Automatic Web Spreadsheet Data Extraction

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COMPUTER SCIENCE AND ENGINEERING
UNIVERSITY of MICHIGAN ■ COLLEGE of ENGINEERING

Spreadsheets Are Everywhere

More than 400 million Excel users worldwide.

–Microsoft

50 to 80% of enterprises use standalone spreadsheets for critical applications.

–Forester

Spreadsheets Are Everywhere

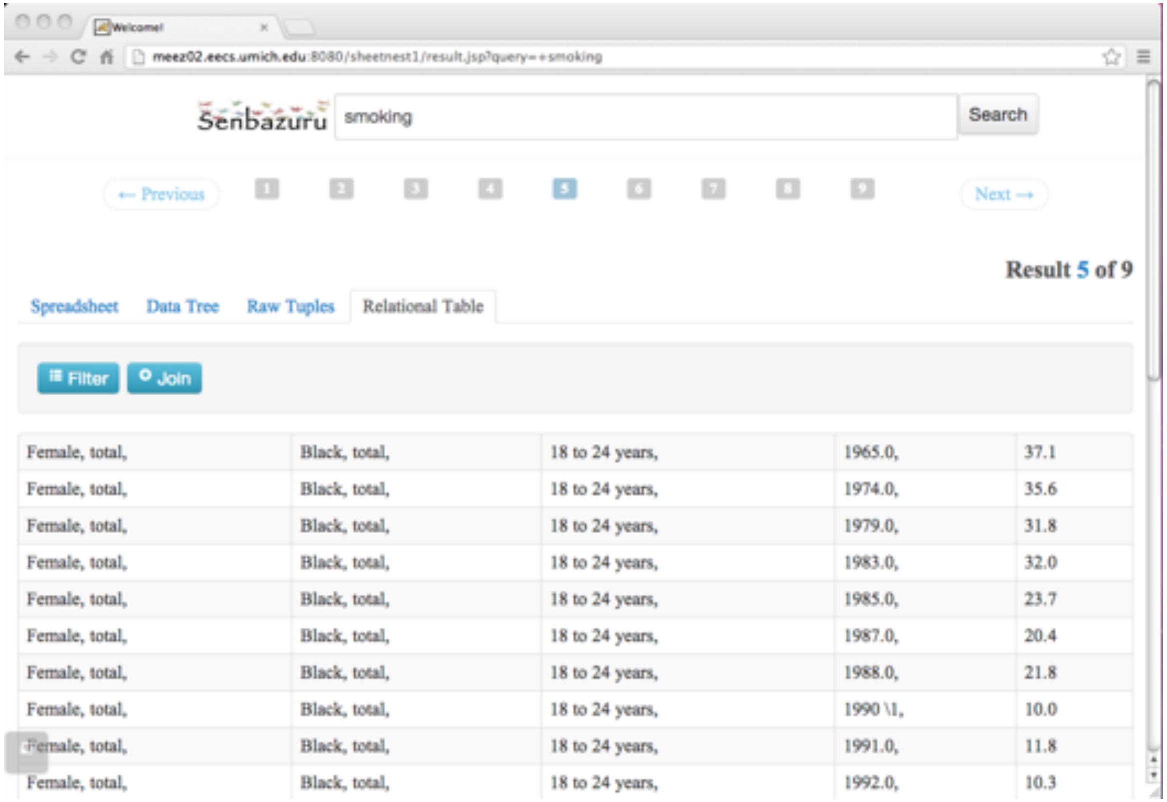
- Our Web crawl obtained *410,554* Microsoft Excel Files from *51,252* distinct Internet domains.

Domains	# of spreadsheets	% of total
www.bts.gov	12435	3.03%
www.census.gov	7862	1.91%
www.stat.co.jp	6633	1.62%
www.bankofengland.co.uk	5520	1.34%
www.ers.usda.gov	4328	1.05%
www.agr.gc.ca	4186	1.02%
www.wto.org	3863	0.94%
www.doh.wa.gov	3579	0.87%
www.nsf.gov	2770	0.67%
nces.ed.gov	2177	0.53%

OUR GOAL: Integration

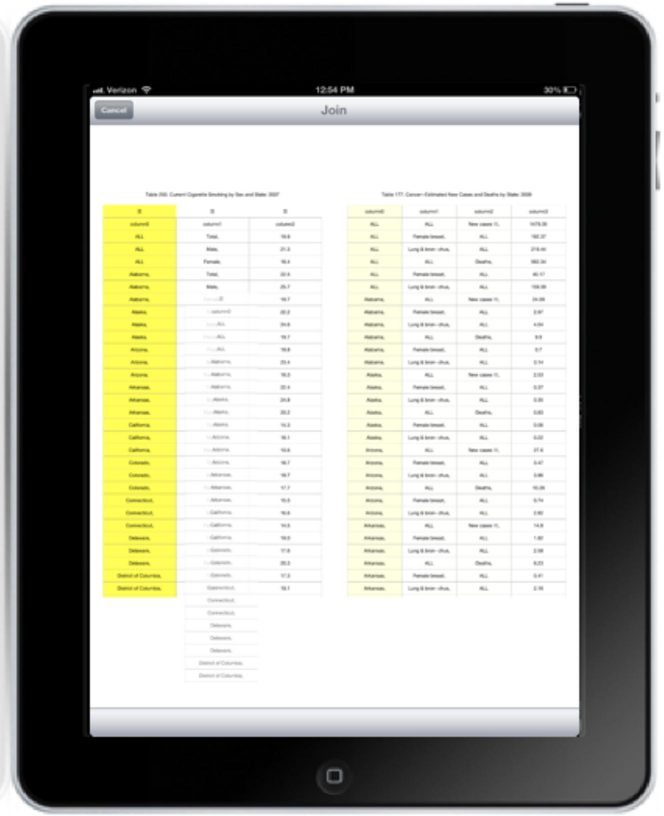
- Spreadsheets often contain data that are roughly relational, but the schema is entirely implicit.
- ***Example***: An analyst may want to combine a spreadsheet about *company sales* with a government produced spreadsheet about *economic performance* to predict future sales.

Relational Data Enables Integration



Result 5 of 9

Female, total,	Black, total,	18 to 24 years,	1965.0,	37.1
Female, total,	Black, total,	18 to 24 years,	1974.0,	35.6
Female, total,	Black, total,	18 to 24 years,	1979.0,	31.8
Female, total,	Black, total,	18 to 24 years,	1983.0,	32.0
Female, total,	Black, total,	18 to 24 years,	1985.0,	23.7
Female, total,	Black, total,	18 to 24 years,	1987.0,	20.4
Female, total,	Black, total,	18 to 24 years,	1988.0,	21.8
Female, total,	Black, total,	18 to 24 years,	1990 \1,	10.0
Female, total,	Black, total,	18 to 24 years,	1991.0,	11.8
Female, total,	Black, total,	18 to 24 years,	1992.0,	10.3

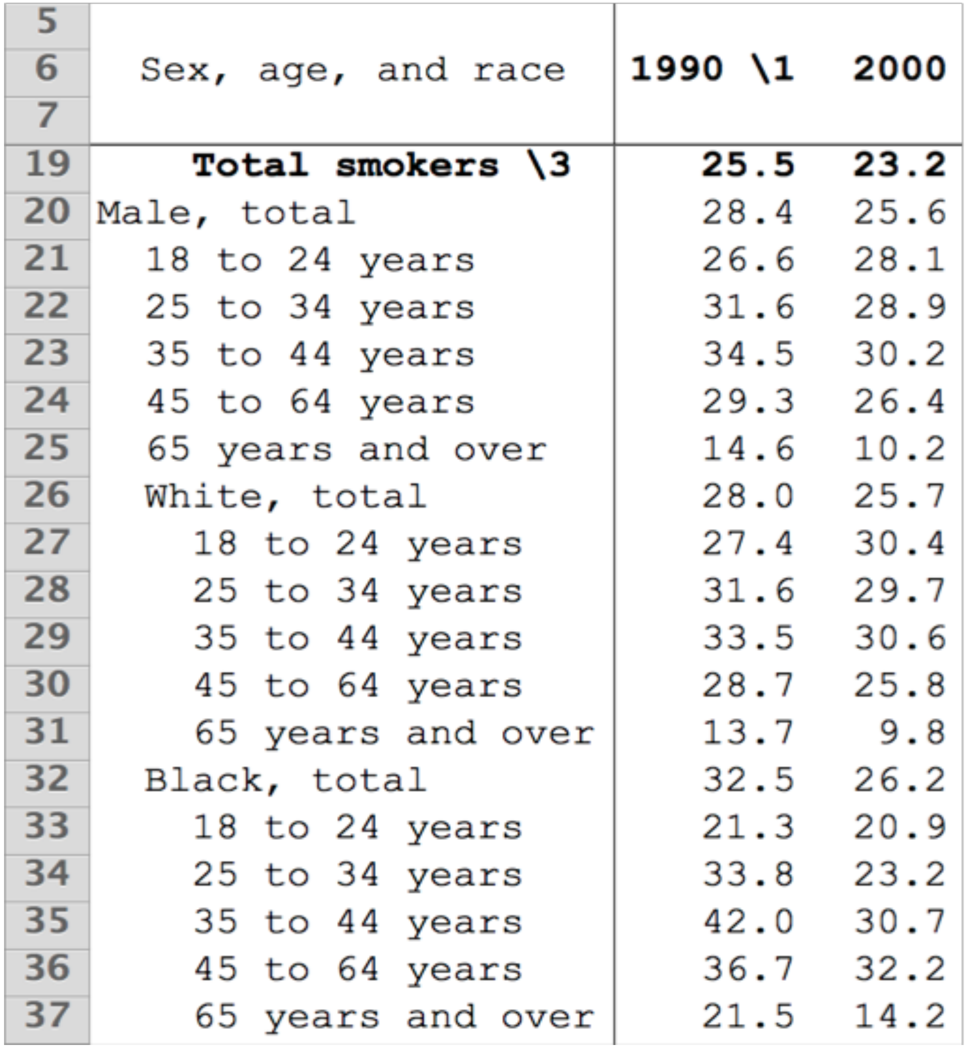


How to Extract Relational Data from Spreadsheets to Enable Integration?

Related Work

- Transform spreadsheets into relational format but require user specified rules, e.g.
  - Hung et al. (transformation languages)
- Automatic extraction on a simple and specific type of spreadsheets, e.g.
  - Cunha et al. (focus on the type of spreadsheets with relational tables)
  - Ahmad et al. (detect spreadsheet errors)

Challenges: Implicit Structures



5 6 7	Sex, age, and race	1990 \1	2000
19	**Total smokers \3**	**25.5**	**23.2**
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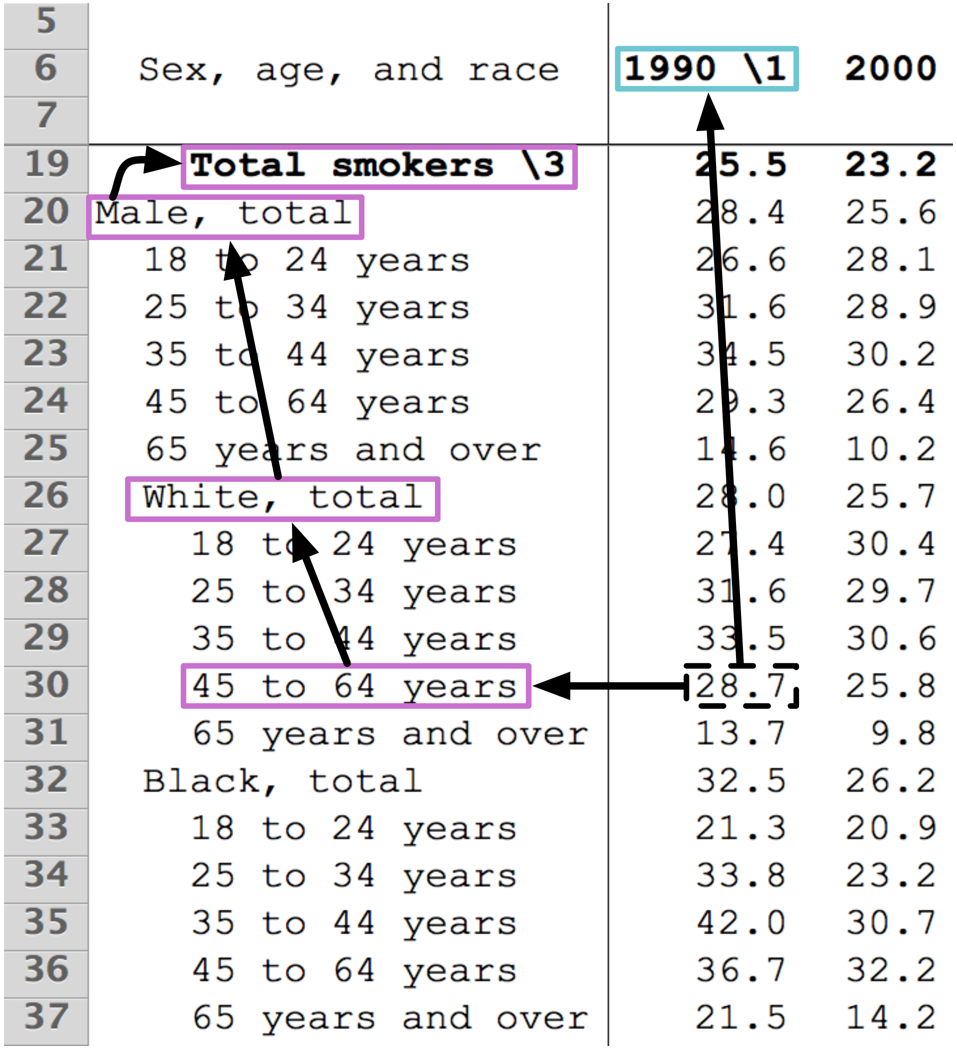
Challenges: Implicit Structures



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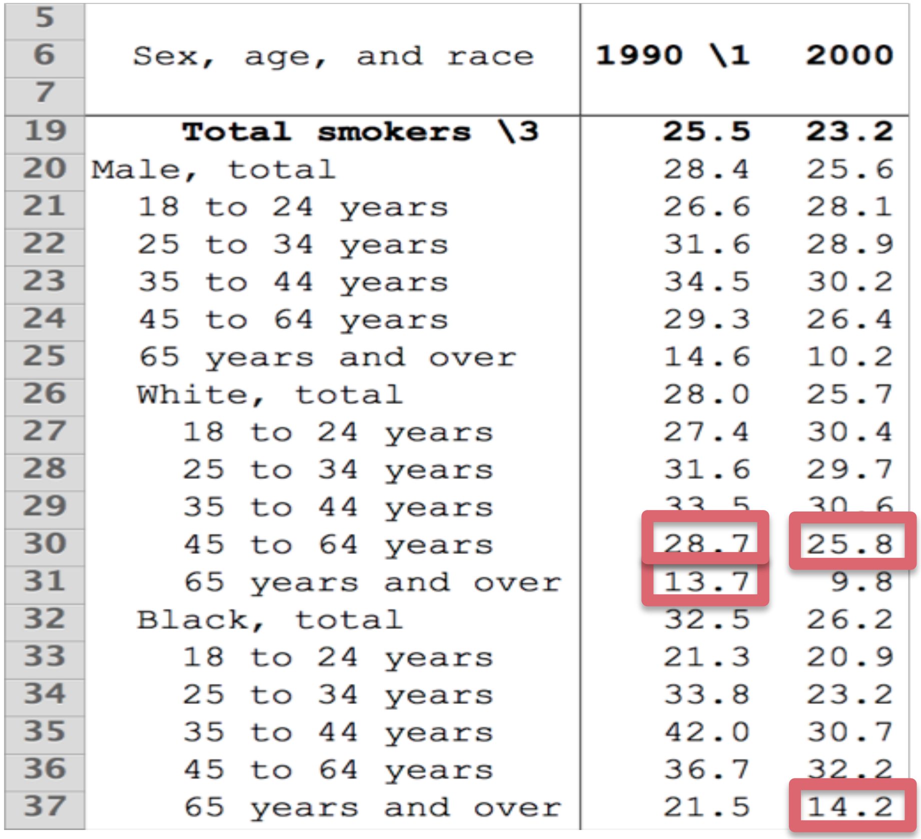

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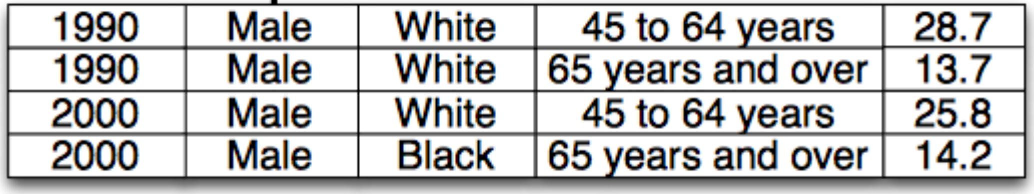
Relational Tuples:



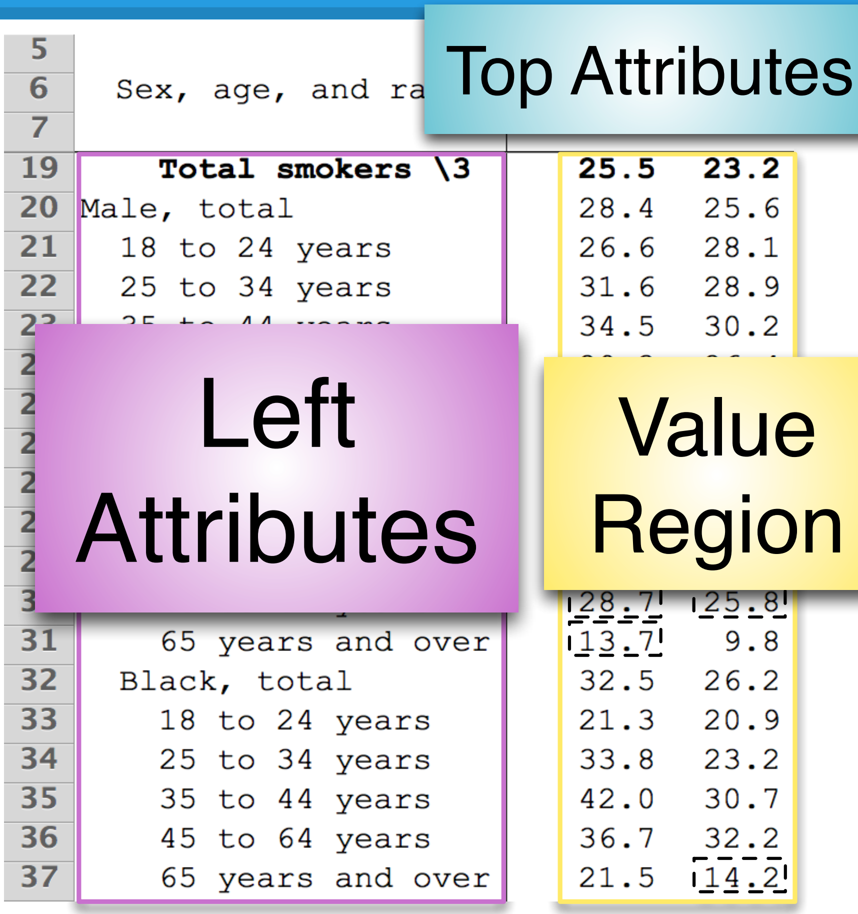
1990	Male	White	45 to 64 years	28.7
1990	Male	White	65 years and over	13.7
2000	Male	White	45 to 64 years	25.8
2000	Male	Black	65 years and over	14.2

Outline

1. Introduction
2. System Framework
3. Experiments
4. Conclusion

Spreadsheet Terminologies

- A *data frame* is a three-part spreadsheet structure, consisting of *attribute* and *value* regions.



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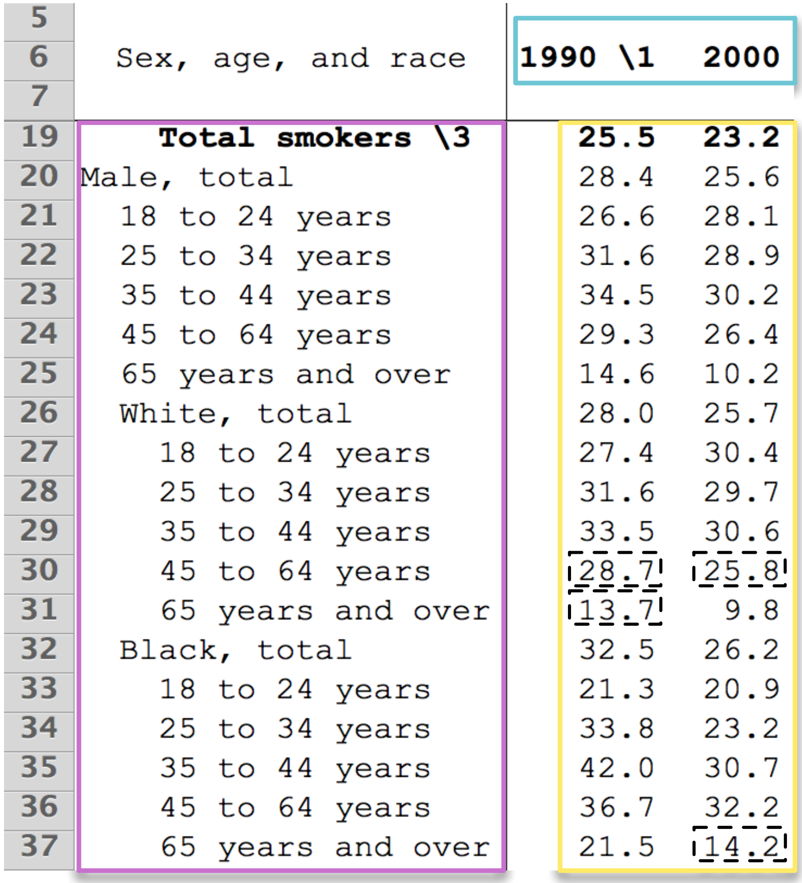
Spreadsheet Terminologies

- A ***hierarchical spreadsheet*** is a data frame spreadsheet with either a hierarchical *left* or *top* attribute region.



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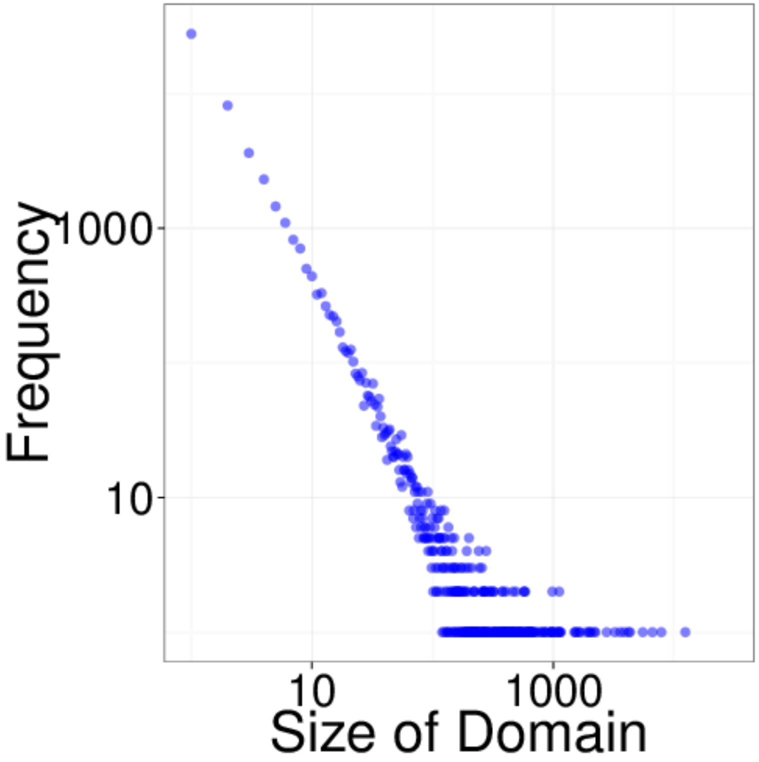
Web Spreadsheets Observations

- *Strongly skewed distribution*



Web Spreadsheets Observations

- *Strongly skewed distribution*.
- *32.5%* of the Web spreadsheets are hierarchical.
- *More than 60%* spreadsheets in the top 10 Internet domains are hierarchical.

Our system requirements

- The system has to process data frame spreadsheets, especially the hierarchical ones.
- The system has to be automatic.

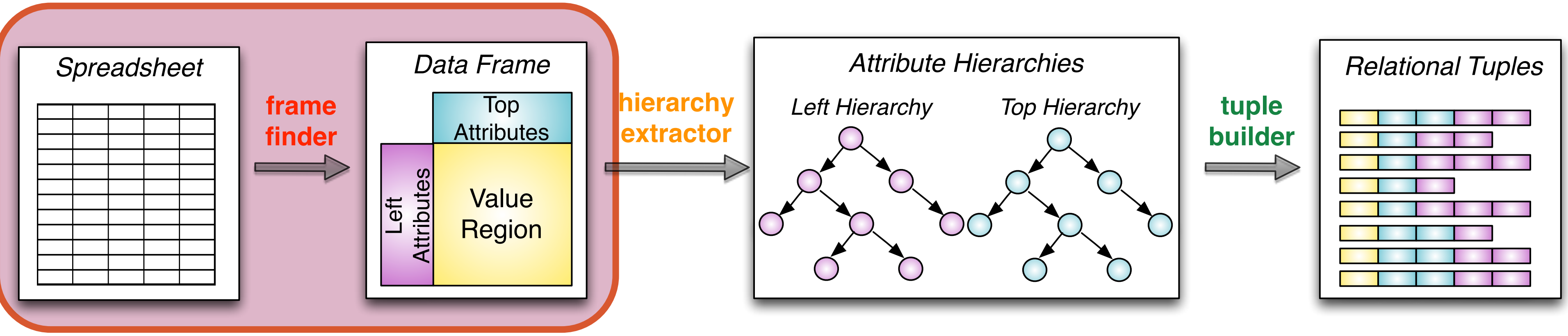
Problem Formulation

We present the first automatic, domain-independent spreadsheet extractor, the first step in building a spreadsheet integration tool.

- **Input**: A *data frame* spreadsheet
- **Output**: The *relational tuples* for the spreadsheet

Three-Stage Pipeline

1. Frame Finder
2. Hierarchy Extractor
3. Tuple Builder



Frame Finder

Three-Stage Pipeline

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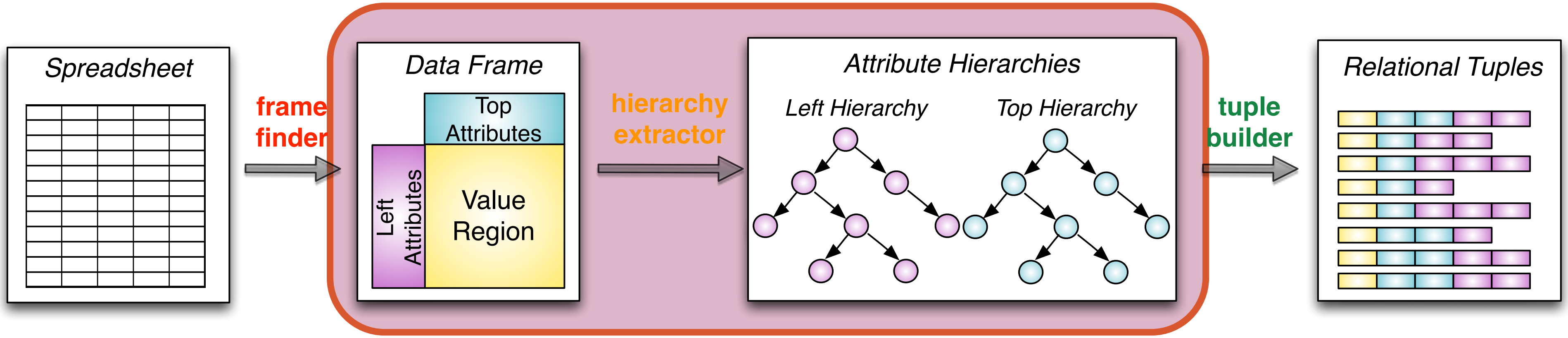

Hierarchy Extractor

Three-Stage Pipeline

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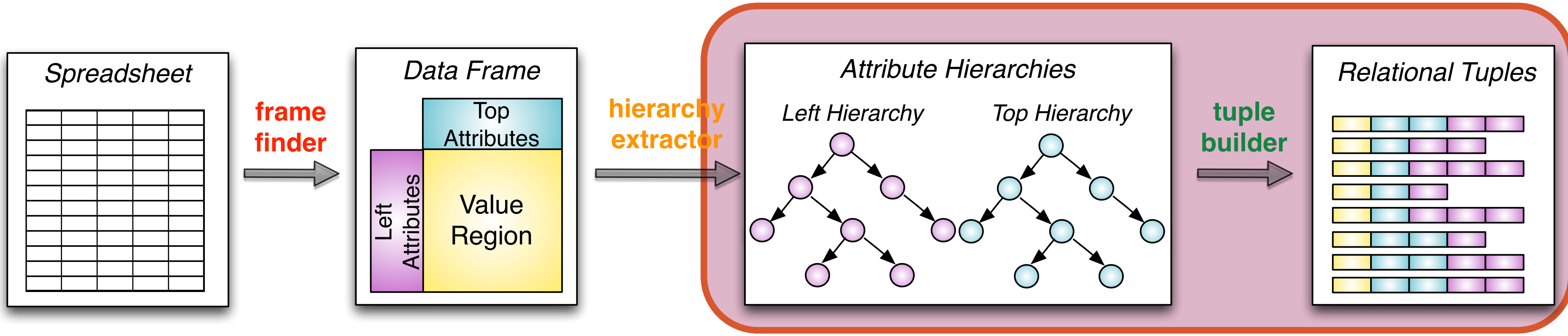


Tuple Builder

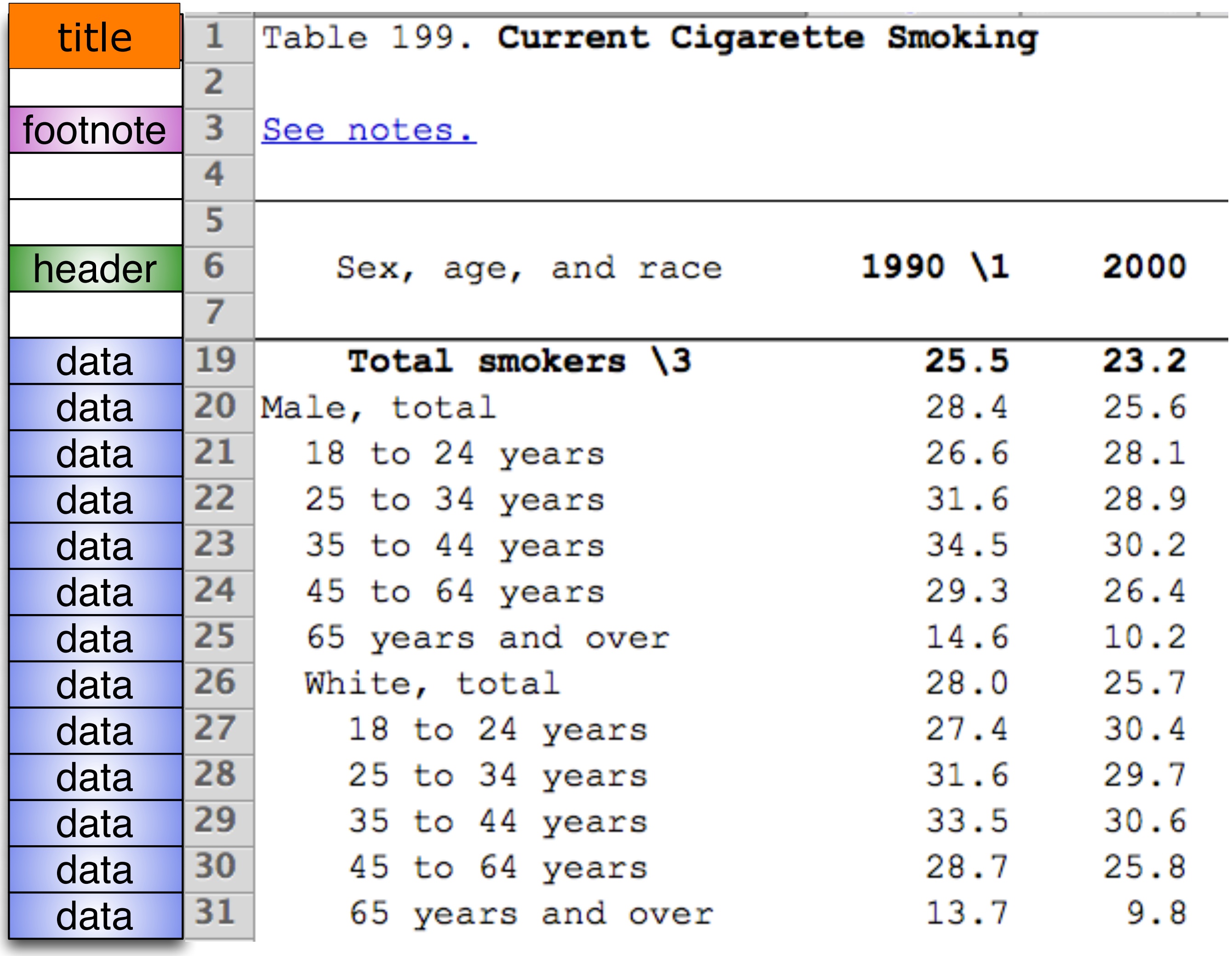
Step 1: Frame Finder

- The *frame finder* detects the three semantic regions in a spreadsheet.
- Simplify the task as a *row labeler* task: For each row in a spreadsheet, assign a label in {*title, header, data, footnote*}.

Step 1: Frame Finder

- The *row labeler* is based on a CRF to encode two types of observations:
  - The properties of each row indicate its semantic label.
  - The labels assigned to adjacent rows are highly related.

Step 1: Frame Finder



title	1	Table 199. **Current Cigarette Smoking**		
	2			
footnote	3	See notes.		
	4			
	5			
header	6	Sex, age, and race	**1990 \1**	**2000**
	7			
data	19	**Total smokers \3**	**25.5**	**23.2**
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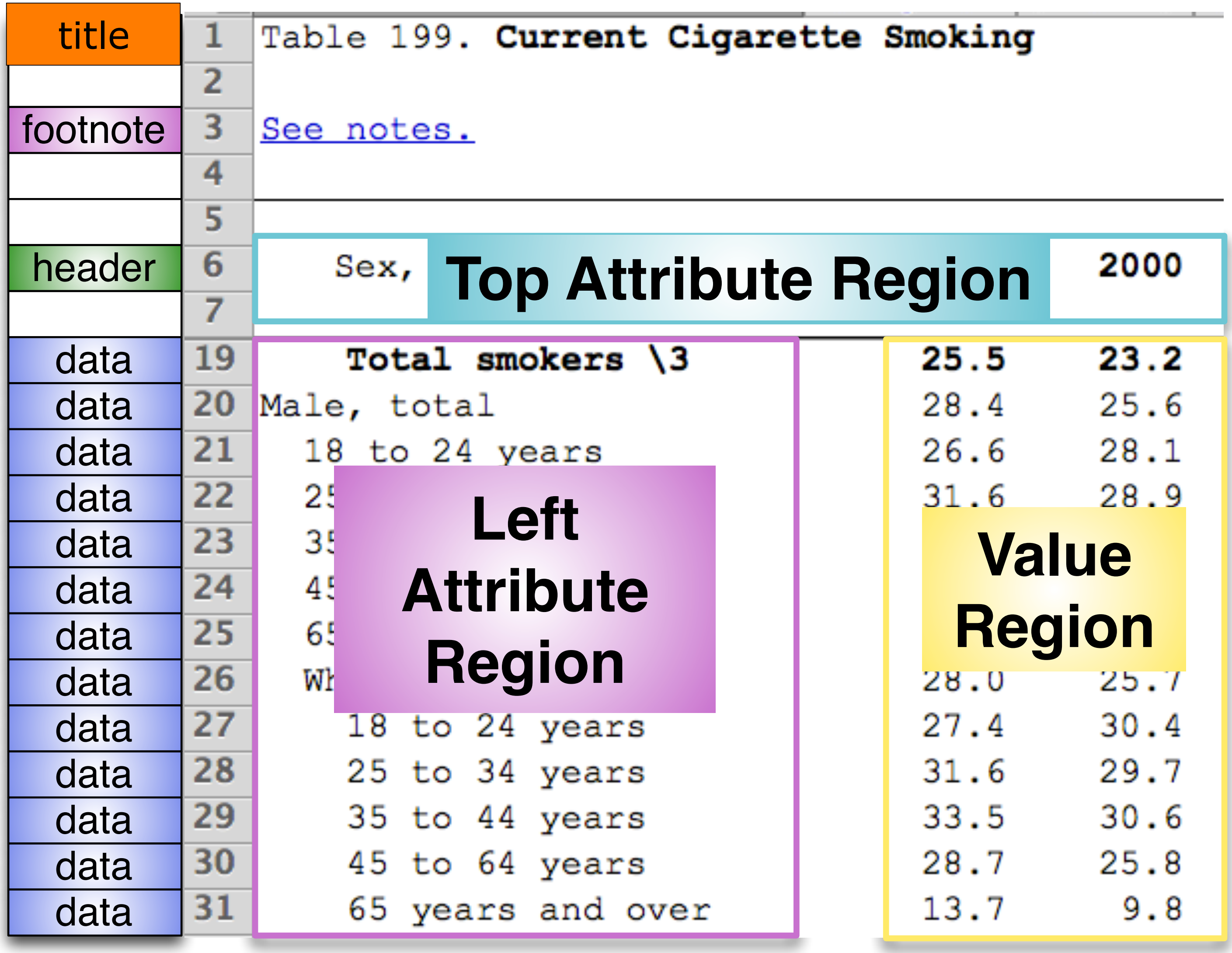

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	4			
	5			
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	7			
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data	24	45		
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Top Attribute Region

Left Attribute Region

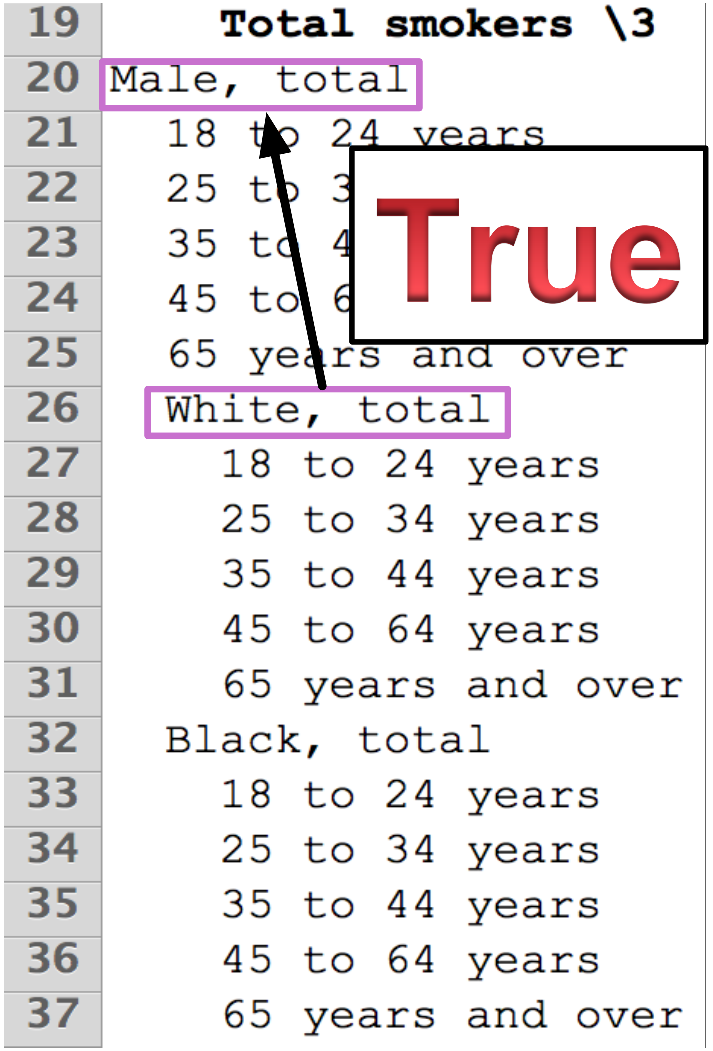
Value Region

Step 2: Hierarchy Extractor

- The *hierarchy extractor* recovers the attribute hierarchy for the left or top attribute region.
- It identifies all the annotation attribute pairs in the attribute region, thus recovering the attribute hierarchy.

Step 2: Hierarchy Extractor

- Algorithm 1: Classification
  - We enumerate all the attribute pairs in an attribute region as the *annotation attribute pair* candidates, and each of the candidate takes a label from {*true*, *false*}.
  - E.g. (White, Male) = *true* and (White, Black) = *false*.



```
19      Total smokers \3
20 Male, total
21    18 to 24 years
22    25 to 3
23    35 to 4
24    45 to 6
25    65 years and over
26   White, total
27      18 to 24 years
28      25 to 34 years
29      35 to 44 years
30      45 to 64 years
31      65 years and over
32   Black, total
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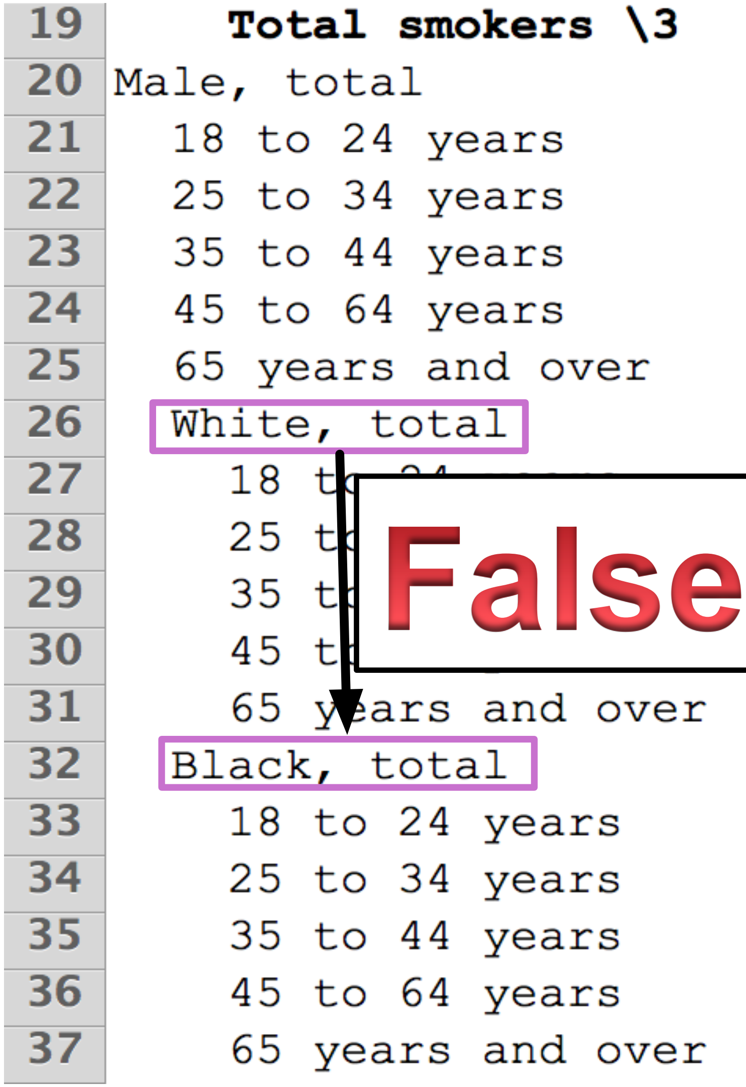

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28      25 t
29      35 t
30      45 t
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```
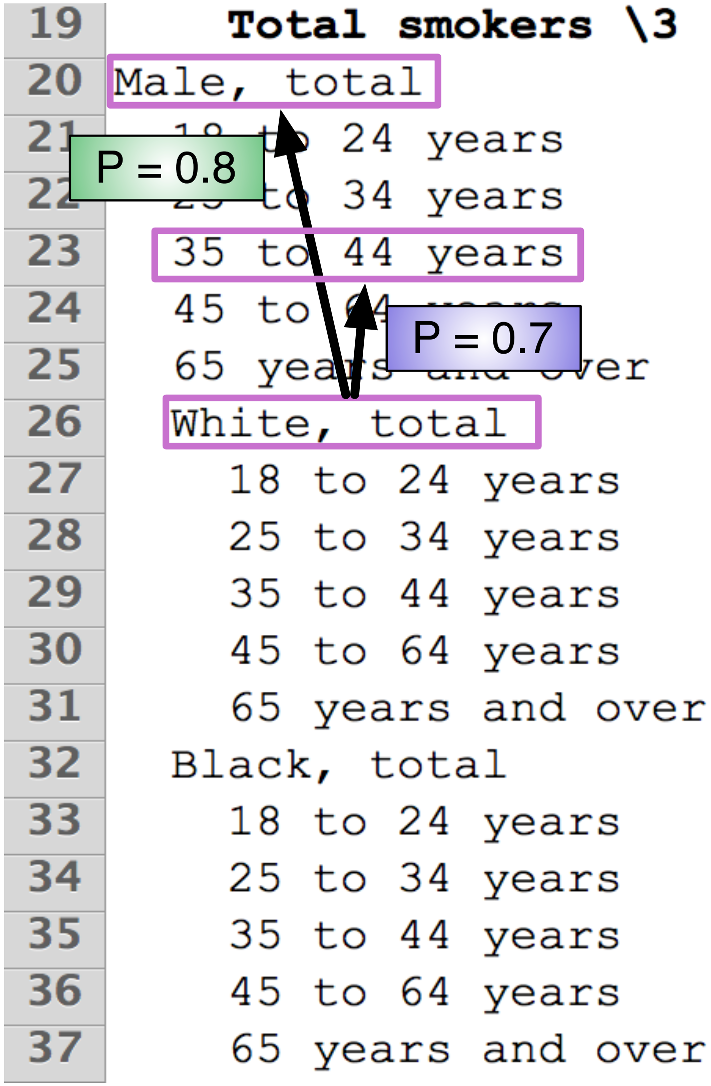

False

Step 2: Hierarchy Extractor

- Algorithm 2: Enforced-tree Classification
  - Obtain the probability associated with each annotation pair during the classification.



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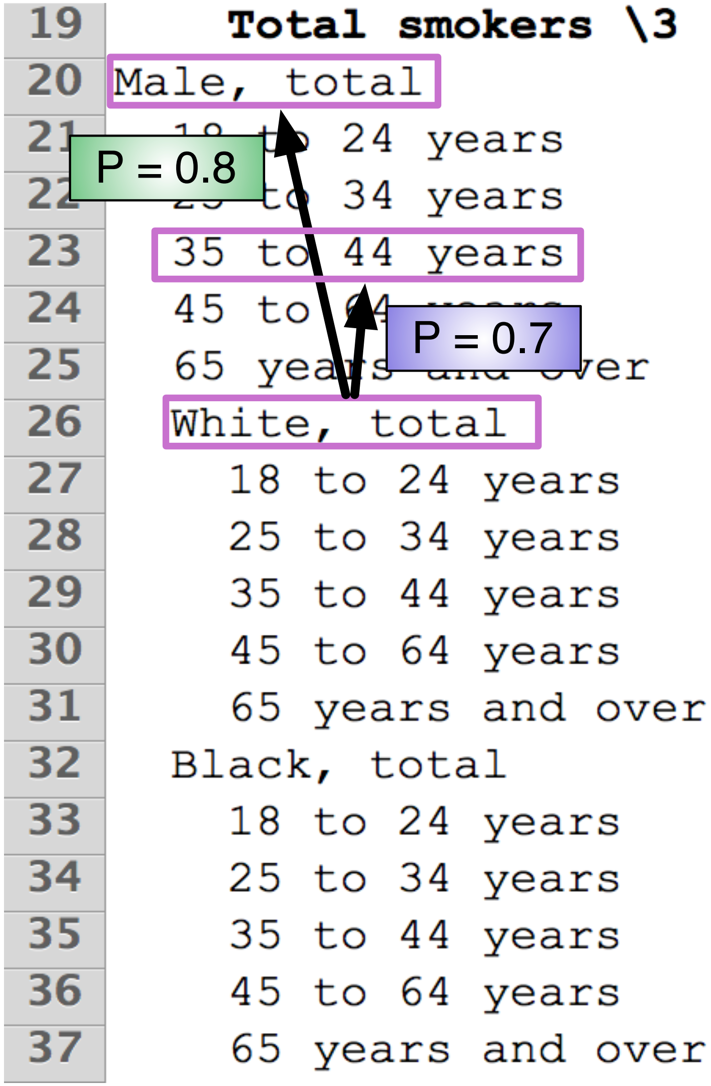
Step 2: Hierarchy Extractor

- Algorithm 2: Enforced-tree Classification
  - Obtain the probability associated with each annotation pair during the classification.
  - For a child, find the parent with the highest probability.



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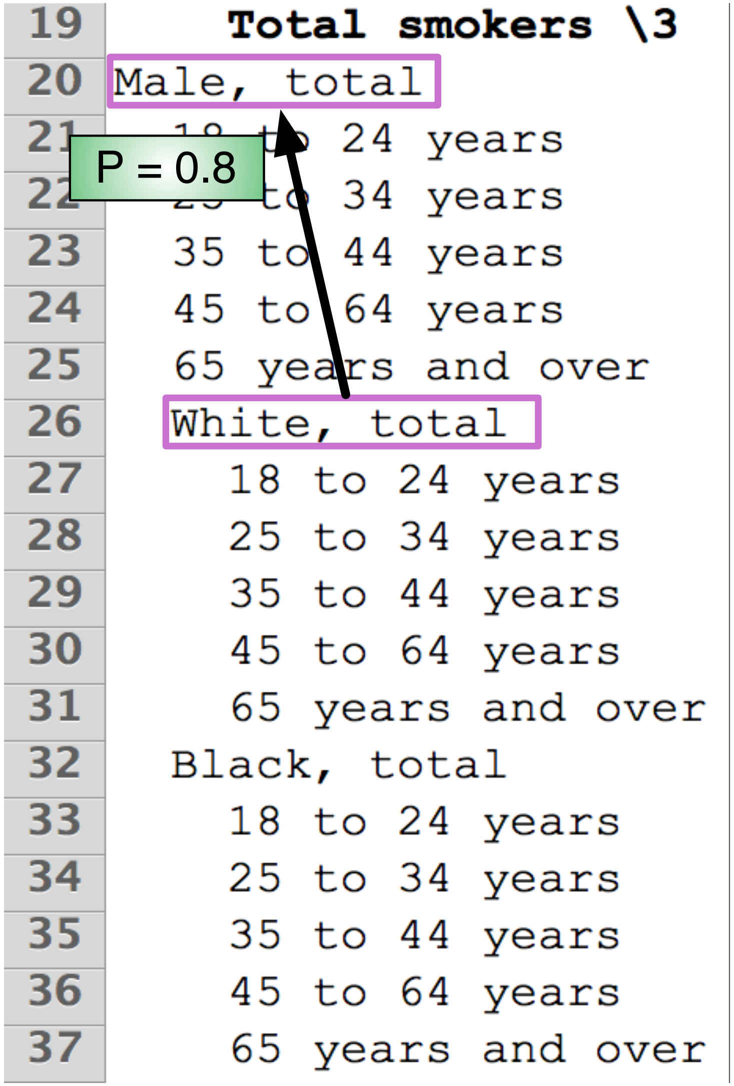

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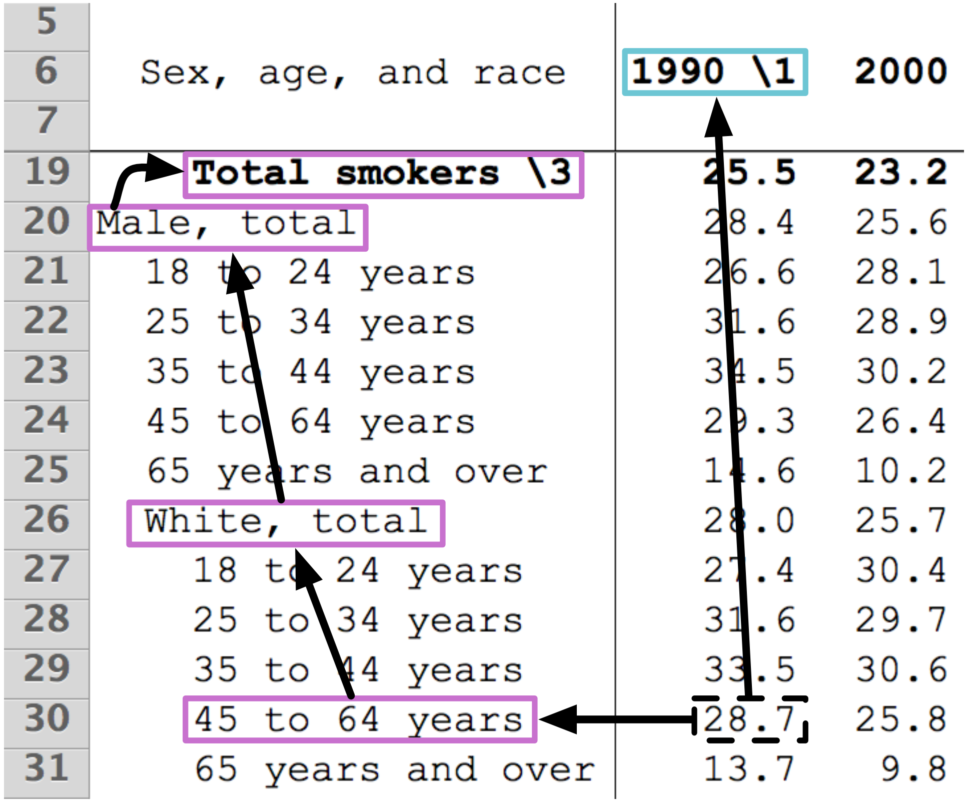
Step 3: Tuple Builder

- The *tuple builder* generates relational tuples for each value in the value region.



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1990	Total smokers	Male, total	White, total	45 to 64 years	28.7

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Experiment Setup

- Our WEB dataset has 410,554 Excel files from 51,252 distinct Internet domains.
  - We randomly selected 100 random *hierarchical* spreadsheets (with hierarchical top or left attributes).
  - Average depth of the *top* hierarchy is 2.14 with the maximum 5.
  - Average depth of the *left* hierarchy is 2.61 with the maximum 9.

Experiment Setup

- For all the experiments, we split the 100 spreadsheets into 50 training and 50 testing for 10 times. conducted equal-sized training and testing for 10 times and obtained the average value for the following metrics:
  - ○ *Precision* and *Recall*
  - ○ *Error per sheet* = (false positive + false negative)/N where N is the # of sheets.

Frame Finder

- The row labeler assigns a label in {title, header, data, footnote} for each non-empty row in a spreadsheet.
- Comparison methods:
  - Base-CRF: textual features
  - Full-CRF: textual features and layout features

Frame Finder

Metric	Methods	title	header	data	footnote
F1	Base-CRF	0.582	0.615	0.982	0.647
	Full-CRF	**0.774**	**0.774**	**0.994**	**0.834**
Error per sheet	Base-CRF	3.534	2.348	6.526	4.208
	Full-CRF	**0.872**	**1.316**	**1.528**	**1.208**

Frame Finder

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2.844

Hierarchy Extractor

- The hierarchy extractor detects all the annotation attribute pairs in an attribute region.
- Comparison methods:
  - Human
  - SVM: classification method
  - EN-SVM: tree-enforced classification method

Hierarchy Extractor

Metric	Methods	Top	Left
F1	SVM	0.919	0.769
	EN-SVM	**0.920**	**0.811**

Metric	Methods	Top	Left
Error per sheet	Human	22.469	58.598
	SVM	1.834	19.554
	EN-SVM	**1.829**	**16.154**

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Conclusion

- We present a novel system to extract spreadsheet relational data automatically, which makes it possible for downstream integration applications.
- The system parses spreadsheets to detect different semantic regions, recognizes the implicit hierarchical structures of the attributes and then constructs relational tuples.

Questions?