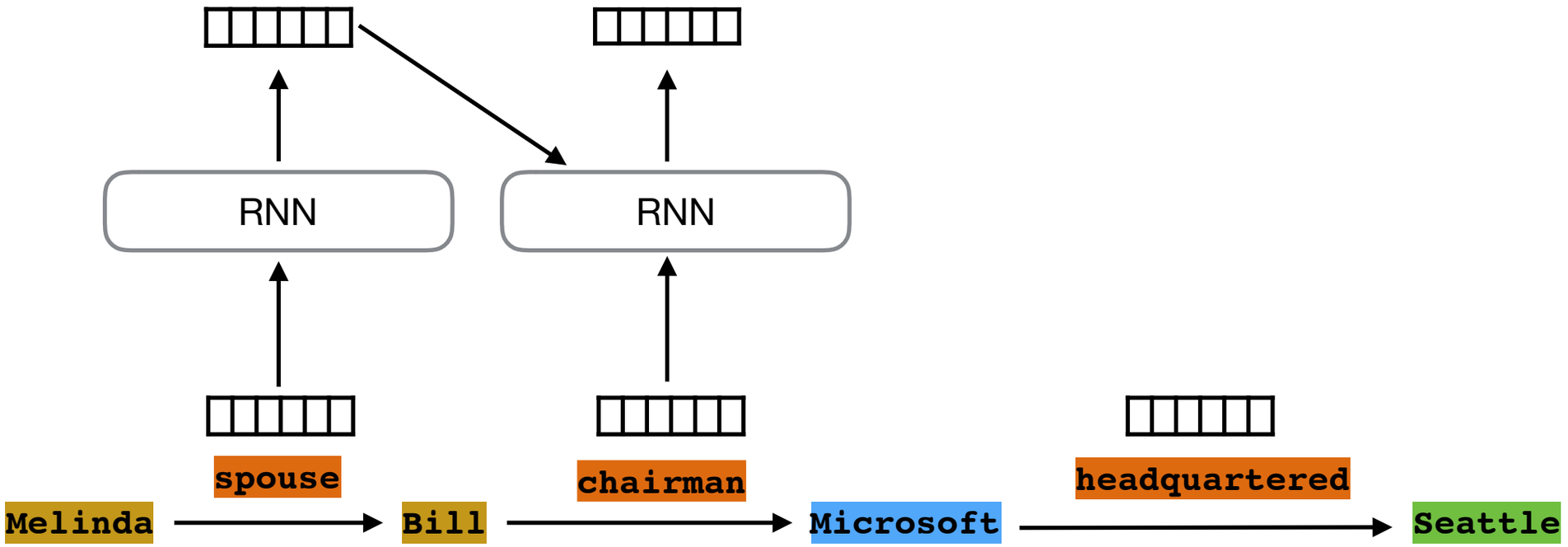
RNNs for Chains of Reasoning



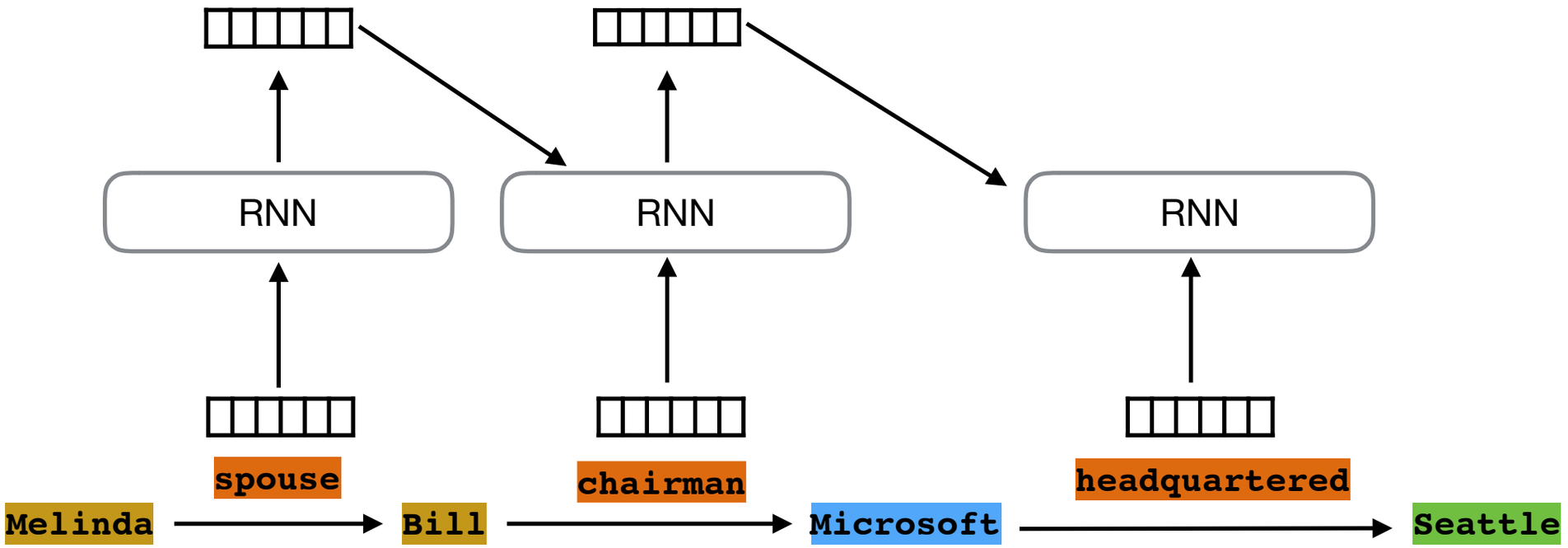
RNNs for Chains of Reasoning



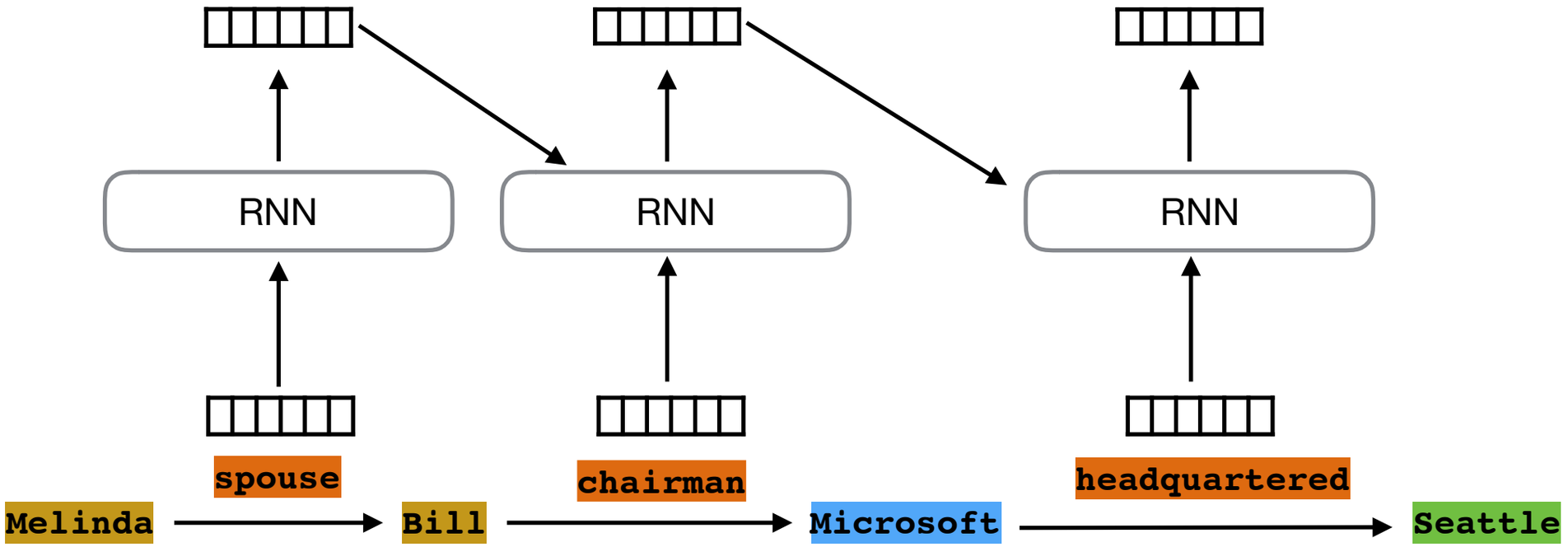
RNNs for Chains of Reasoning



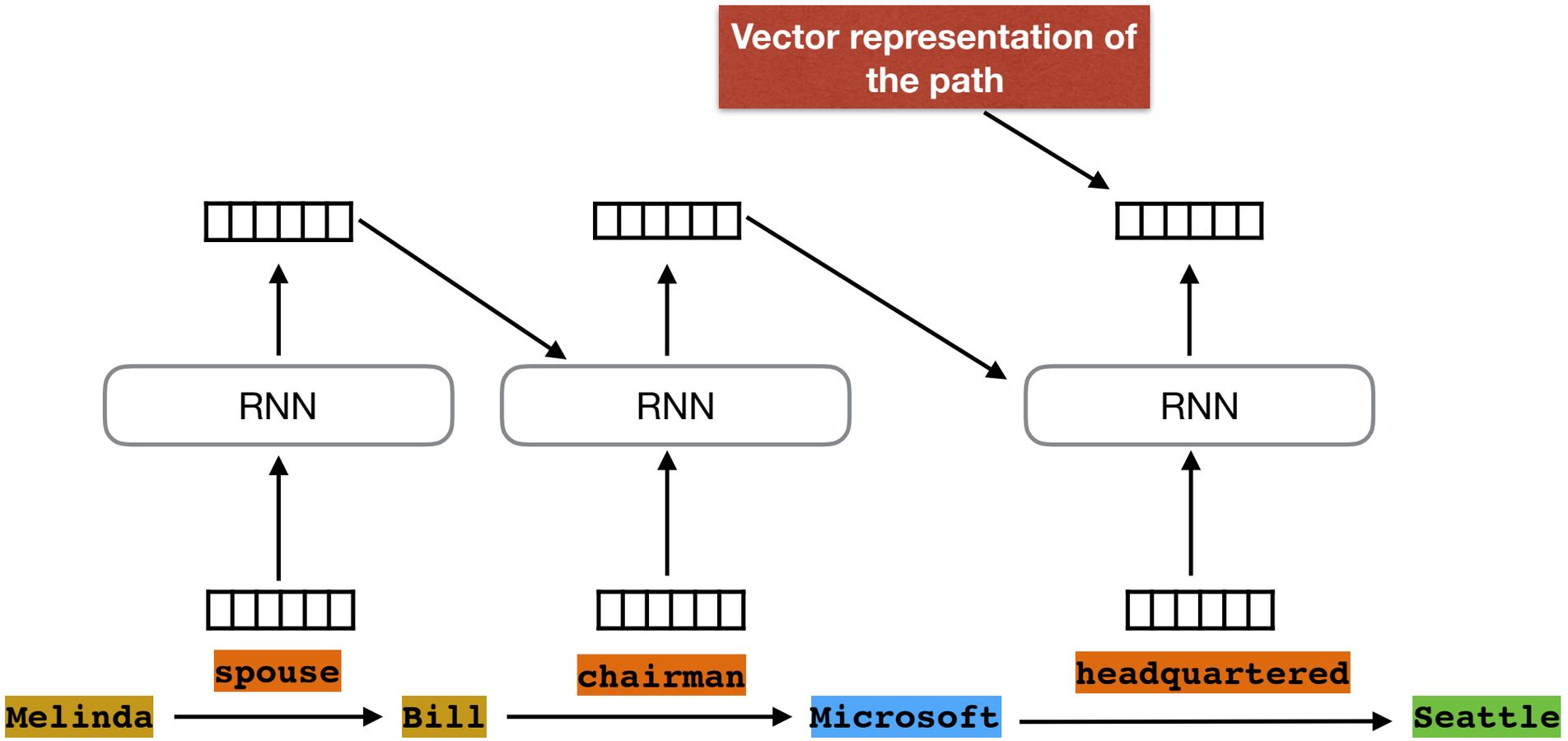
RNNs for Chains of Reasoning



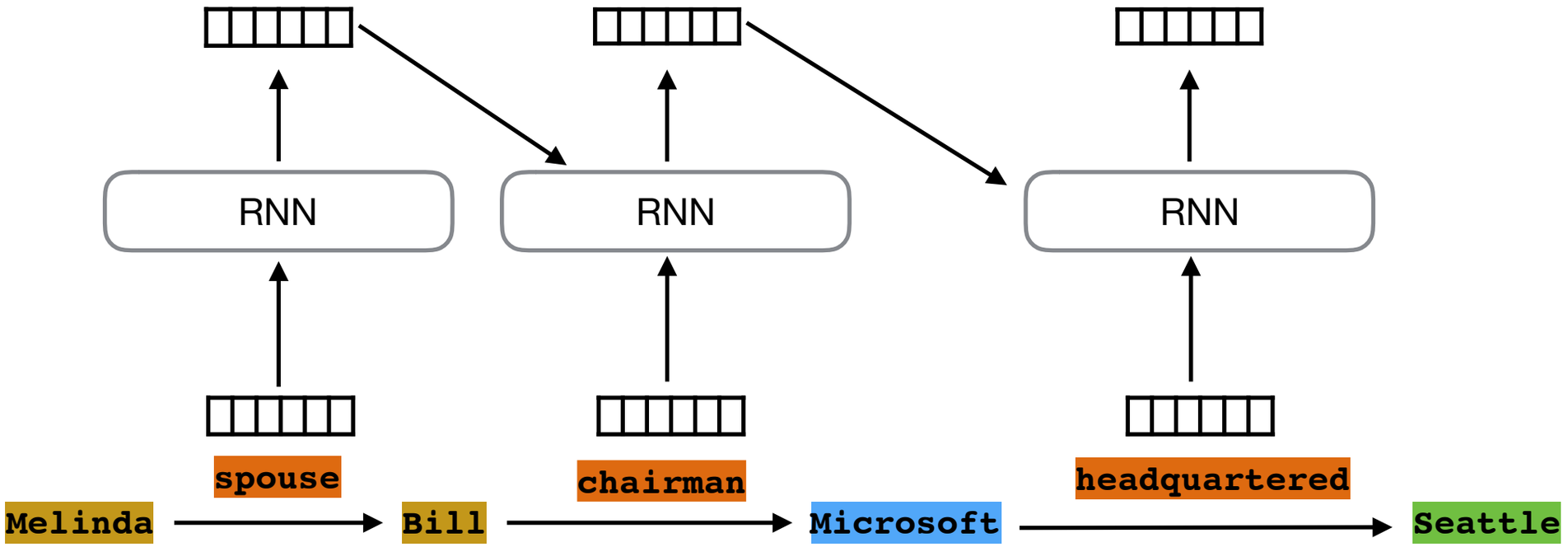
RNNs for Chains of Reasoning



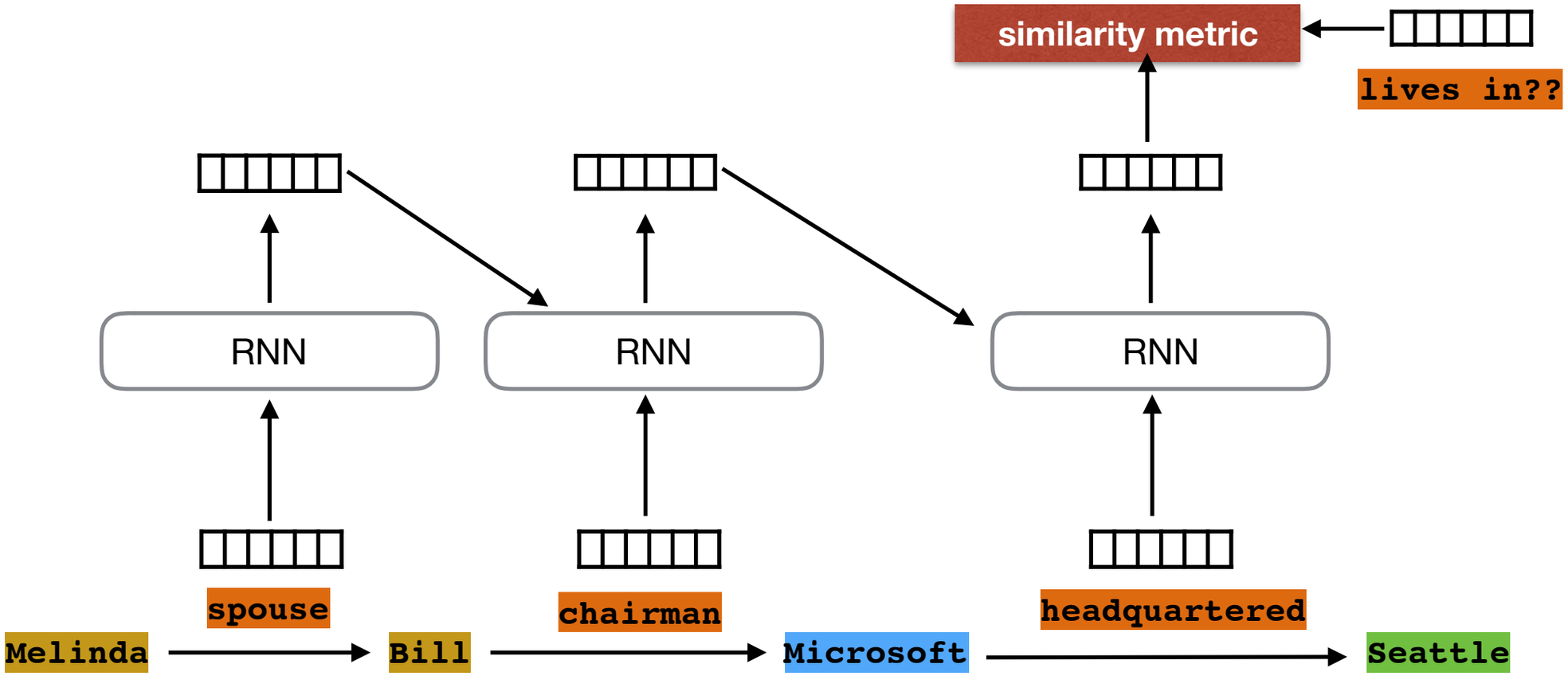
RNNs for Chains of Reasoning



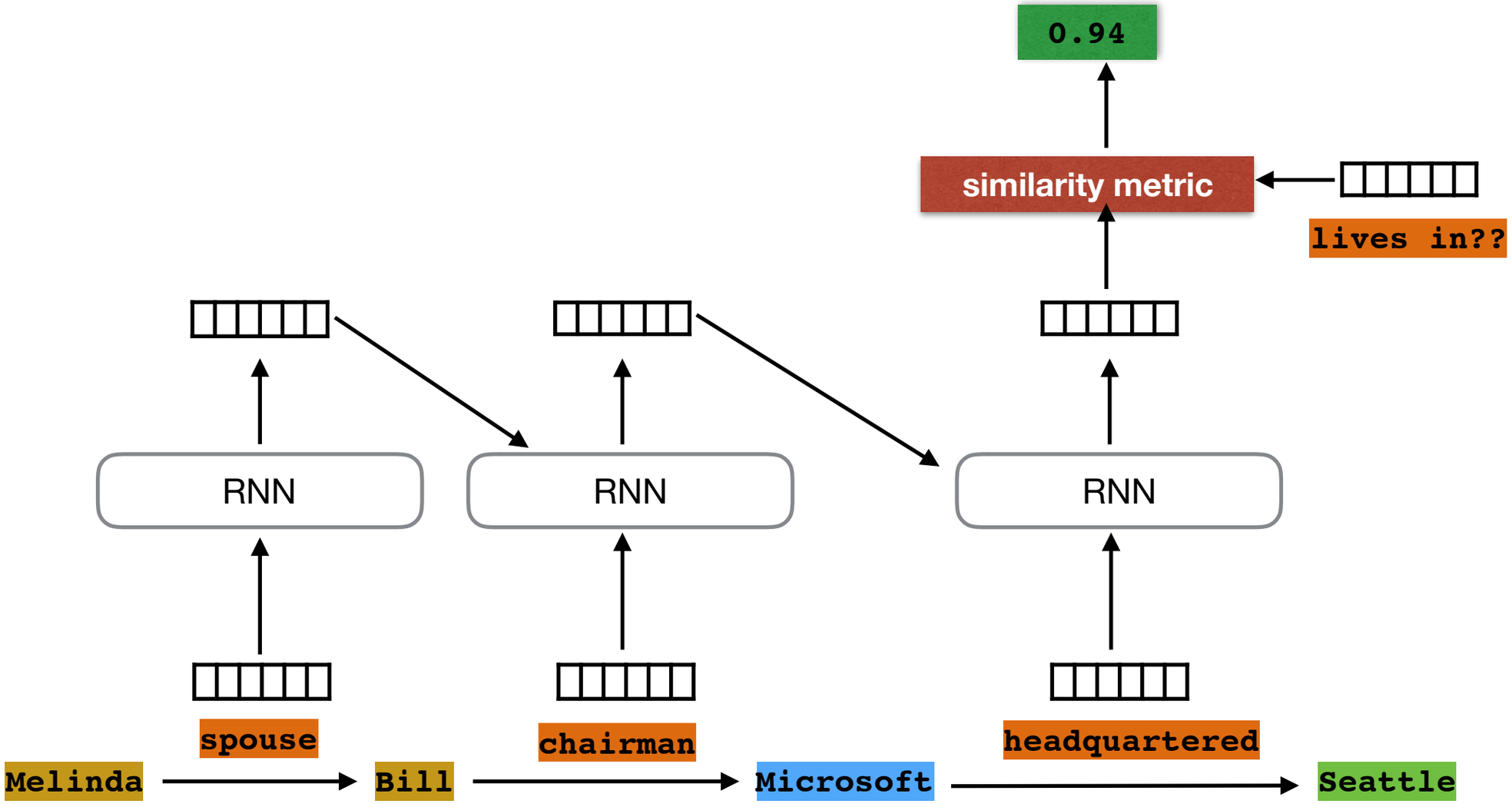
RNNs for Chains of Reasoning



RNNs for Chains of Reasoning

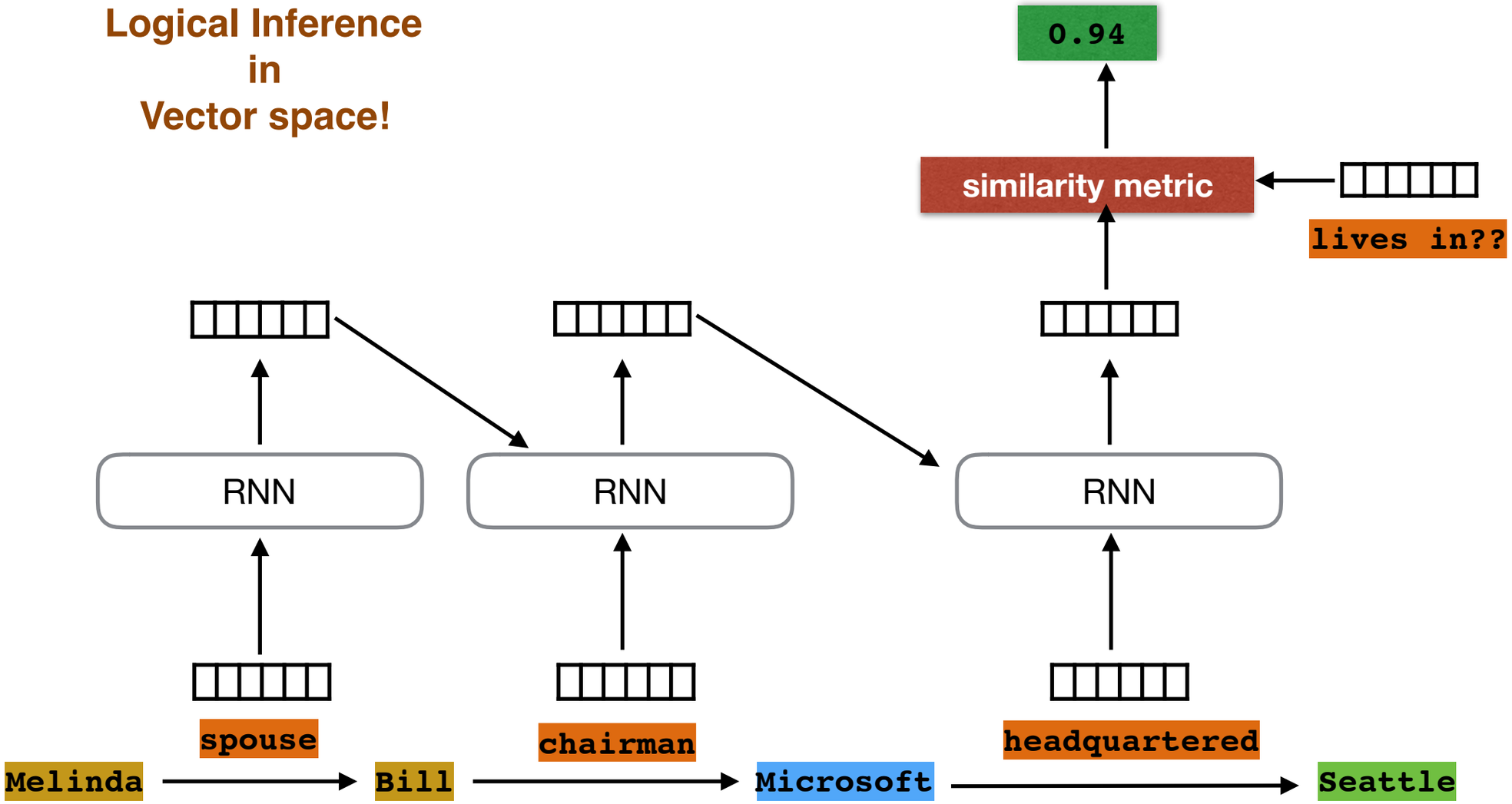


RNNs for Chains of Reasoning



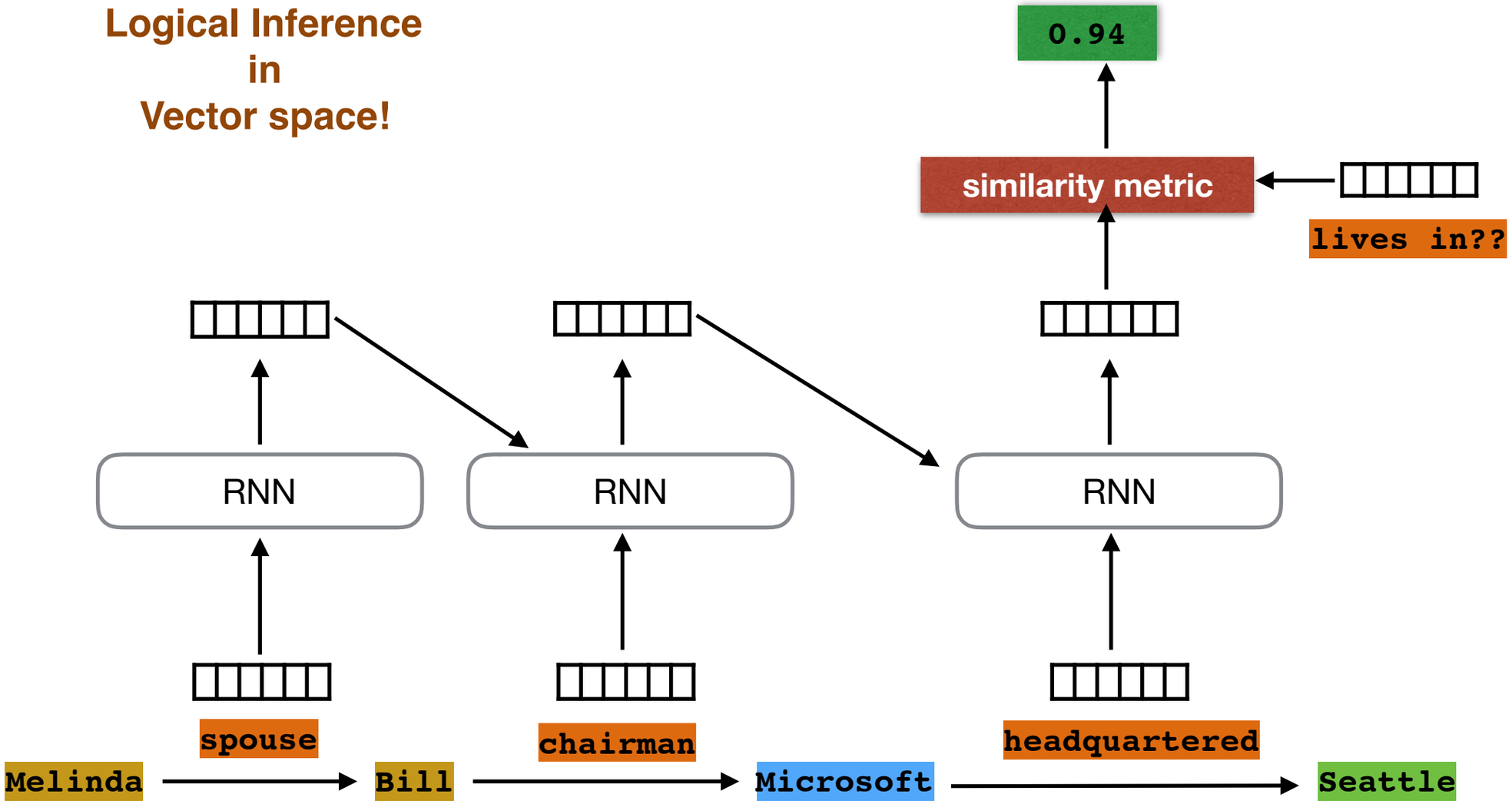
RNNs for Chains of Reasoning

Logical Inference in Vector space!



RNNs for Chains of Reasoning

Logical Inference in Vector space!



Neelakantan et al' 15

Contributions

Contributions

1. Single RNN for chains of reasoning.

Contributions

1. Single RNN for chains of reasoning.

2. Combine evidence from multiple paths between entity pairs.

Contributions

1. Single RNN for chains of reasoning.

2. Combine evidence from multiple paths between entity pairs.

3. Entity Aware RNN for chains of reasoning

Contributions

1. Single RNN for chains of reasoning.

2. Combine evidence from multiple paths between entity pairs.

3. Entity Aware RNN for chains of reasoning

%MAP 64.43% ——————————— **73.26%**

Contributions

1. Single RNN for chains of reasoning.

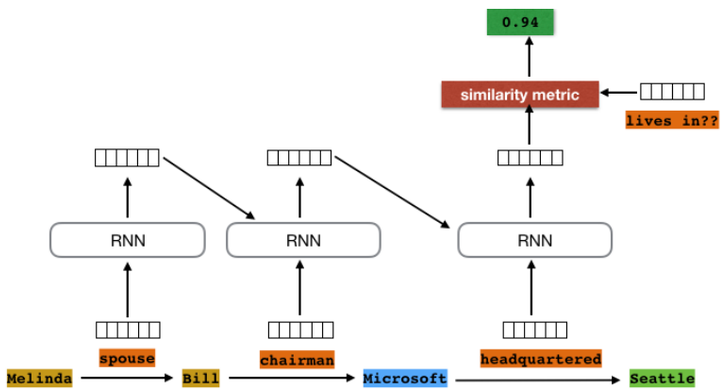
2. Combine evidence from multiple paths between entity pairs.

3. Entity Aware RNN for chains of reasoning

%MAP 64.43% —— 13.7% —— **73.26%**

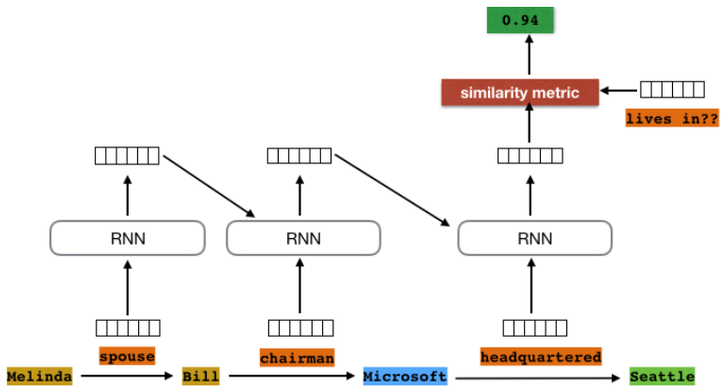
1. Single RNN for chains of reasoning.

1. Single RNN for chains of reasoning.

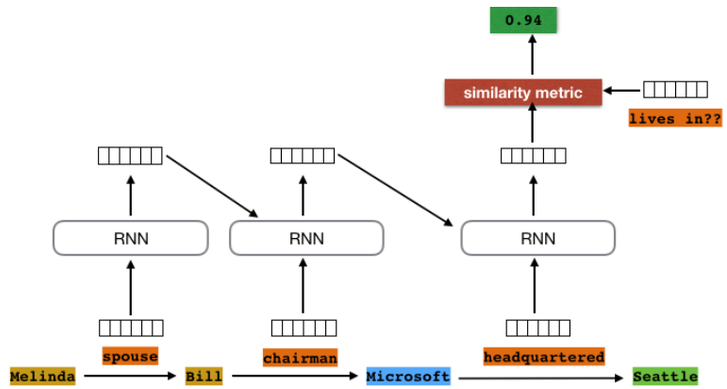


lives in??

1. Single RNN for chains of reasoning.

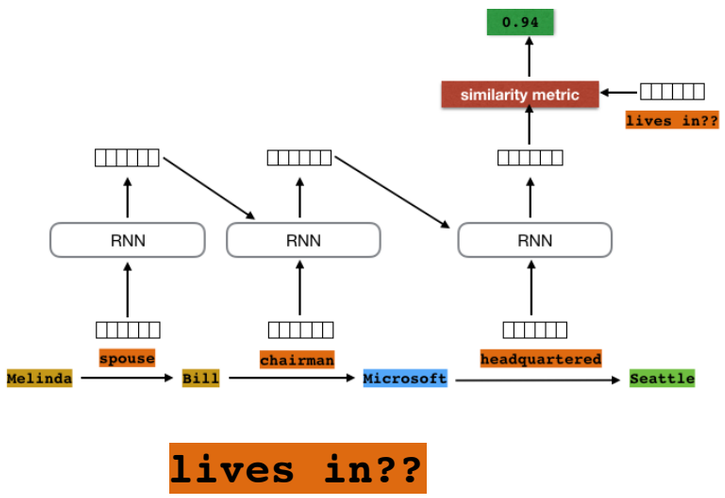


lives in??

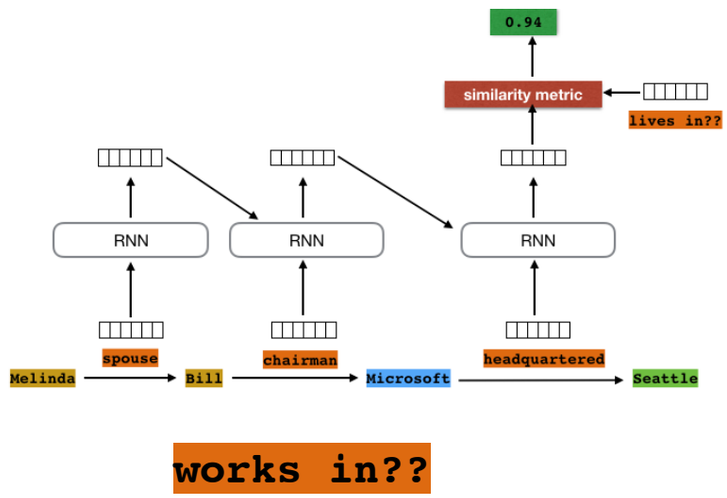


works in??

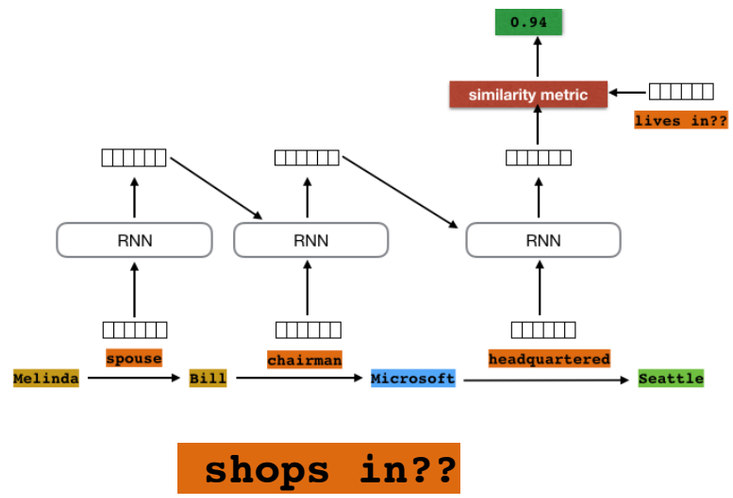
1. Single RNN for chains of reasoning.



lives in??

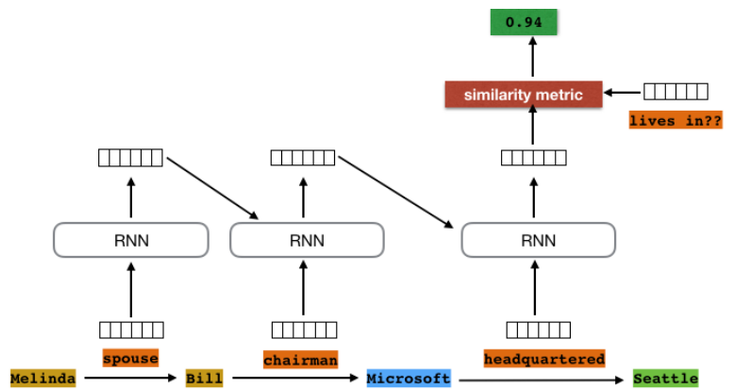


works in??



shops in??

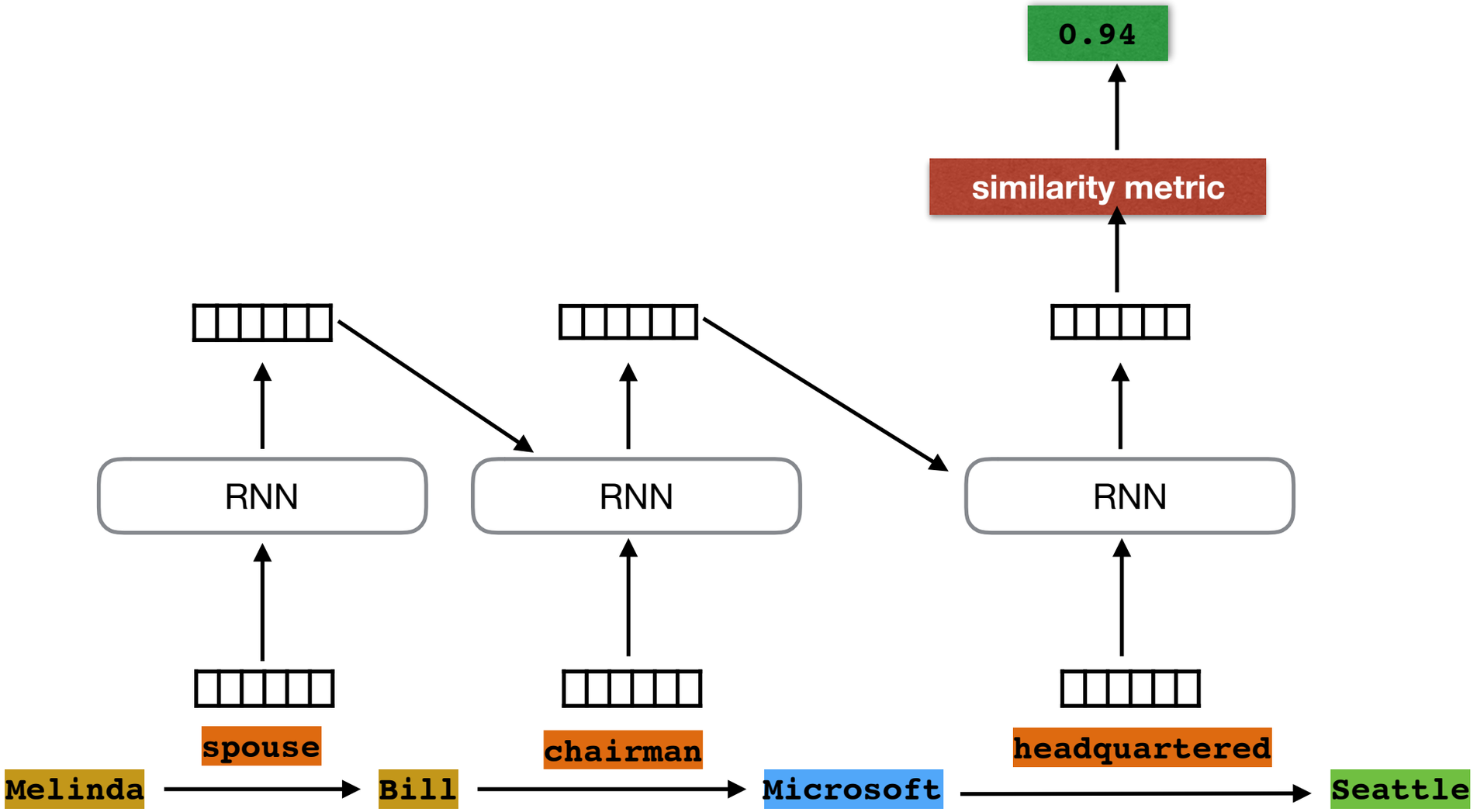
1. Single RNN for chains of reasoning.



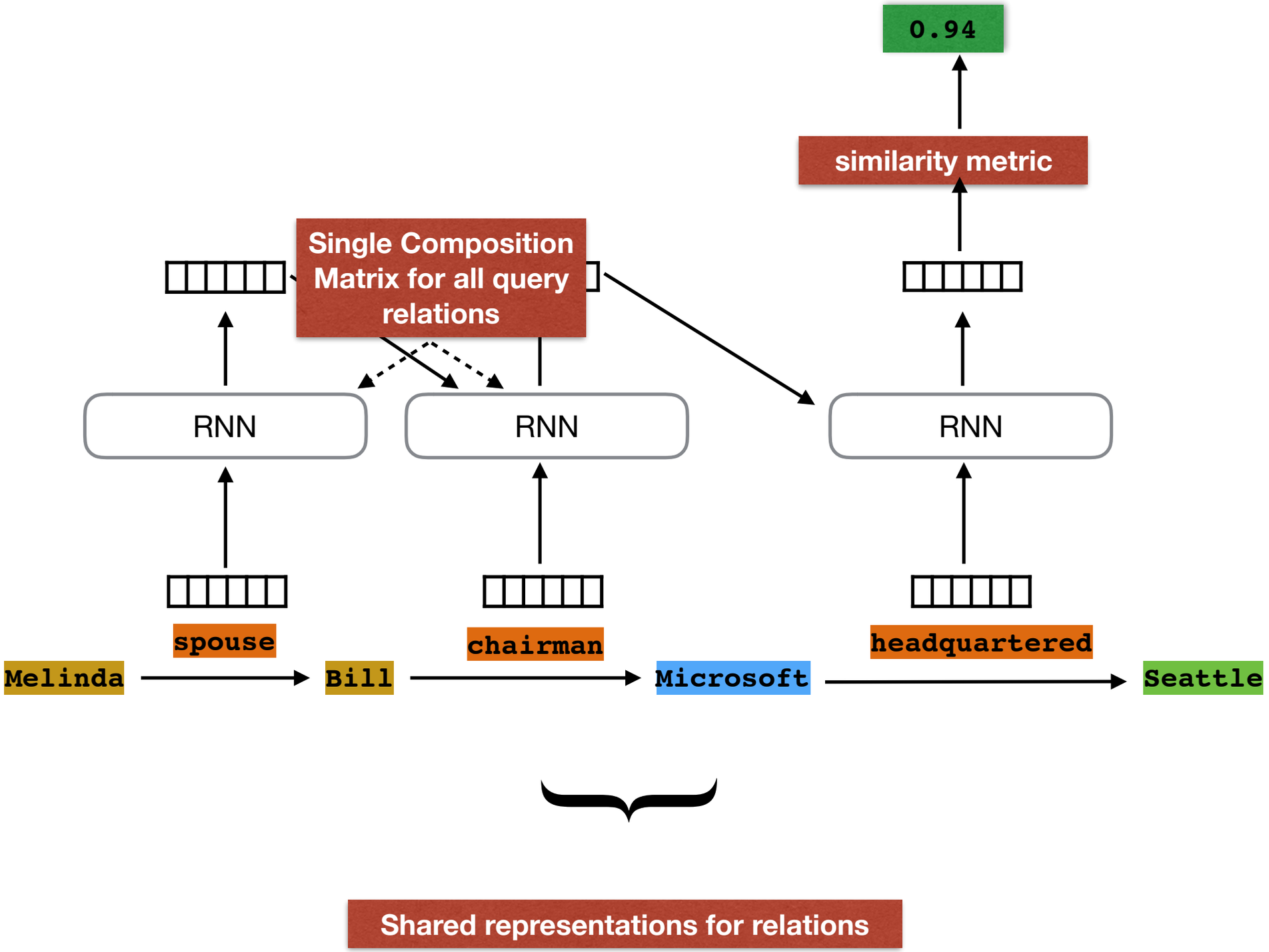
lives in?? / **works in??** / **shops in??** /....

1. Single RNN for chains of reasoning.

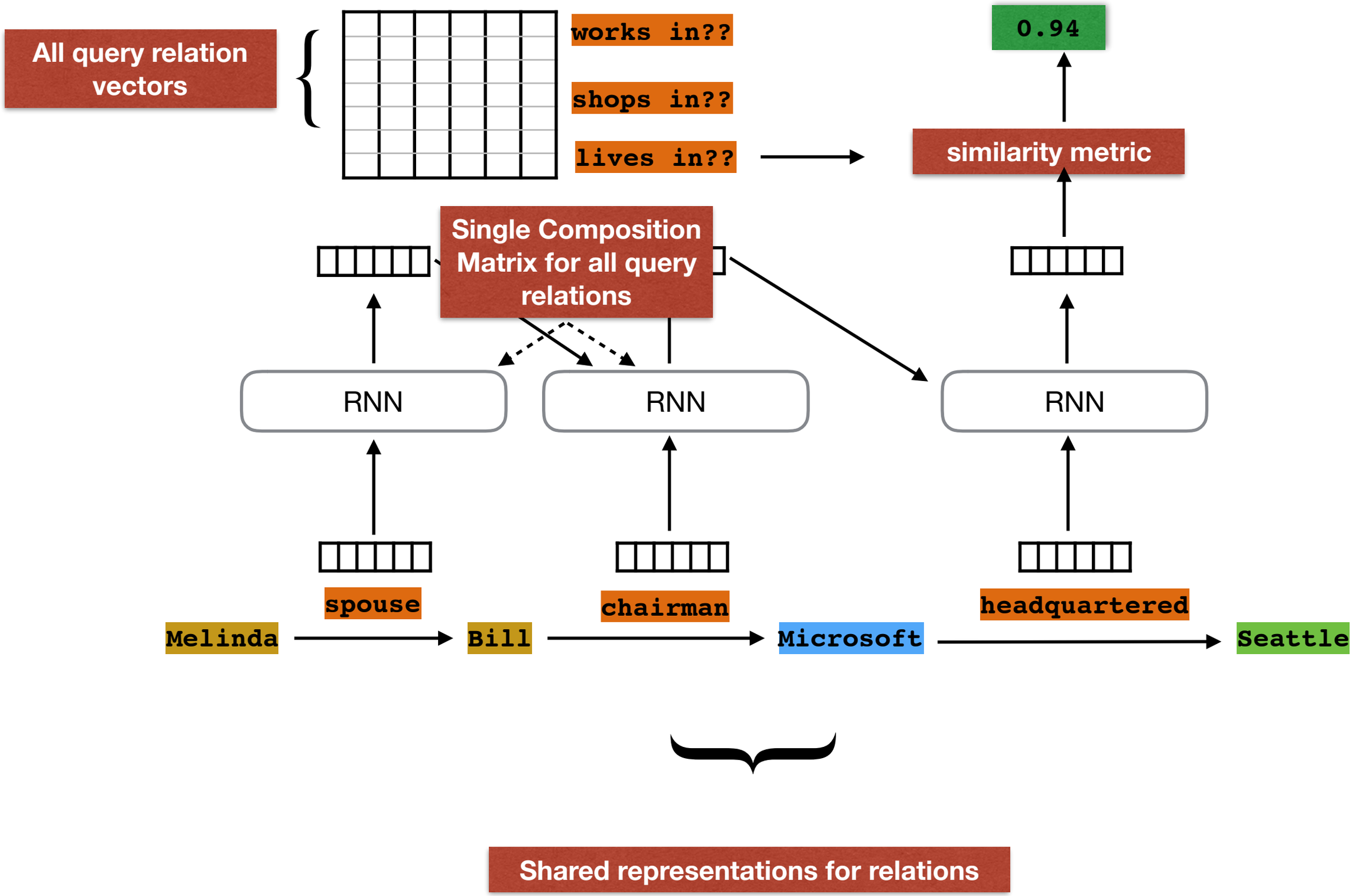
1. Single RNN for chains of reasoning.



1. Single RNN for chains of reasoning.



1. Single RNN for chains of reasoning.



Results

Results

Model	%MAP
PRA	64.43
PRA + Bigram	64.93

Results

Model	%MAP
PRA	64.43
PRA + Bigram	64.93
RNN-Path (Neelakantan' 15)	65.23

Results

Model	%MAP
PRA	64.43
PRA + Bigram	64.93
RNN-Path (Neelakantan' 15)	65.23
Single Model	68.77

Results

Model	%MAP
PRA	64.43
PRA + Bigram	64.93
RNN-Path (Neelakantan' 15)	65.23
Single Model	68.77

5%

$p < 5e\text{-}6$

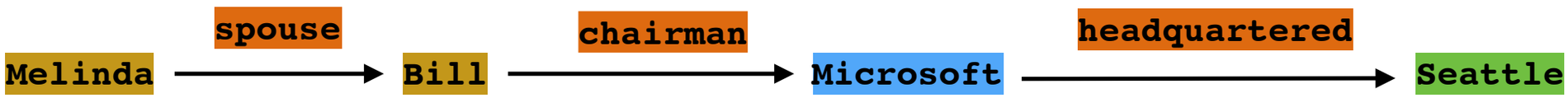
Contributions

1. Single RNN for chains of reasoning. ✔

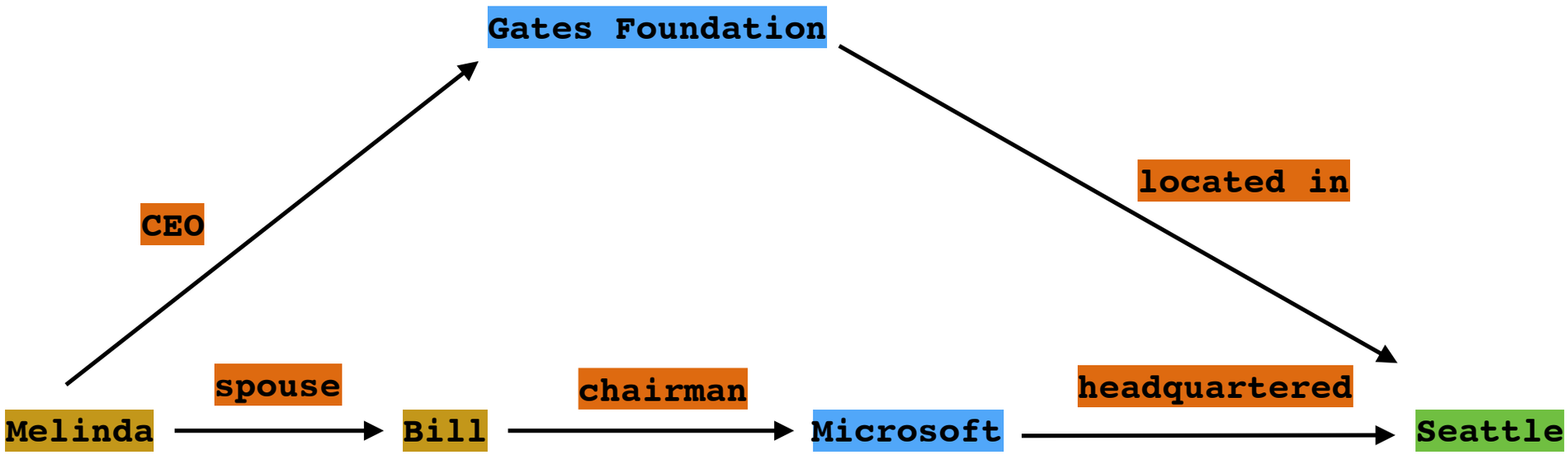
2. Combine evidence from multiple paths between entity pairs.

3. Entity Aware RNN for chains of reasoning

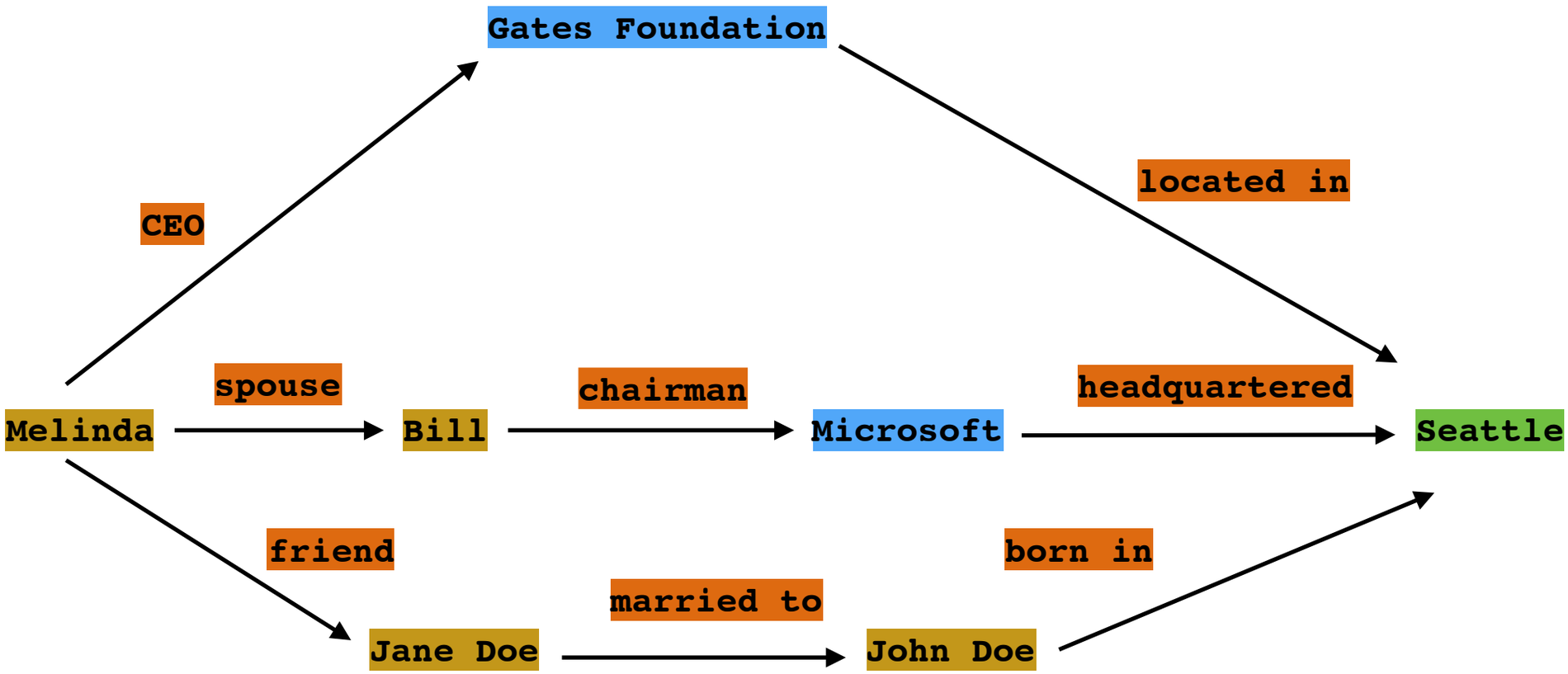
Multiple Paths



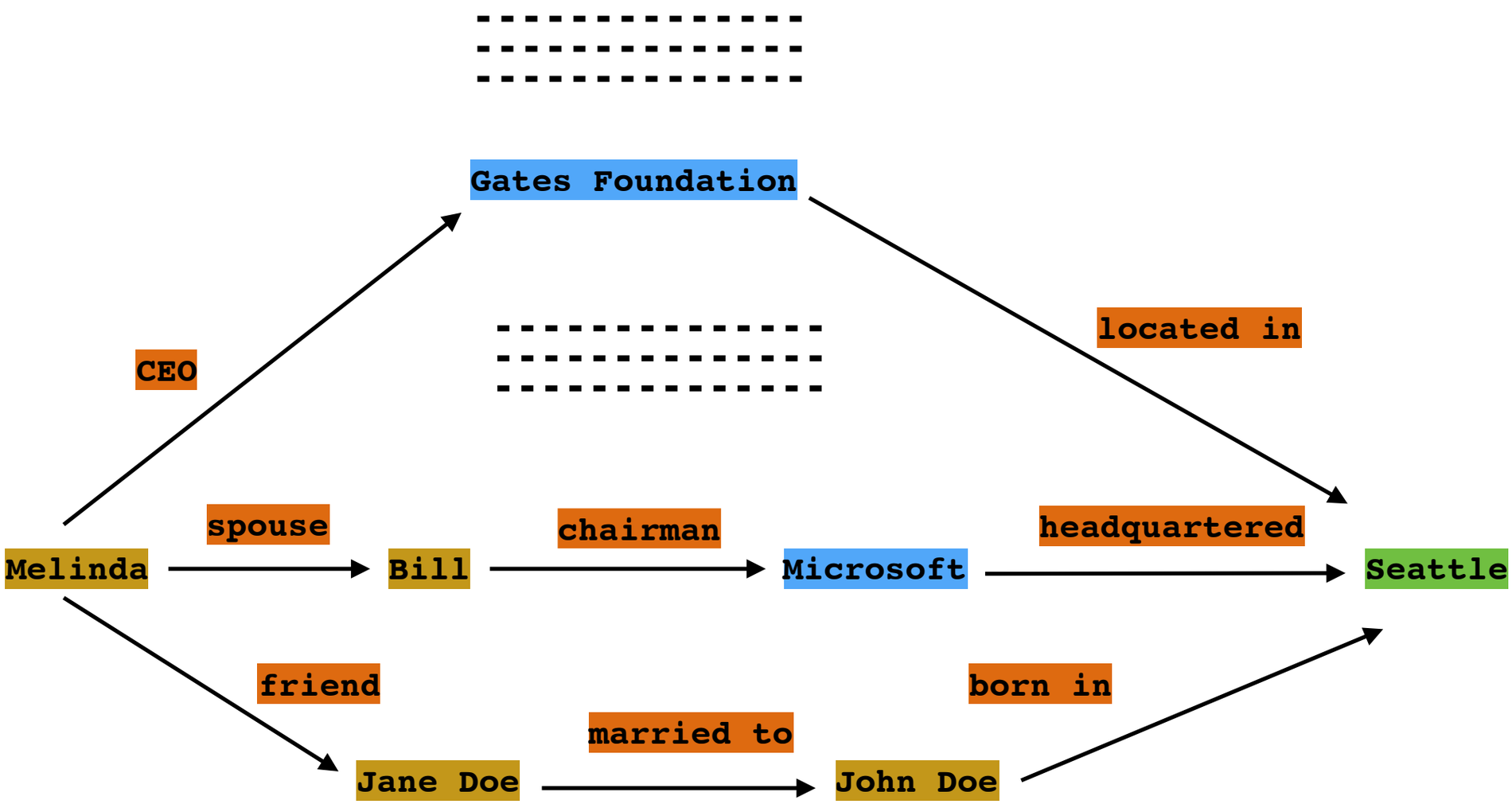
Multiple Paths



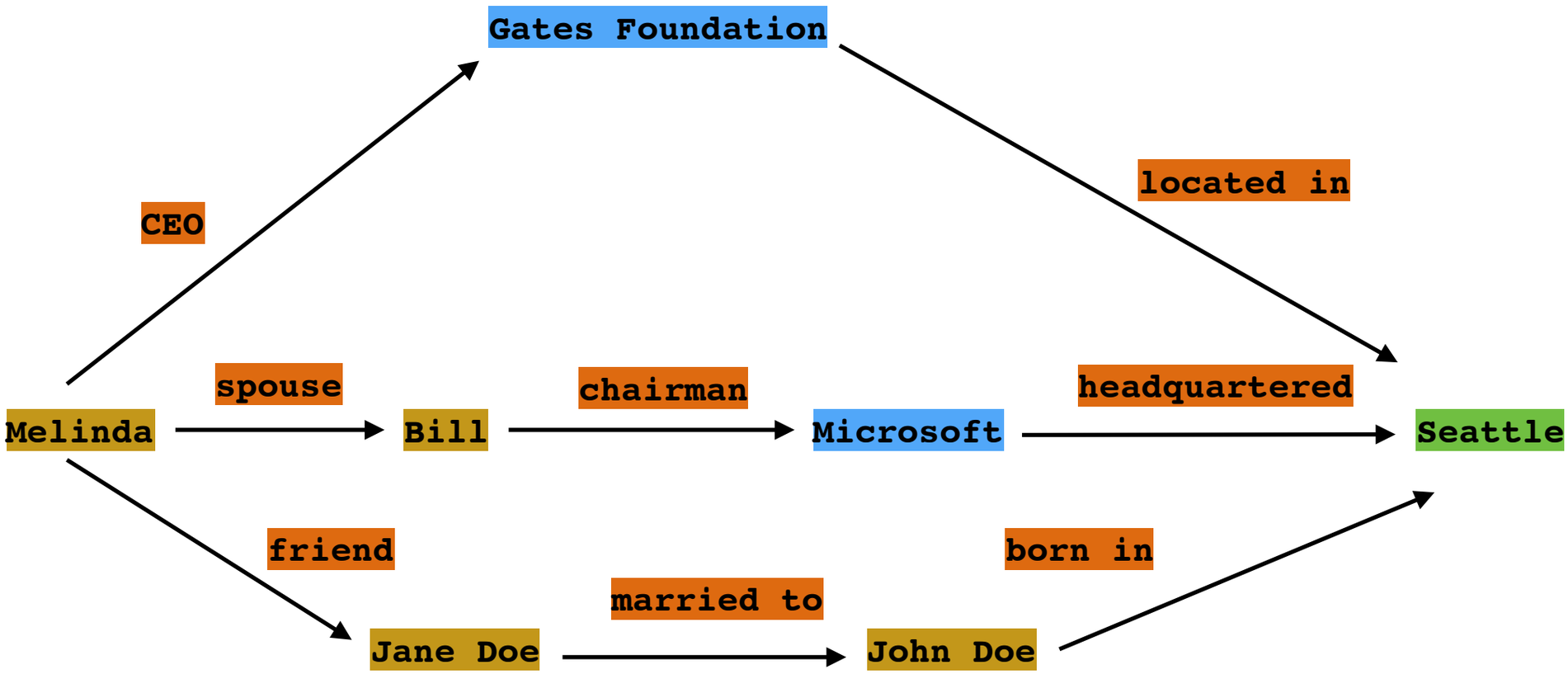
Multiple Paths



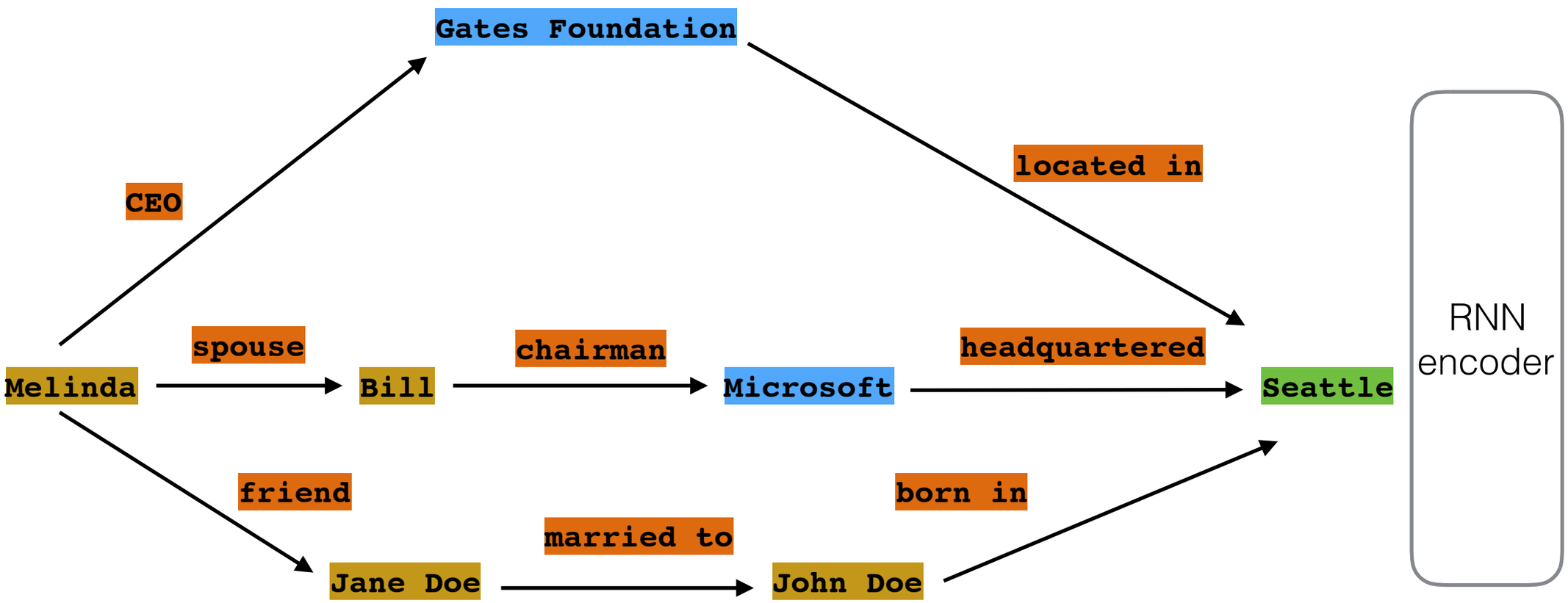
Multiple Paths



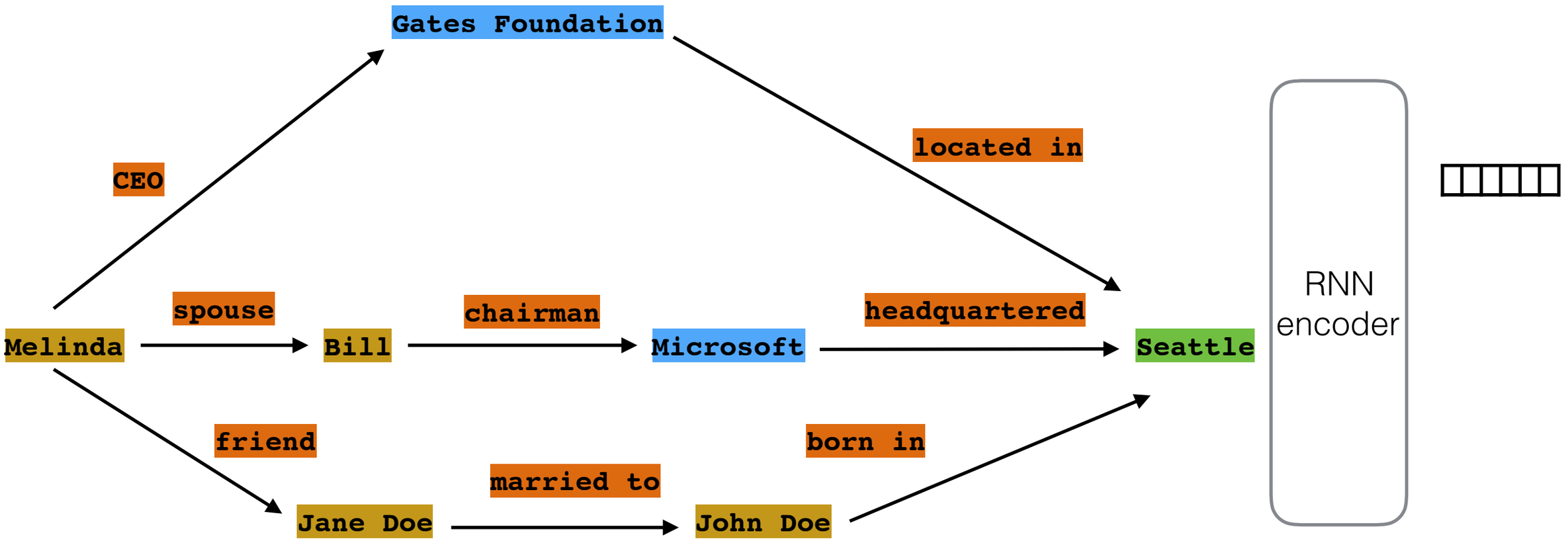
Multiple Paths



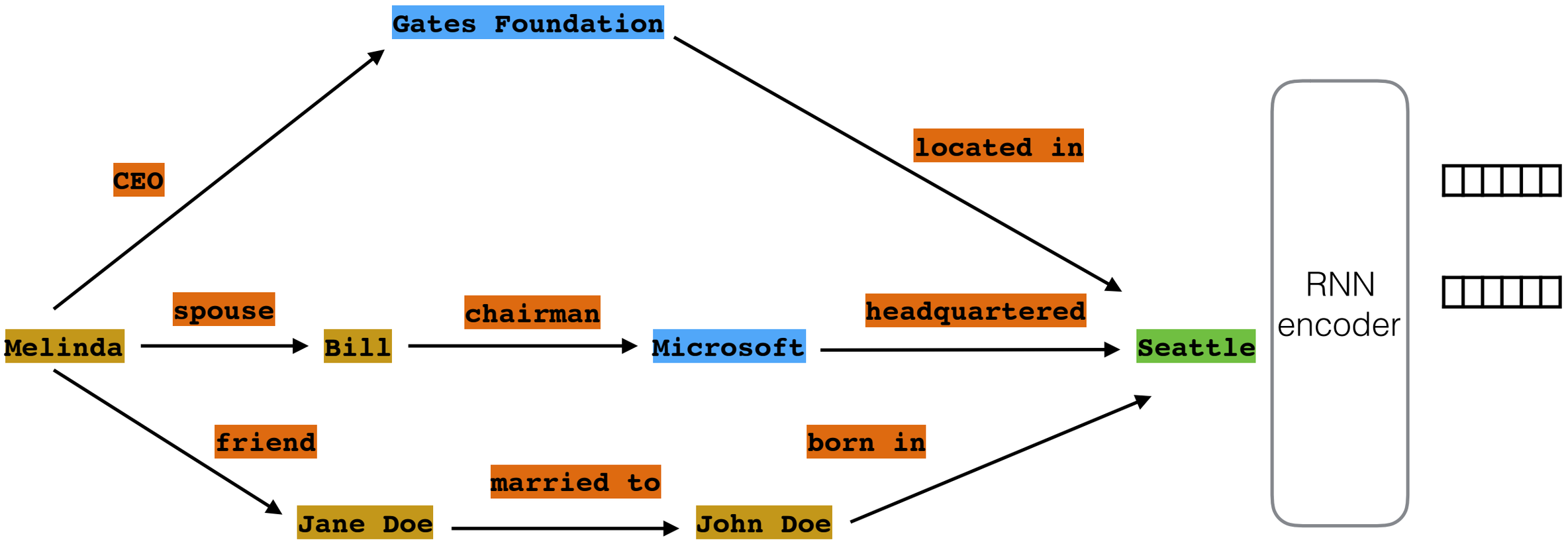
Multiple Paths



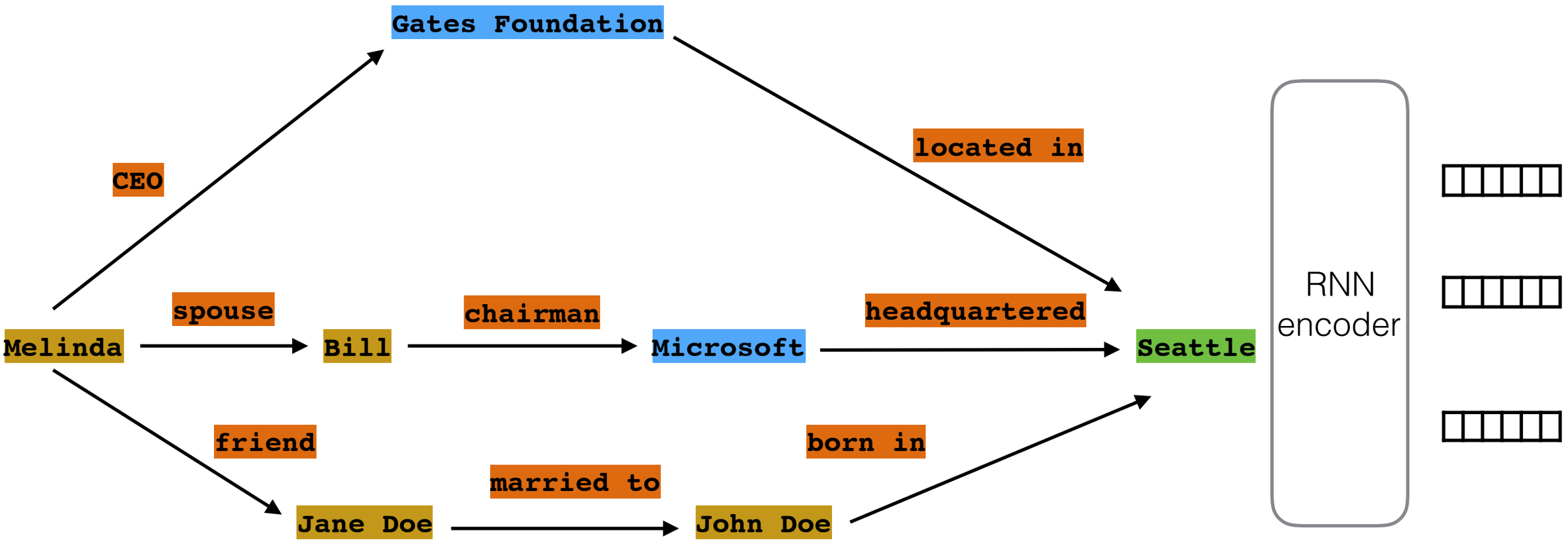
Multiple Paths



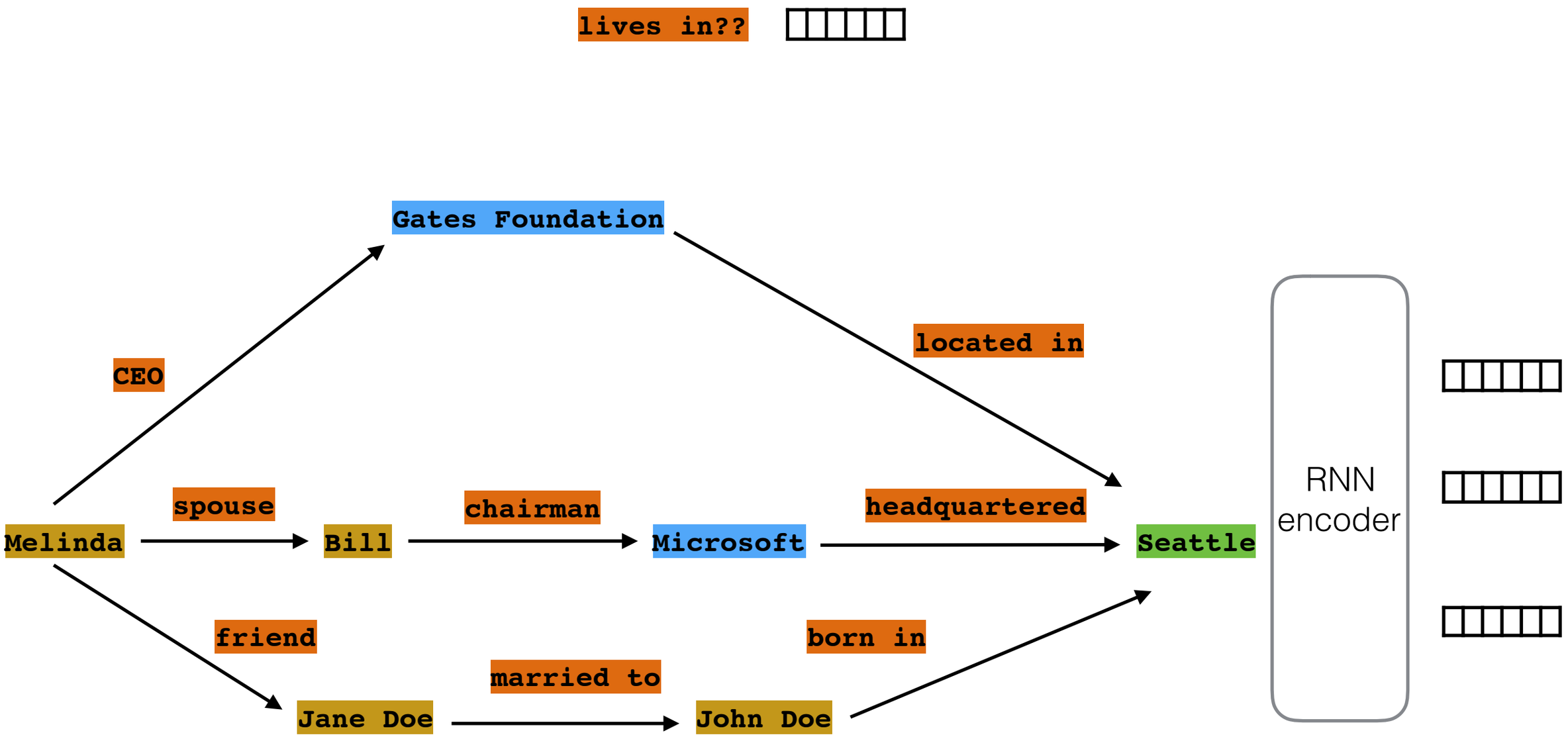
Multiple Paths



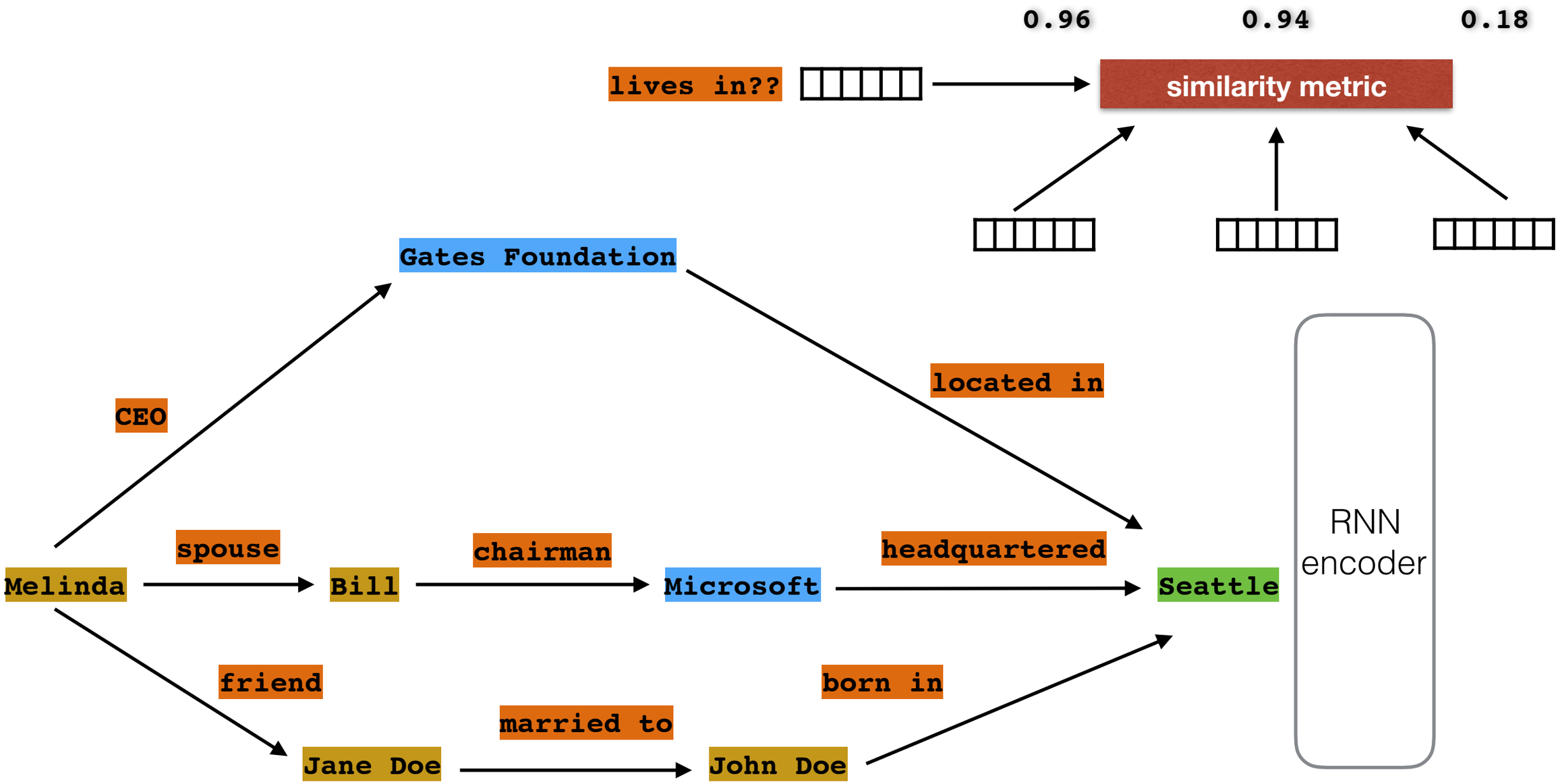
Multiple Paths



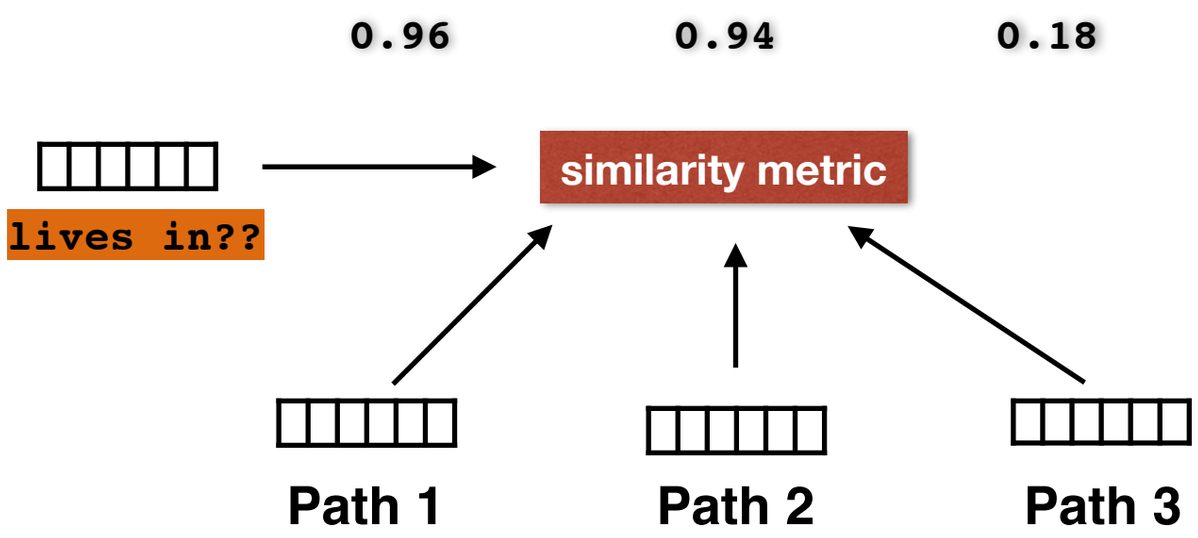
Multiple Paths



Multiple Paths



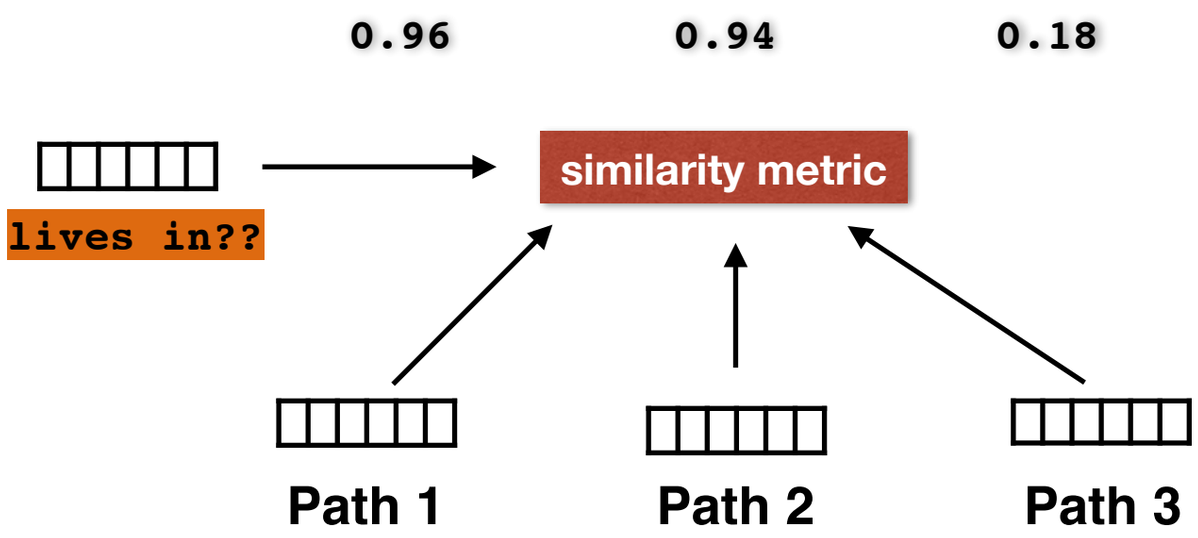
Score Pooling



Score Pooling

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

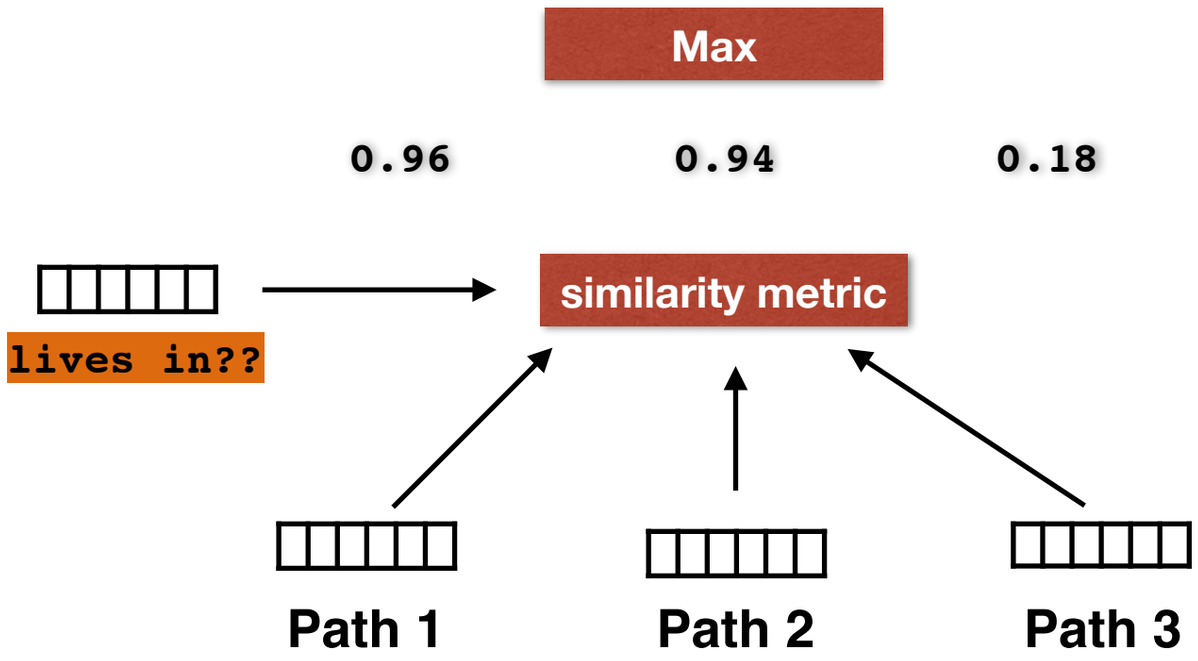
Neelakantan et al' 15



Score Pooling

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

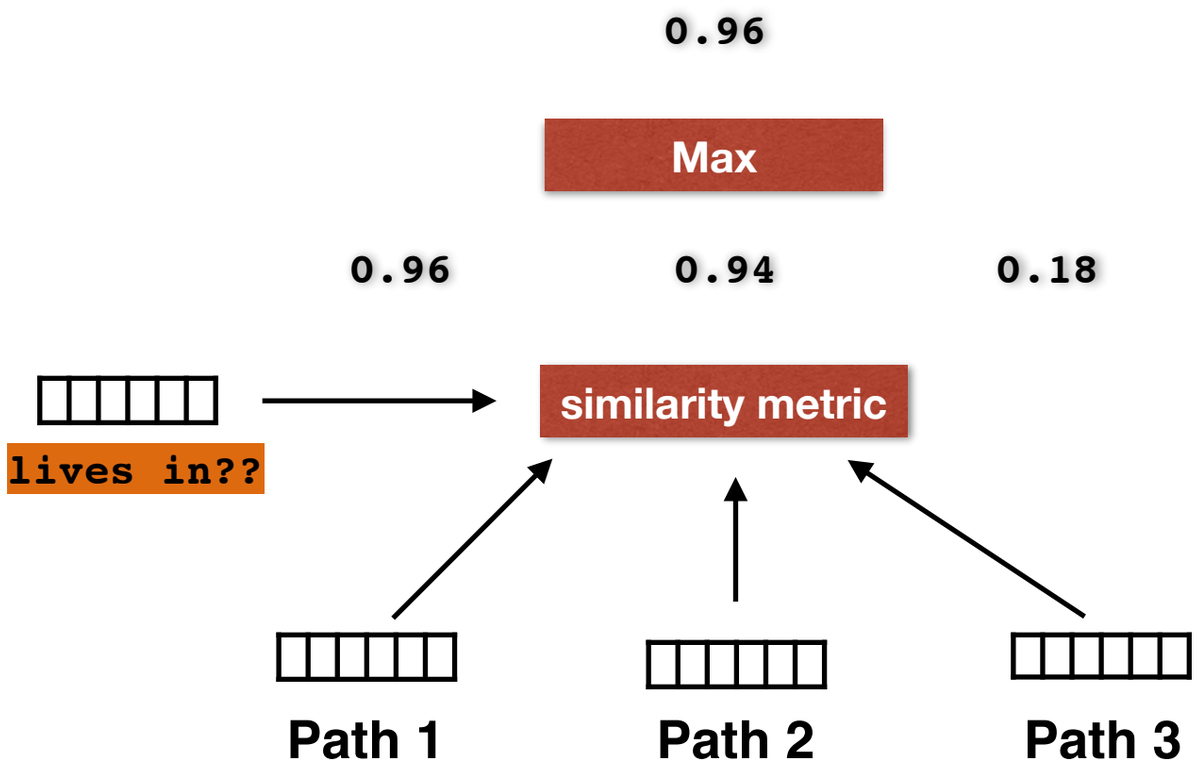
Neelakantan et al' 15



Score Pooling

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

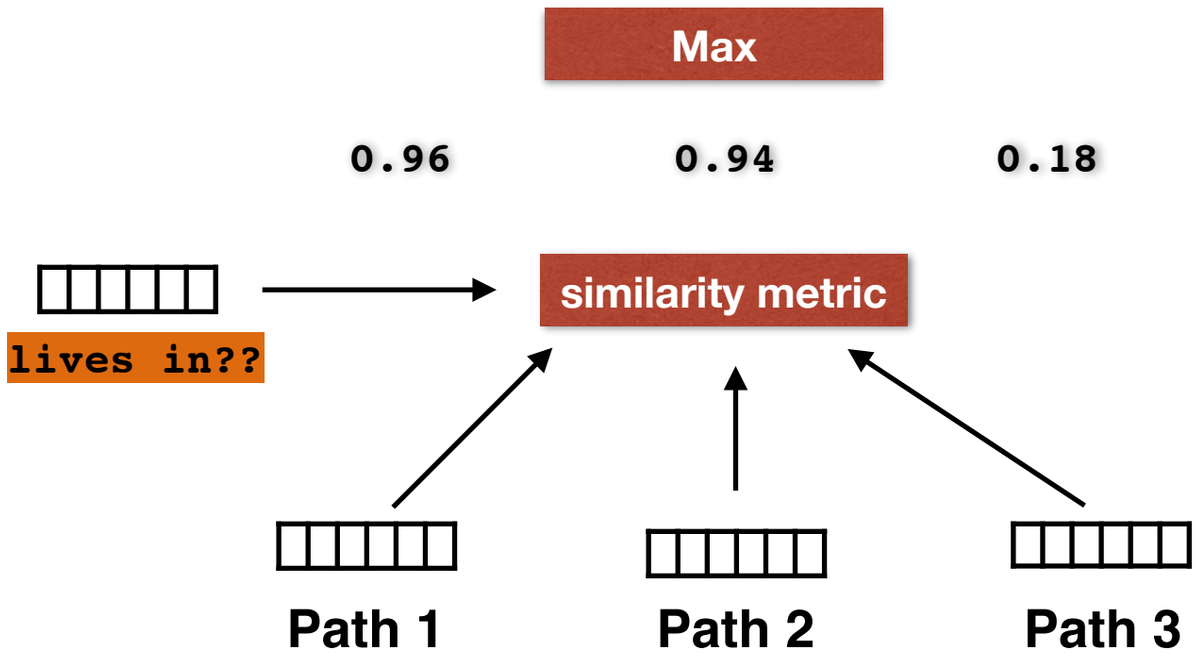
Neelakantan et al' 15



Score Pooling

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

Neelakantan et al' 15

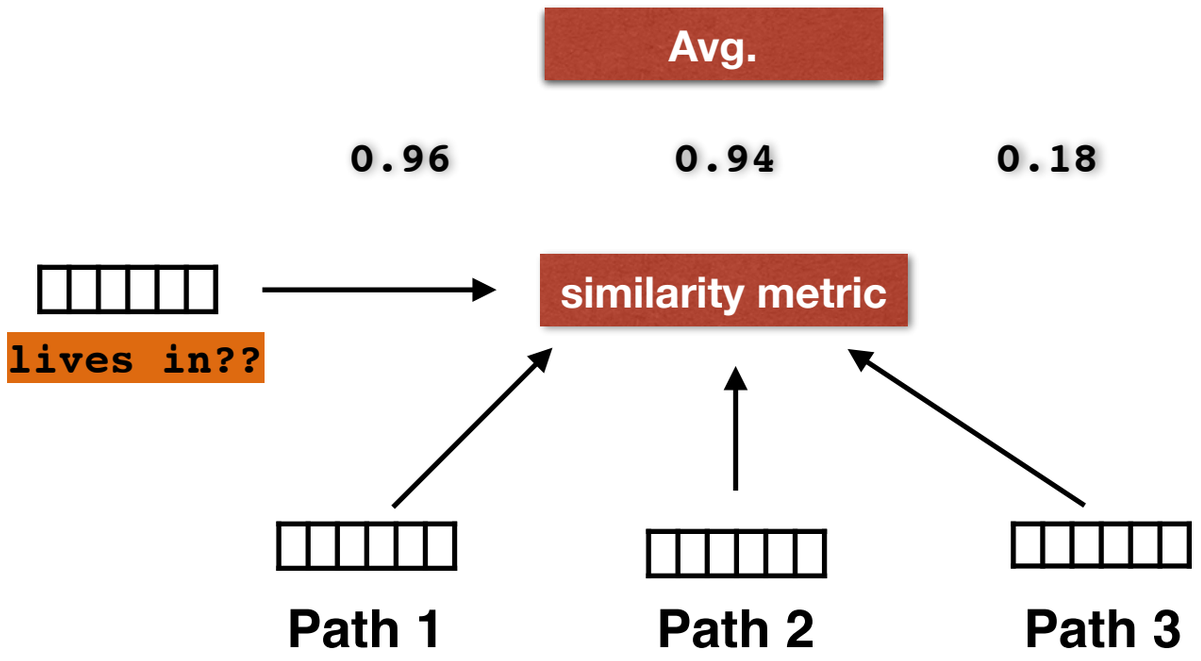


Score Pooling

Neelakantan et al' 15

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

2. Avg. pool: $\frac{1}{N}\left(\sum_{i=1}^{N} \alpha_i\right)$

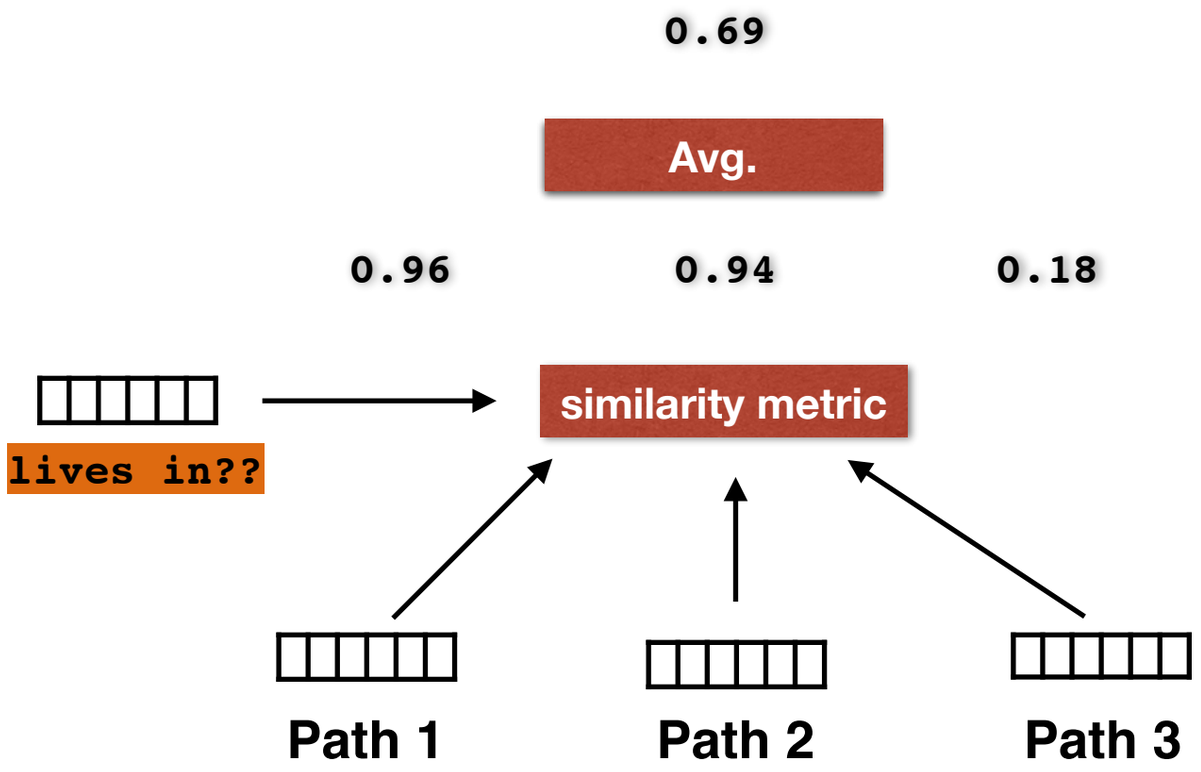


Score Pooling

Neelakantan et al' 15

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

2. Avg. pool: $\frac{1}{N}\left(\sum_{i=1}^{N} \alpha_i\right)$

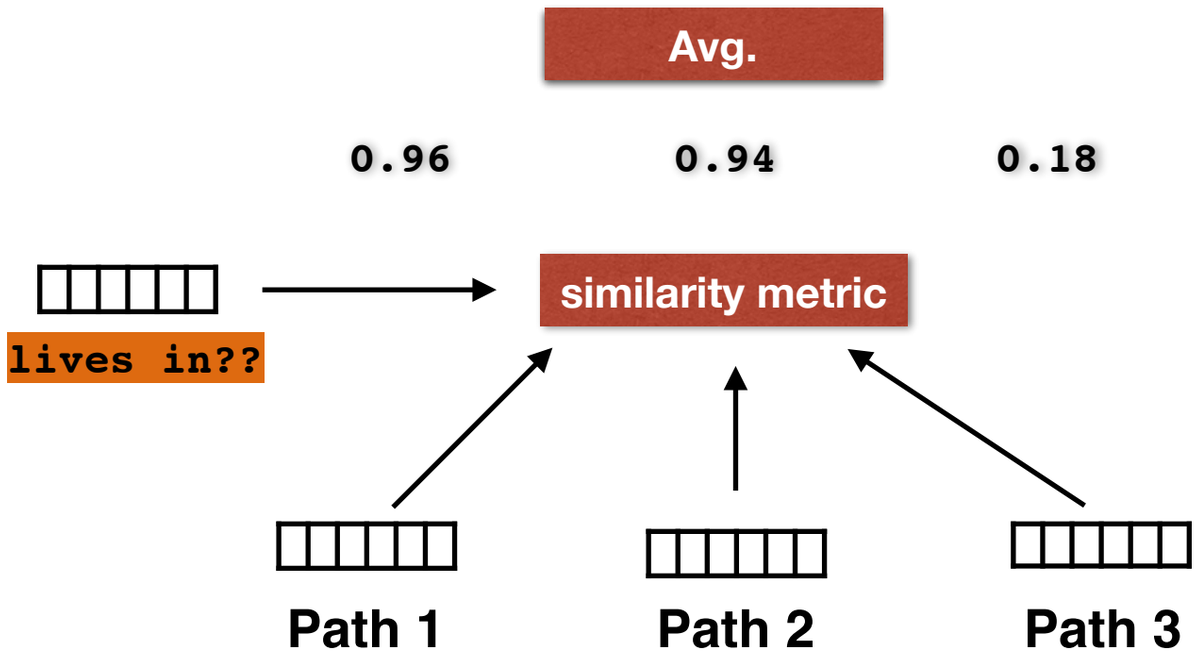


Score Pooling

Neelakantan et al' 15

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

2. Avg. pool: $\frac{1}{N}\left(\sum_{i=1}^{N} \alpha_i\right)$



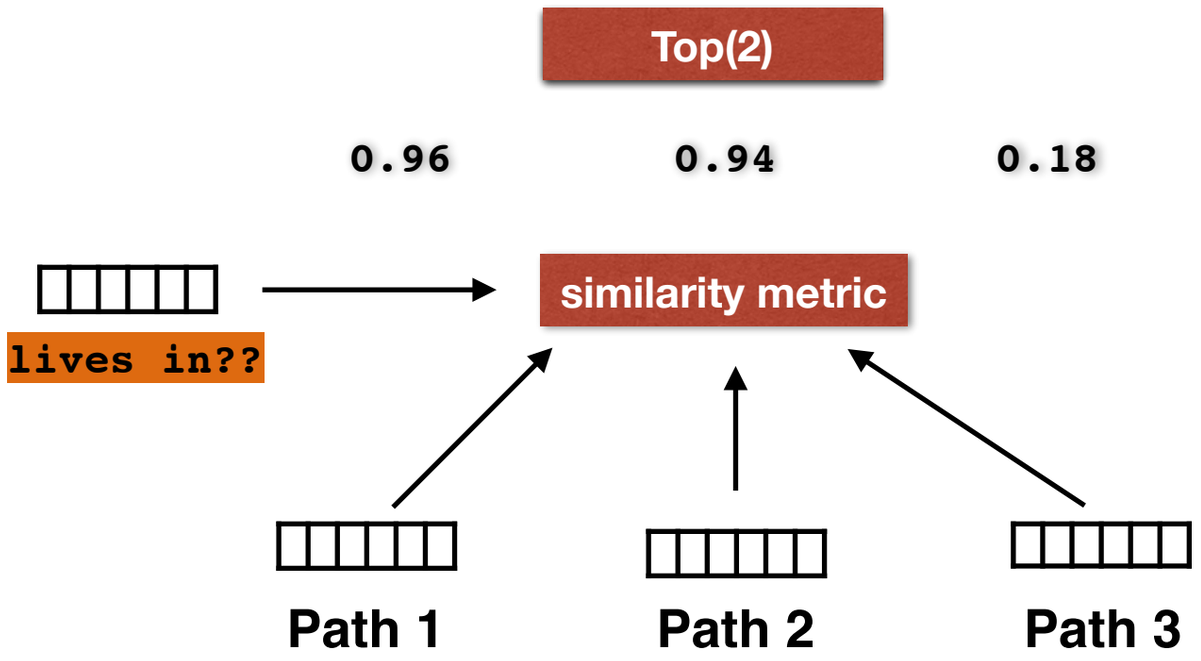
Score Pooling

Neelakantan et al' 15

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

2. Avg. pool: $\frac{1}{N}\left(\sum_{i=1}^{N} \alpha_i\right)$

3. Top(k): $\frac{1}{k}\left(\sum_{i=1}^{k} s_i\right)$



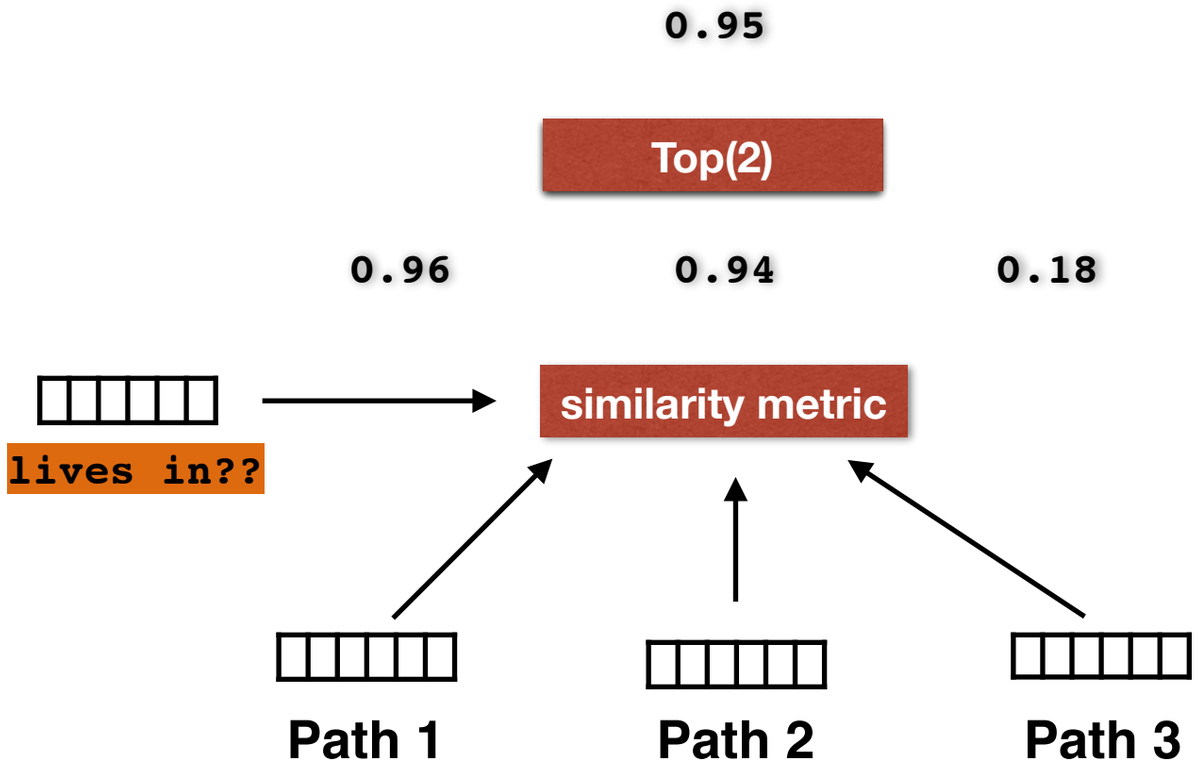
Score Pooling

Neelakantan et al' 15

1. Max pool: $\max(\alpha_1, \alpha_2, \ldots, \alpha_N)$

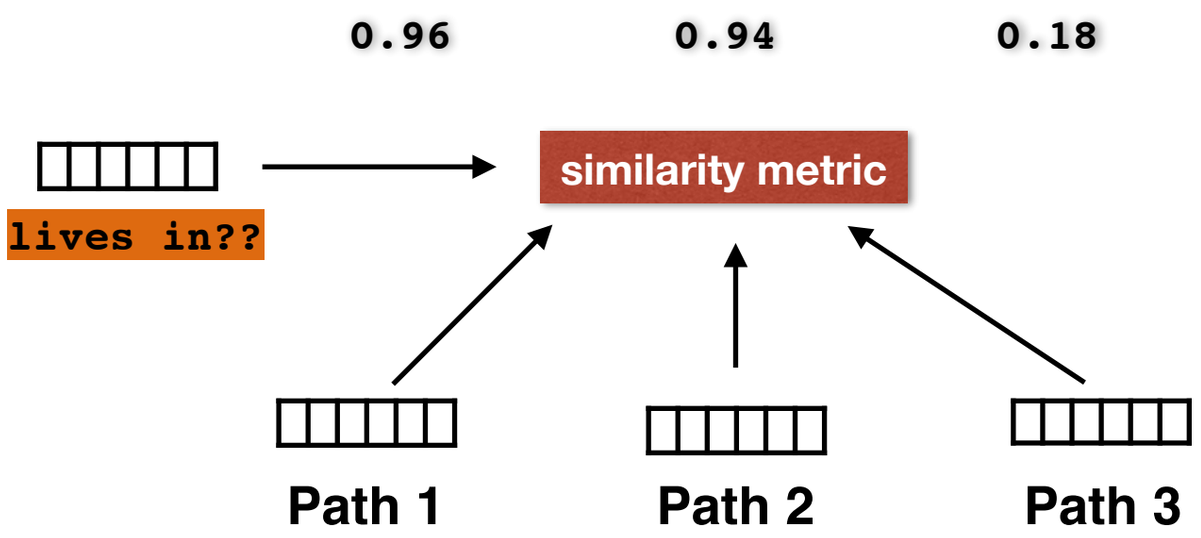
2. Avg. pool: $\frac{1}{N}\left(\sum_{i=1}^{N} \alpha_i\right)$

3. Top(k): $\frac{1}{k}\left(\sum_{i=1}^{k} s_i\right)$



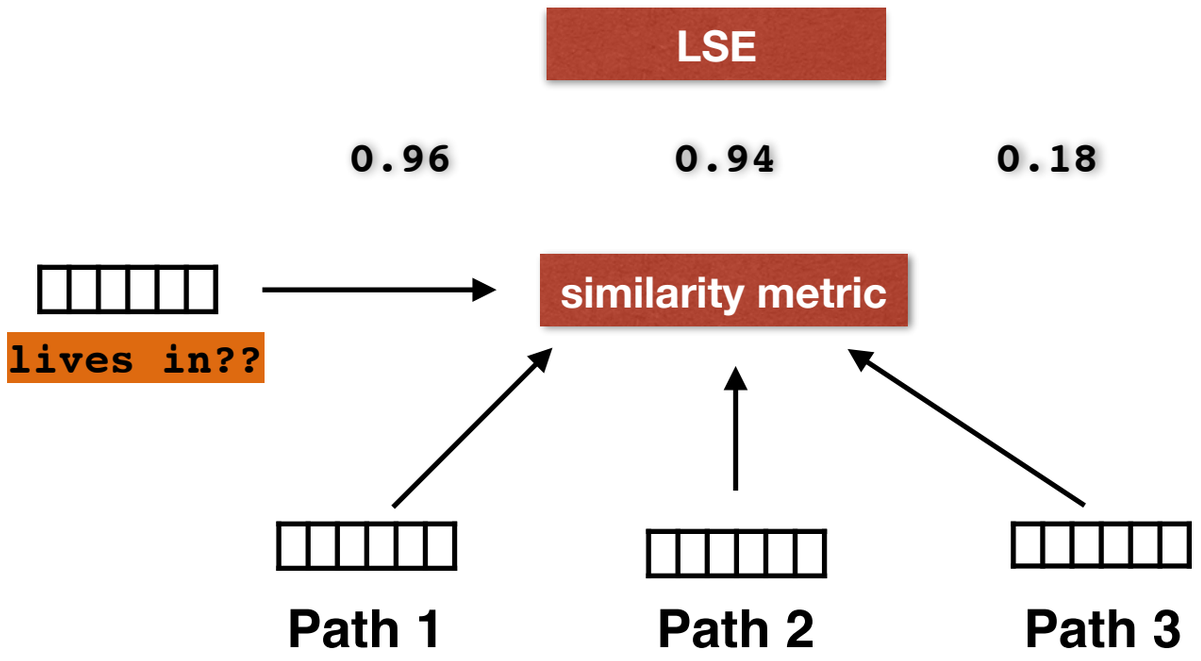
Score Pooling

4. LogSumExp: $$\log(\sum_{i=1}^{N} \exp(\alpha_i))$$



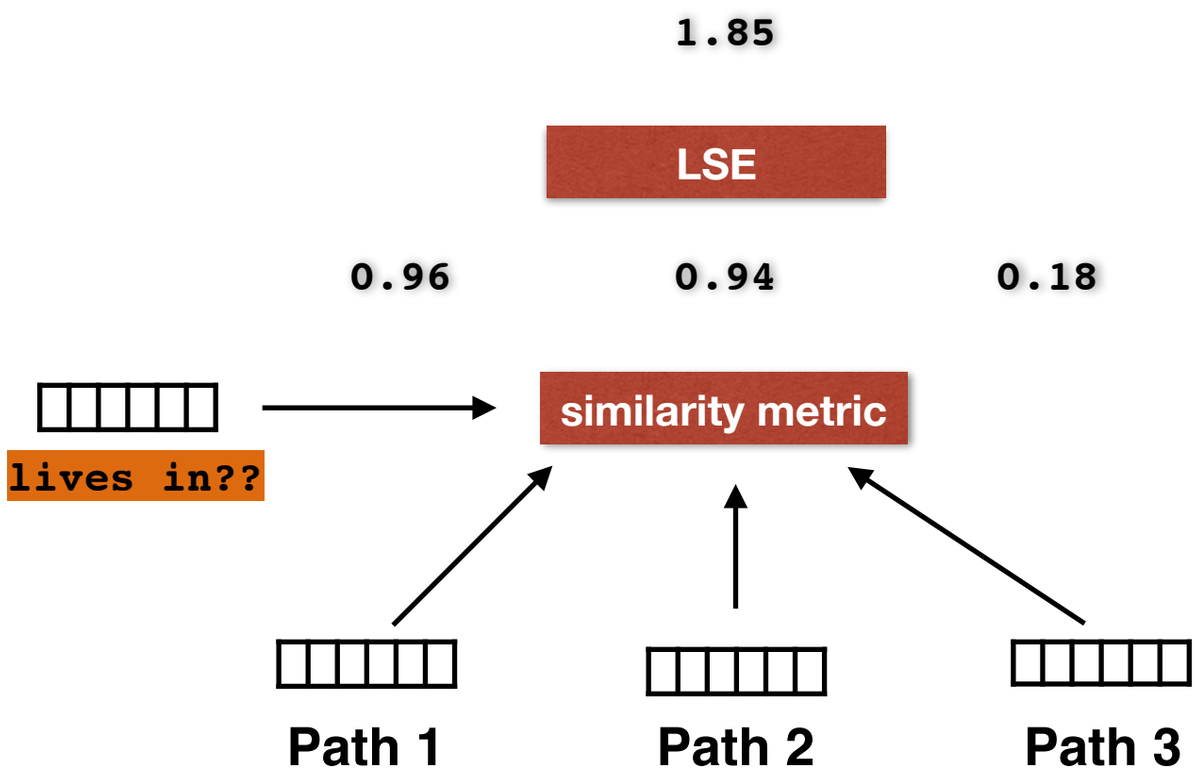
Score Pooling

4. LogSumExp: $$\log(\sum_{i=1}^{N} \exp(\alpha_i))$$



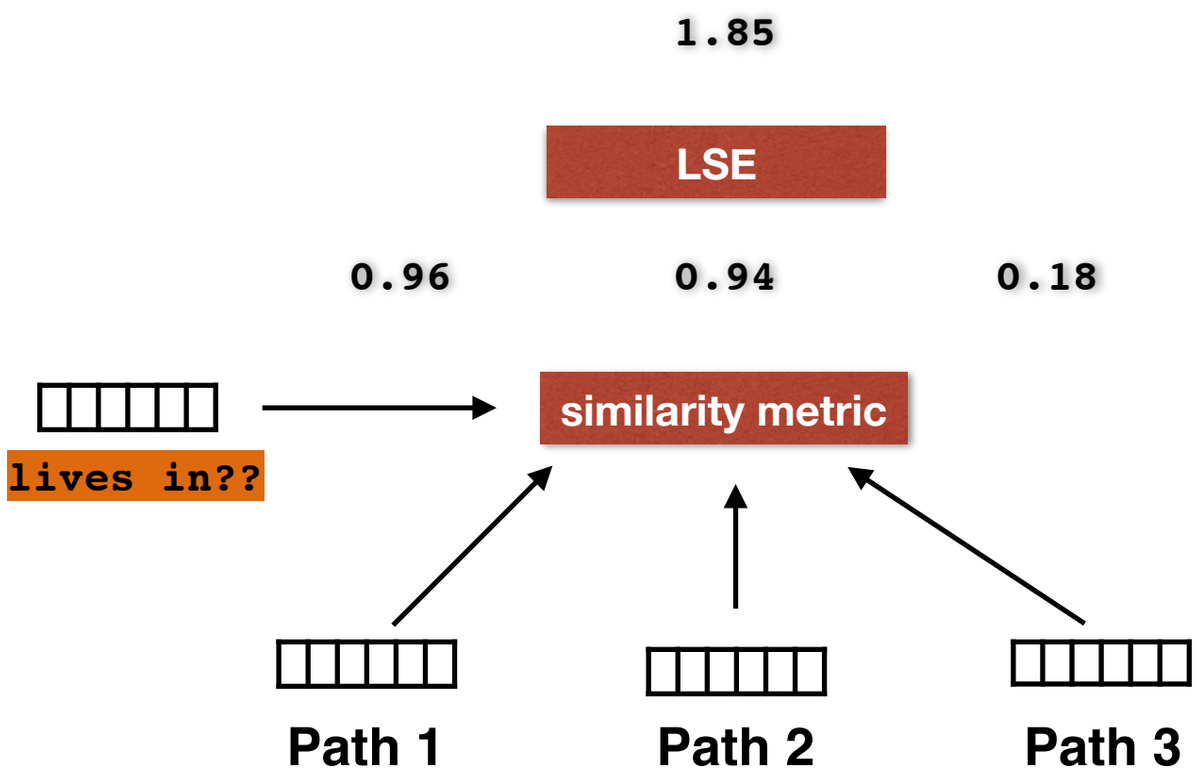
Score Pooling

4. LogSumExp: $$\log(\sum_{i=1}^{N} \exp(\alpha_i))$$



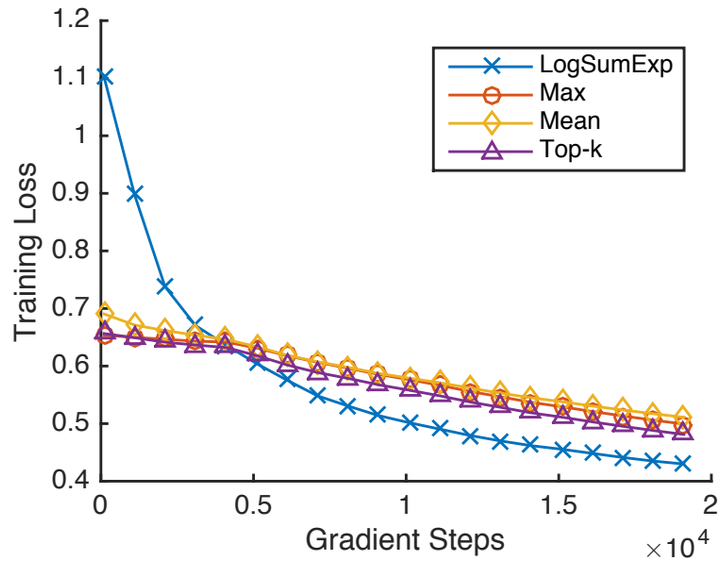
Score Pooling

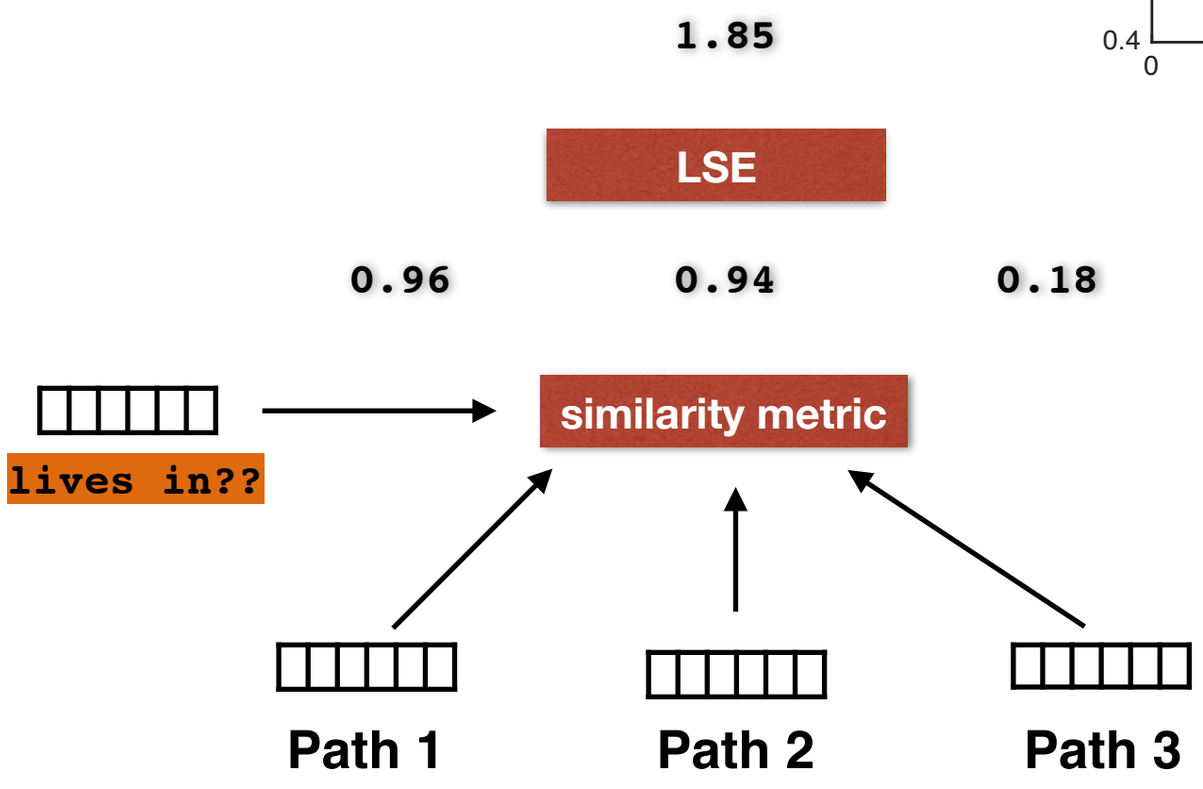
4. LogSumExp: $\log(\sum_{i=1}^{N} \exp(\alpha_i))$ $\frac{\partial LSE}{\partial \alpha_i} = \frac{\exp(\alpha_i)}{\sum_i \exp(\alpha_i)}$



Score Pooling

4. LogSumExp: $\log(\sum_{i=1}^{N} \exp(\alpha_i))$ $\frac{\partial LSE}{\partial \alpha_i} = \frac{\exp(\alpha_i)}{\sum_i \exp(\alpha_i)}$





Results

Results

Model	%MAP	Pooling
RNN-Path (Neelakantan ’15)	65.23	Max

Results

Model	%MAP	Pooling
RNN-Path (Neelakantan ’15)	65.23	Max
RNN-Path	**68.43**	LogSumExp

Results

Model	%MAP	Pooling
RNN-Path (Neelakantan ’15)	65.23	Max
RNN-Path	**68.43**	LogSumExp
Single Model	68.77	Max
Single Model	**55.8**	Avg.
Single Model	68.20	Top(K)

Results

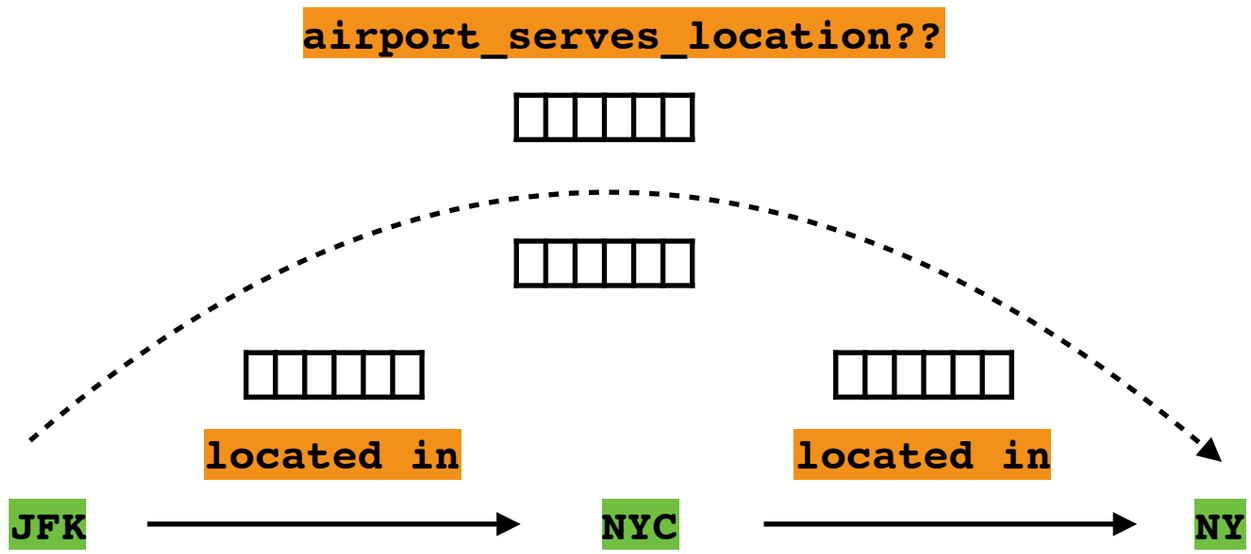
Model	%MAP	Pooling
RNN-Path (Neelakantan ’15)	65.23	Max
RNN-Path	**68.43**	LogSumExp
Single Model	68.77	Max
Single Model	**55.8**	Avg.
Single Model	68.20	Top(K)
Single Model	**70.11**	LogSumExp

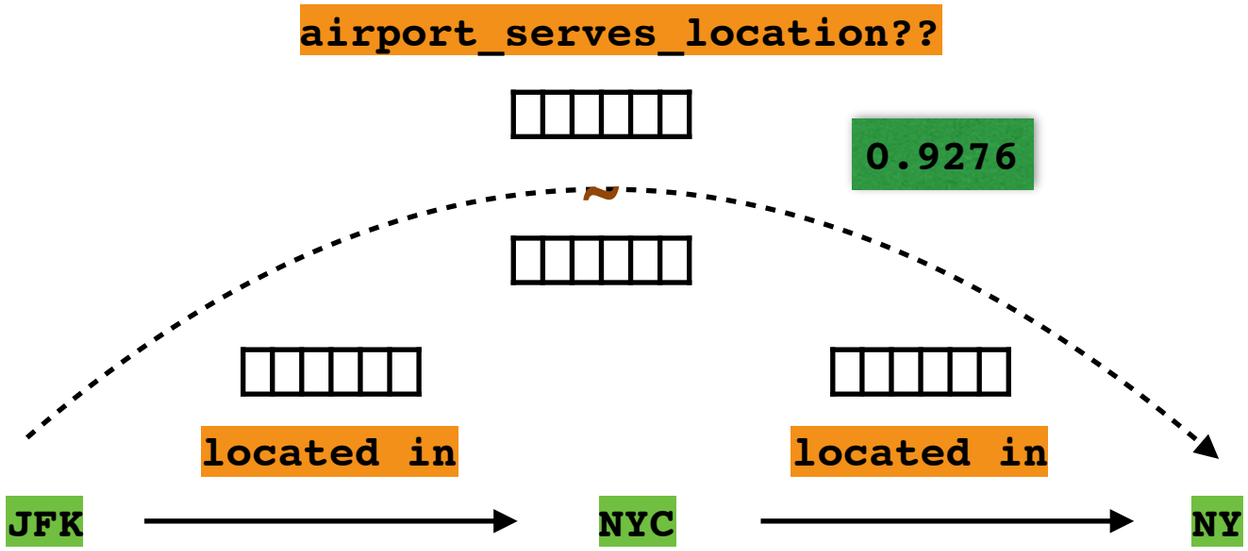
Contributions

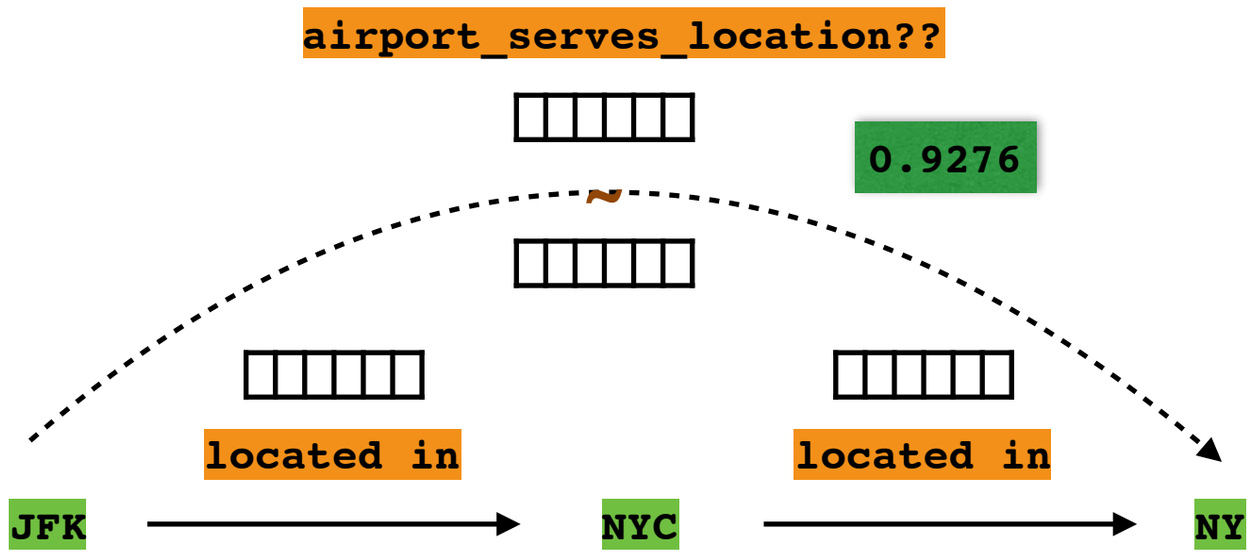
1. Single RNN for chains of reasoning. ✓

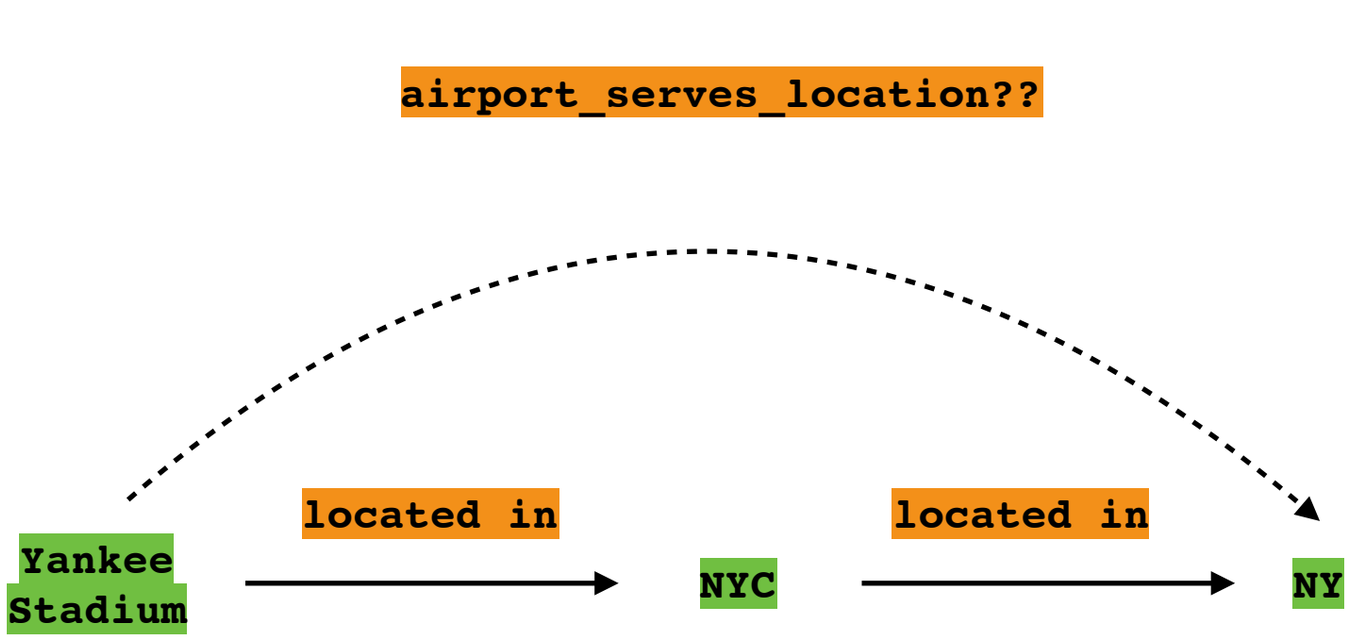
2. Combine evidence from multiple paths between entity pairs. ✓

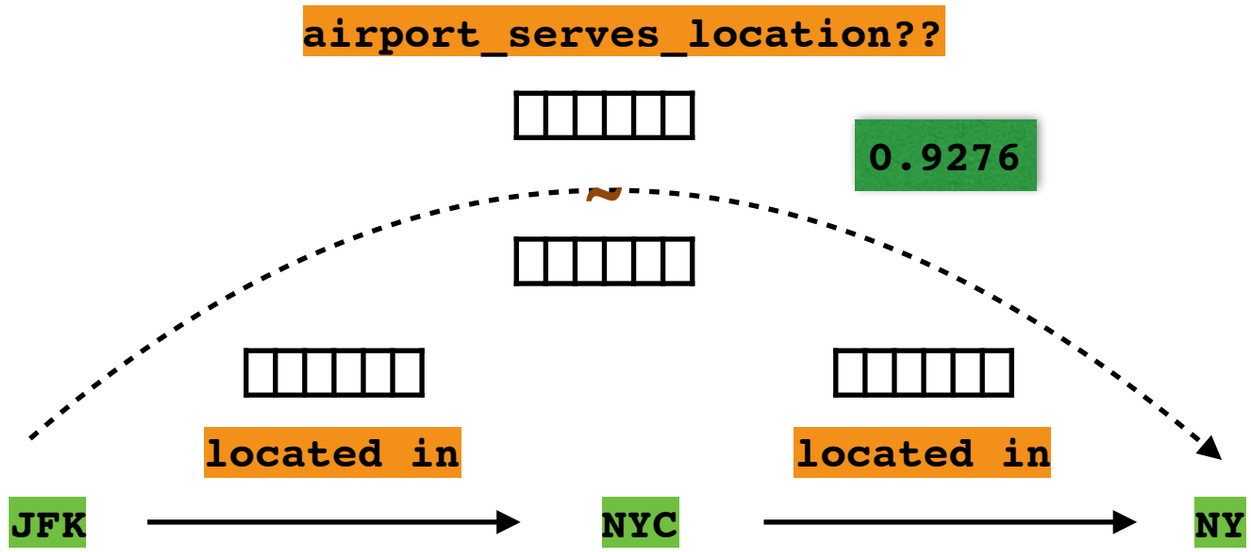
3. Entity Aware RNN for chains of reasoning

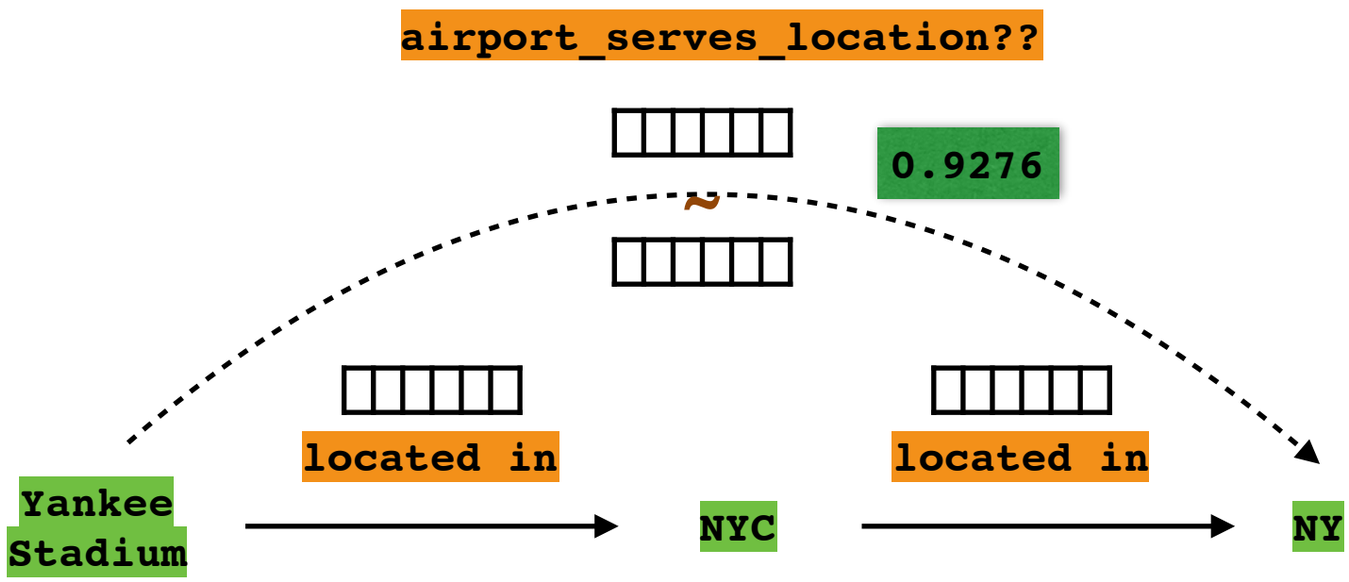

airport_serves_location??
located in
located in
JFK
NYC
NY

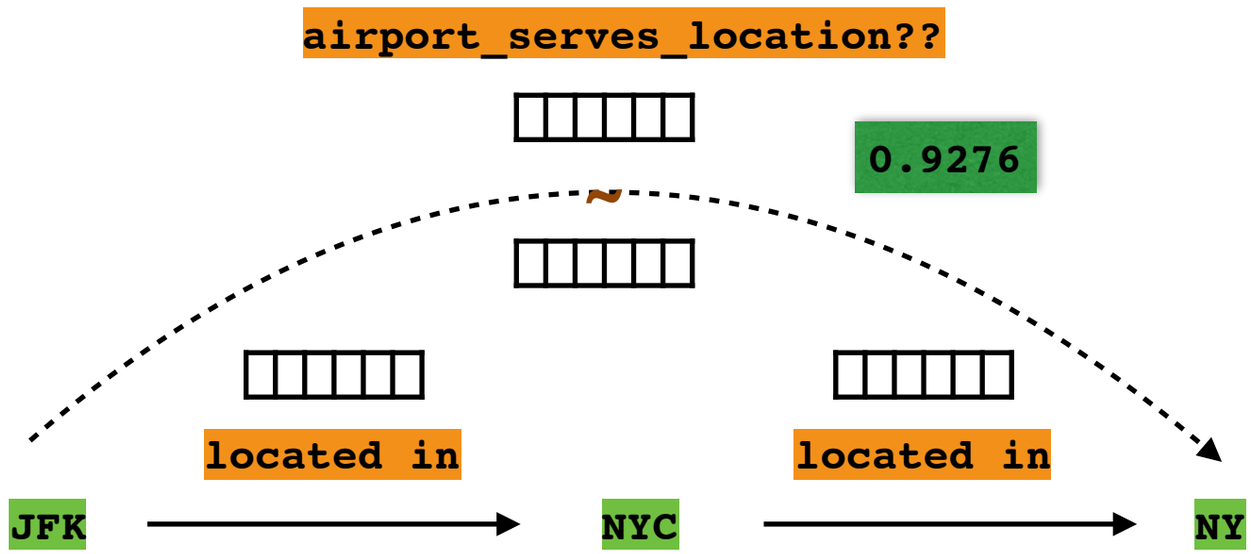

airport_serves_location??
0.9276
located in
located in
JFK
NYC
NY

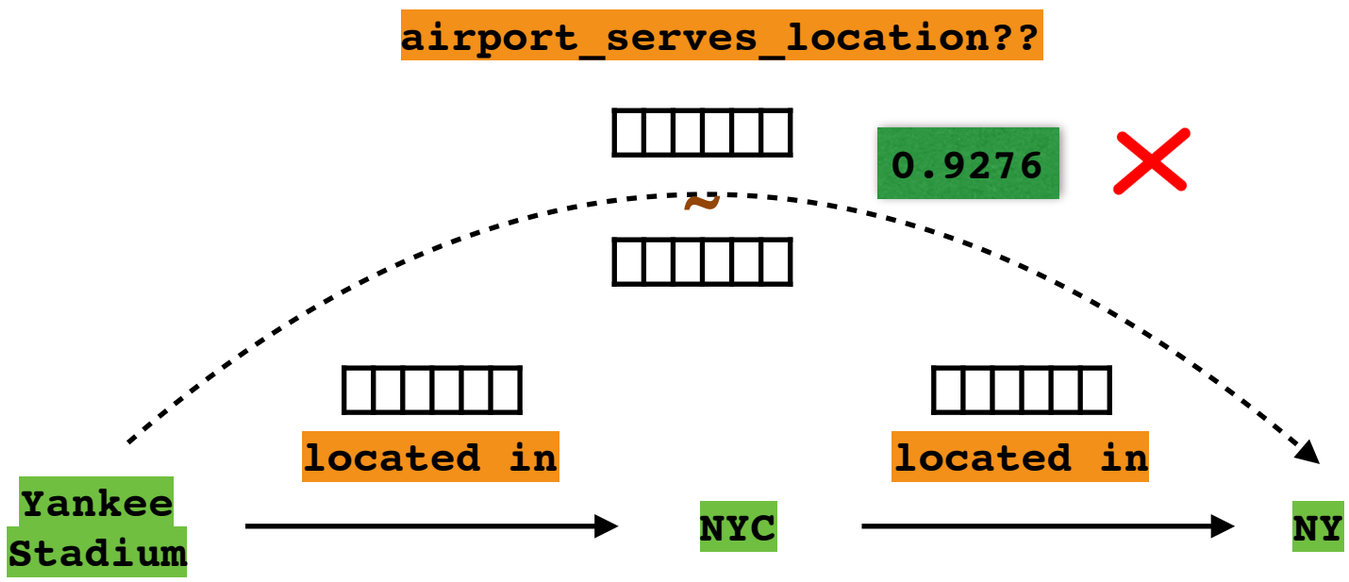

airport_serves_location??
0.9276
located in
located in
JFK
NYC
NY


airport_serves_location??
located in
located in
Yankee Stadium
NYC
NY

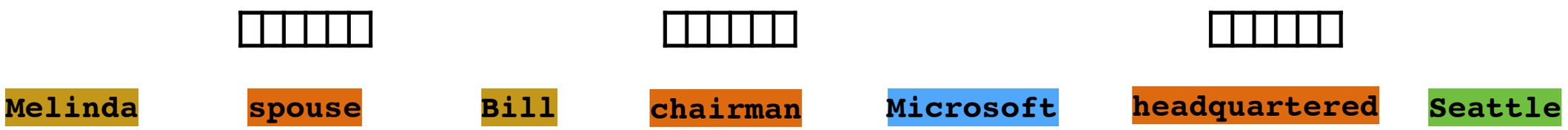

airport_serves_location??
0.9276
located in
located in
JFK
NYC
NY


airport_serves_location??
0.9276
located in
located in
Yankee Stadium
NYC
NY

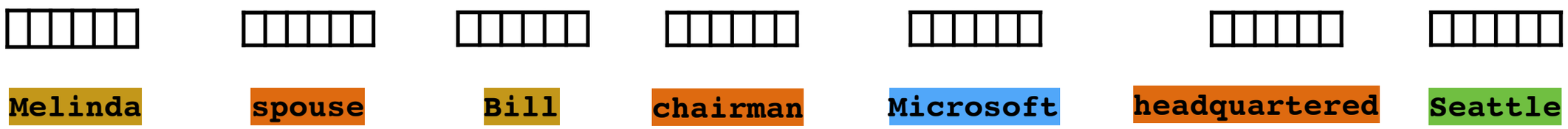

airport_serves_location??
0.9276
located in
located in
JFK
NYC
NY


airport_serves_location??
0.9276
located in
located in
Yankee Stadium
NYC
NY

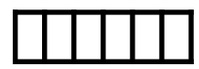
Entity Representation



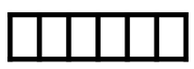
Entity Representation



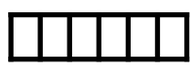
Entity Representation



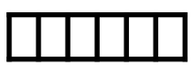
Melinda



Bill



Microsoft



Seattle

Entity Representation

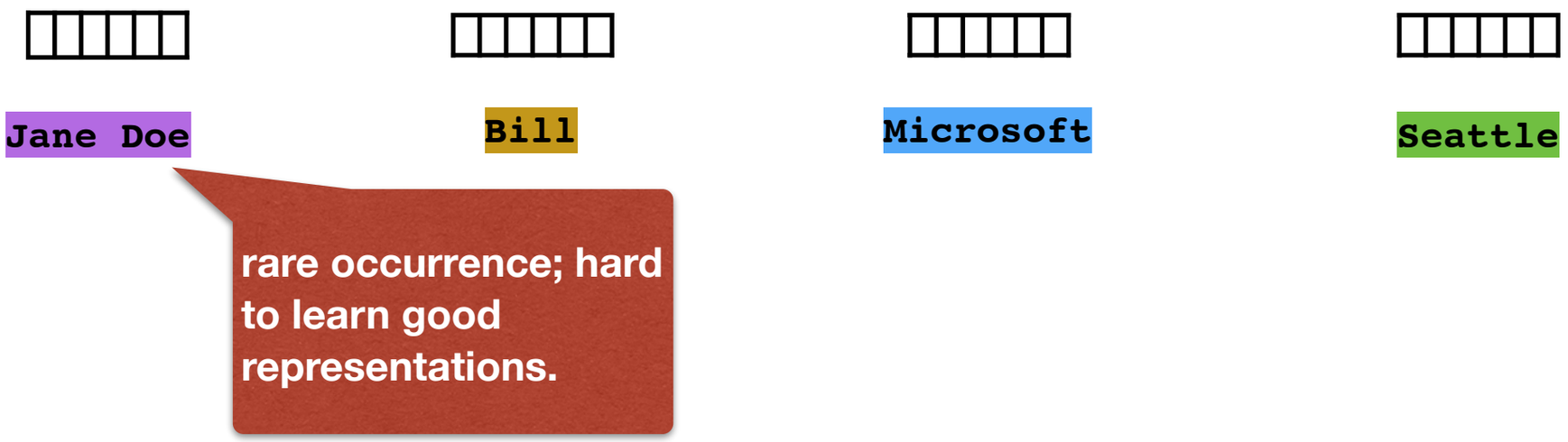
1. Learn separate representation for each entity.

Entity Representation

1. Learn separate representation for each entity.

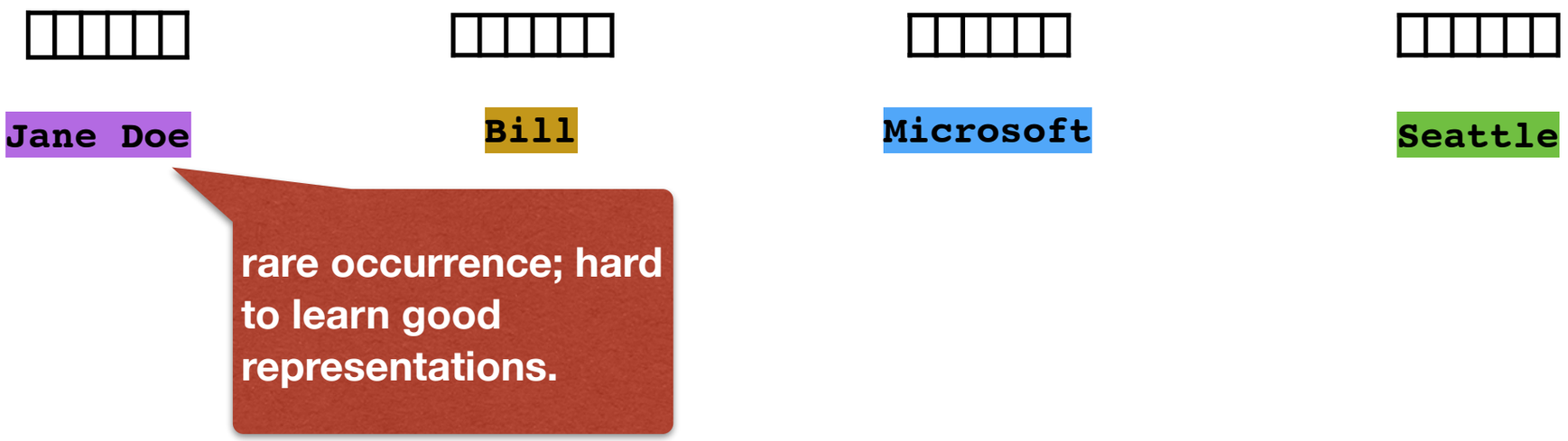
Entity Representation

1. Learn separate representation for each entity.



Entity Representation

1. Learn separate representation for each entity.
2. Represent entities by their annotated types



Entity Representation

1. Learn separate representation for each entity.
2. Represent entities by their annotated types

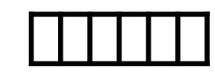
Annotated types in KB

Melinda

1. CEO
2. Philanthropist
3. Duke University alumni
4. American Citizen

Jane Doe

1. American Citizen
2. Small business owner



Jane Doe

Bill

Microsoft

Seattle

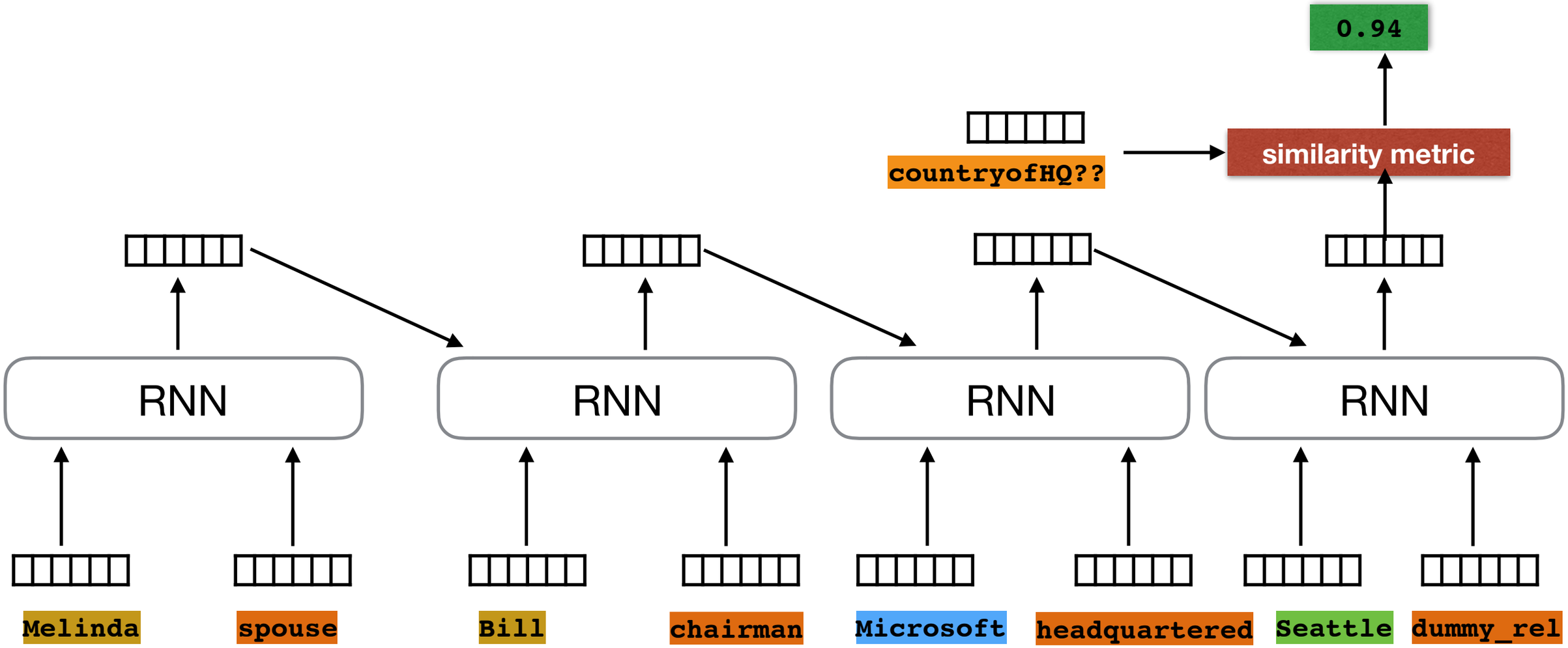
rare occurrence; hard to learn good representations.

Entity Representation

Entity Representation

Entity is represented as the sum of their annotated types

Entity Aware RNNs for Chains of Reasoning



Results

Results

Model	%MAP
Single Model	70.11

Results

Model	%MAP
Single Model	70.11
Single Model + Entity	71.74

Results

Model	%MAP
Single Model	70.11
Single Model + Entity	71.74
Single Model + Types	**73.26**

Results

Model	%MAP
Single Model	70.11
Single Model + Entity	71.74
Single Model + Types	**73.26**

4.4%

$p < 5e\text{-}6$

Results

Results

Model	%MAP	Pooling
PRA	64.43	n/a
RNN-Path (Neelkantan et al'15)	65.23	Max

Results

Model	%MAP	Pooling
PRA	64.43	n/a
RNN-Path (Neelkantan et al'15)	65.23	Max
Single Model	68.77	Max

Results

Model	%MAP	Pooling
PRA	64.43	n/a
RNN-Path (Neelkantan et al'15)	65.23	Max
Single Model	68.77	Max
Single Model	70.11	LogSumExp

Results

Model	%MAP	Pooling
PRA	64.43	n/a
RNN-Path (Neelkantan et al'15)	65.23	Max
Single Model	68.77	Max
Single Model	70.11	LogSumExp
Single Model + Types	**73.26**	LogSumExp

Results

Model	%MAP	Pooling
PRA	64.43	n/a
RNN-Path (Neelkantan et al'15)	65.23	Max
Single Model	68.77	Max
Single Model	70.11	LogSumExp
Single Model + Types	**73.26**	LogSumExp

13.7%

Predictive Clauses

Predictive Clauses

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

Predictive Clauses

Freebase

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

Predictive Clauses

Freebase

/people/person/place_of_birth(A,B) ⟷

Textual relations

’was born in’(A,X) & ‘commonly known as’(X,B)

Predictive Clauses

Universal Schema

Freebase

/people/person/place_of_birth(A,B) ⟷

Textual relations

'was born in'(A,X) & 'commonly known as'(X,B)

Predictive Clauses

Freebase

/people/person/place_of_birth(A,B) ⟷

Textual relations

’was born in’(A,X) & ‘commonly known as’(X,B)

Predictive Clauses

Freebase

Textual relations

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

/book/written_work/original_language(A,B) ⟷ /book/written_work_author(A,X) & 'address'(X,Y)

& /people/person/nationality^{-1}(Y,Z) & people/person/languages(Z,B)

Predictive Clauses

Freebase

/people/person/place_of_birth(A,B) ⟷ Textual relations: ’was born in’(A,X) & ‘commonly known as’(X,B)

/book/written_work/original_language(A,B) ⟷ /book/written_work_author(A,X) & ‘address’(X,Y)

& /people/person/nationality^{-1}(Y,Z) & people/person/languages(Z,B)

Entity Aware Model

Predictive Clauses

Freebase

Textual relations

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

/book/written_work/original_language(A,B) ⟷ /book/written_work_author(A,X) & 'address'(X,Y)

& /people/person/nationality^{-1}(Y,Z) & people/person/languages(Z,B)

Entity Aware Model

Predictive Clauses

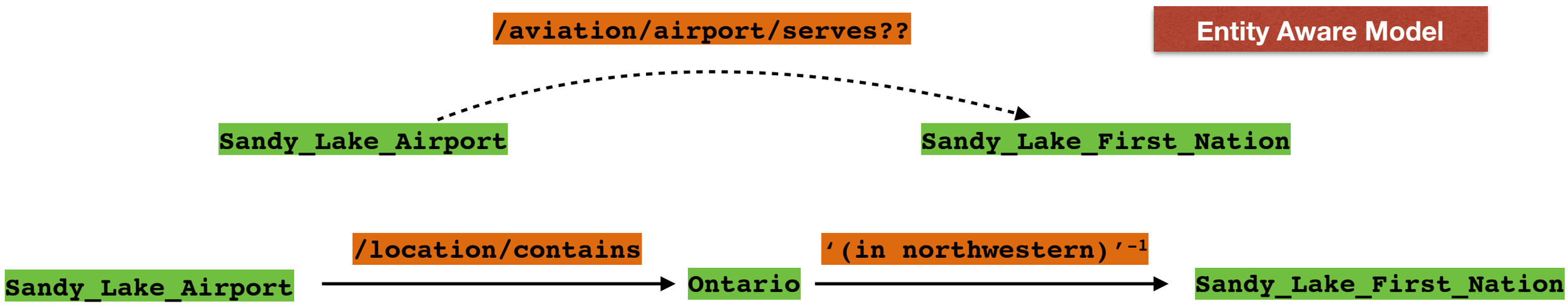
Freebase

Textual relations

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

/book/written_work/original_language(A,B) ⟷ /book/written_work_author(A,X) & 'address'(X,Y)

& /people/person/nationality^{-1}(Y,Z) & people/person/languages(Z,B)



Predictive Clauses

Freebase

Textual relations

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

/book/written_work/original_language(A,B) ⟷ /book/written_work_author(A,X) & 'address'(X,Y)

& /people/person/nationality^{-1}(Y,Z) & people/person/languages(Z,B)

Entity Aware Model

Predictive Clauses

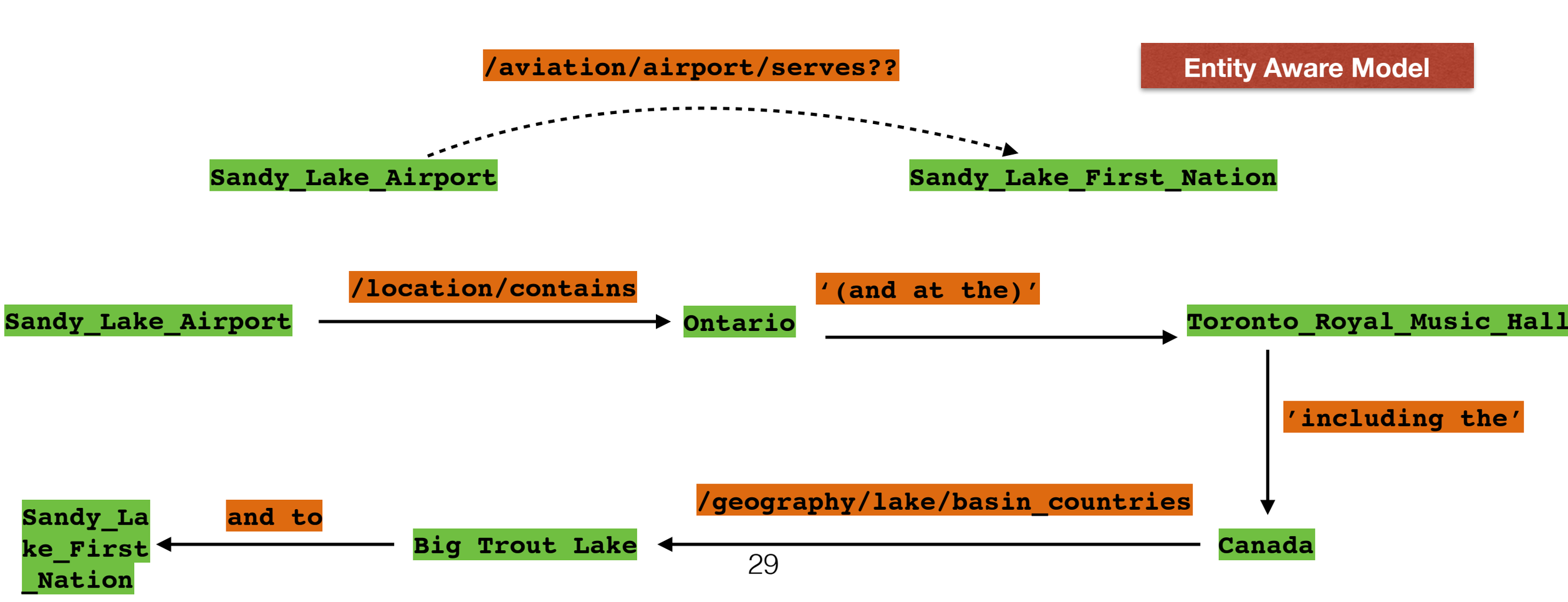
Freebase

Textual relations

/people/person/place_of_birth(A,B) ⟷ 'was born in'(A,X) & 'commonly known as'(X,B)

/book/written_work/original_language(A,B) ⟷ /book/written_work_author(A,X) & 'address'(X,Y)

& /people/person/nationality^{-1}(Y,Z) & people/person/languages(Z,B)



Conclusion

Conclusion

- Introduced a high-capacity single RNN model for relation extraction

Conclusion

- Introduced a high-capacity single RNN model for relation extraction
- Combines evidences among multiple paths and sources of evidence

Conclusion

- Introduced a high-capacity single RNN model for relation extraction
- Combines evidences among multiple paths and sources of evidence
- Entity Aware!

Conclusion

- Introduced a high-capacity single RNN model for relation extraction
- Combines evidences among multiple paths and sources of evidence
- Entity Aware!

Thanks!