APPLYING LOCAL DIFFERENTIAL PRIVACY TO TEXT

Besat Kassaie

December 2017

Optometry Sample Record

Patient Name: [redacted]

Health Number: [redacted]
Date Of Birth: [redacted]
General Practitioner:

Exam Date: September 09, 2015
Practitioner: Hadley, K
Occupation:

[redacted] Cell)
[redacted]
Canada

General Information
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@16:19

Accompanied By
Alone

Driver's License (Type | Restrictions)
G - Normal

Hobbies/Activities/Computer Use
want to get glasses mostly for reading

Chief Complaint Extended
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@16:20

Chief Complaint
GP suspect px has constricted peripheral vision

lost her glasses from last year (readers), and bought drug store readers to read, and like this one better, cause they are stronger than the ones from UW optical services

safety glasses filled in too last year, but rarely used them

occasional dryness OU, same as last year , esp after wake up

px hit by a truck when she was 18yo, and had migraine and short term memory loss ever after, and taking depression meds.

Blur | Diplopia
No

Asthenopia | Headaches
No

Flashes | Floaters
No

Patient Ocular History
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:15

Last Full Eye Exam (Where | When | Outcome)
PC | 2013 May

Previous Injuries/Infections
No

Previous Eye Surgery
No

Amblyopia/Strabismus/VT Patching
No

Other Eye Conditions
No

Current or previous CL/spectacle wear
No

Patient General Health
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:16

Last Medical Exam
Routine two months ago | Dr Mclean

Health Conditions / Investigations
No

Diabetes
pre-DM | controlled with exercise | not sure about the blood sugar level

Hypertension | Heart Disease/Stroke
no

COPD/Asthma | Allergies
no | dust allergy

Tobacco Use
Never

Current Medications
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:13

Other Prescription Medication
ALmotriptan tablets for migraines

Fluoxetine HCL 20mg for anti-depression

Other OTC Medication
Meds for Allergy, low aspirin,

Family History
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:13

☐ Family History Unknown

Glaucoma
No

Blindness/Visual Impairment
No

Other Ocular Conditions
No

Other Health Conditions
DM | older brother

Habitual Rx
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:13

℞ Date last year | Lens Type Single Vision

Mat/Tint

	Sphere	Cyl	Axis	PD	ADD	PD
OD	+1.50					
OS	+1.50					

External Notes:

Visual Acuity
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:13

Acuity Test Used Distance
Snellen

Near Method
40cm

Unaided
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:20

	Dx OD	Dx OS	Dx OU	Nx OD	Nx OS	Nx OU
Unaided	6/6	6/6	6/6			

Aided
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:19

	Dx OD	Dx OS	Dx OU	Nx OD	Nx OS	Nx OU
Specs				0.4M	0.4M	0.4M

Cover Test
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:22

Cover Test	Unilateral		Alternating
Distance	Non-Strab		Ortho
Near	Non-Strab		4 exo

Broad H
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:22

Method
Associated

Results
Unrestricted

Pursuits Full Equal Smooth an Saccades

NPC
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:22

NPC 6/6/6 cm

Pupils
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:22

Direct pupil reflex
4+ Brisk | 4+ Brisk

Consensual pupil reflex
4+ Brisk | 4+ Brisk

Accommodative Reflex
Present | Present

Pupil shape
Round | Round

Relative afferent pupil defect
Negative

Finding
PERRL & RAPD Negative

Confrontation Fields
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:22

Confrontation Fields
Full to finger count | Full to finger count

Pupillary Distance
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:22

OU PD (Dx | Nx)
65 | 60

		Sphere	Cyl	Axis	Acuity
Static	OD	-0.25	Sph		6/6
	OS	Plano			6/6

Method Retinoscopy | User Y39HE

		Sphere	Cyl	Axis	Acuity
Subjective	OD	-0.25	Sph		6/6
	OS	-0.25	Sph		6/6
	OU				6/6

Add Determination
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:35

Method Age | WD 40 cm

	Add	Acuity	BMA	WD Range
OD	+1.75		Low	30 cm
OS	+1.75		High	50 cm

Note

Final Add
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:36

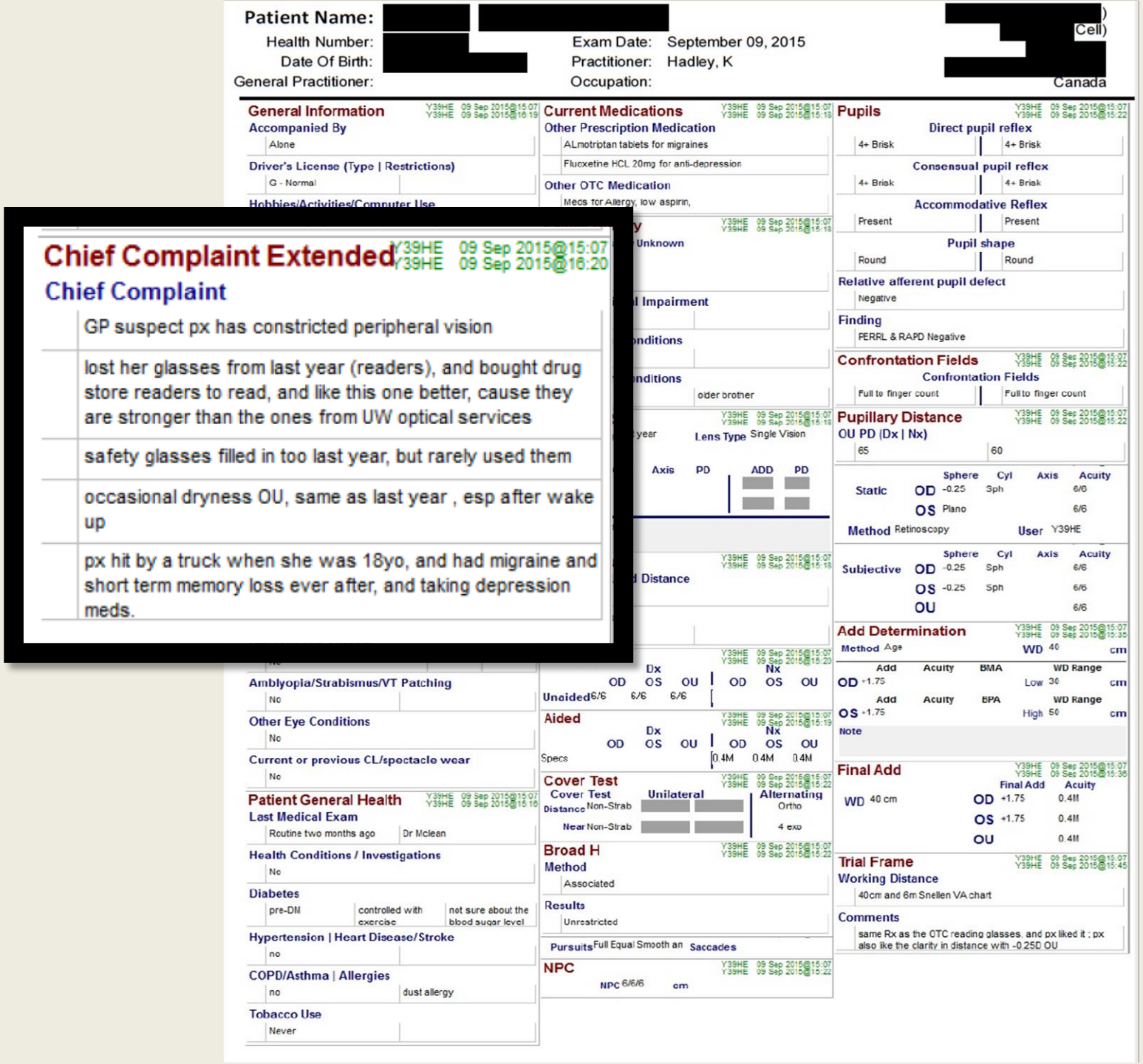
WD 40 cm

	Final Add	Acuity
OD	+1.75	0.4M
OS	+1.75	0.4M
OU		0.4M

Trial Frame
Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:45

Working Distance
40cm and 6m Snellen VA chart

Comments
same Rx as the OTC reading glasses. and px liked it ; px also like the clarity in distance with -0.25D OU



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Y39HE 09 Sep 2015@15:07
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Unknown

l Impairment

nditions

nditions

older brother

Y39HE 09 Sep 2015@15:07
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year | Lens Type: Single Vision

Axis	PD	ADD	PD

Y39HE 09 Sep 2015@15:07
Y39HE 09 Sep 2015@15:13

d Distance

Y39HE 09 Sep 2015@15:07
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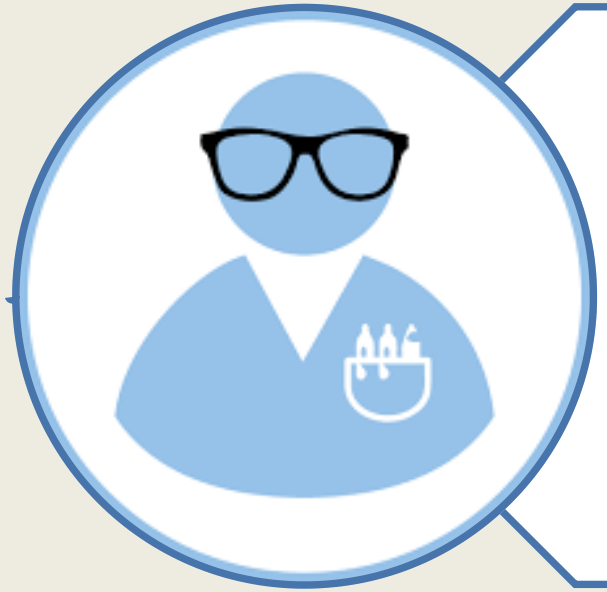
Electronic Health Record (EHR) For Medical Research



Researchers like to access all the data available in a clinical database to conduct accurate studies

Patients are cautious about their medical data which are considered as private information

Records with consent

- Comprehensiveness
- Accuracy

Records with no consent

- Comprehensiveness
- Accuracy
- Privacy

Records with consent

Comprehensiveness

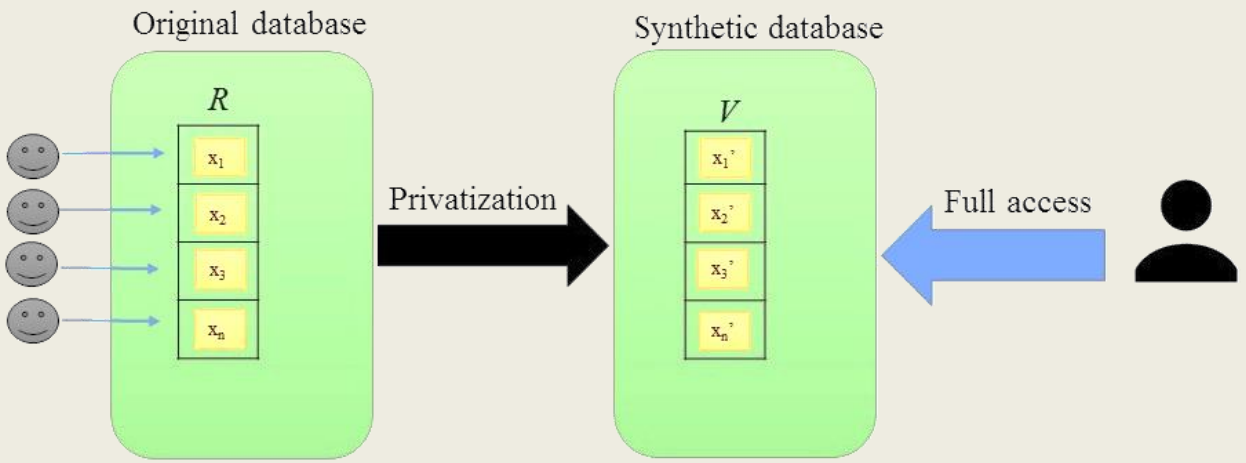
Accuracy

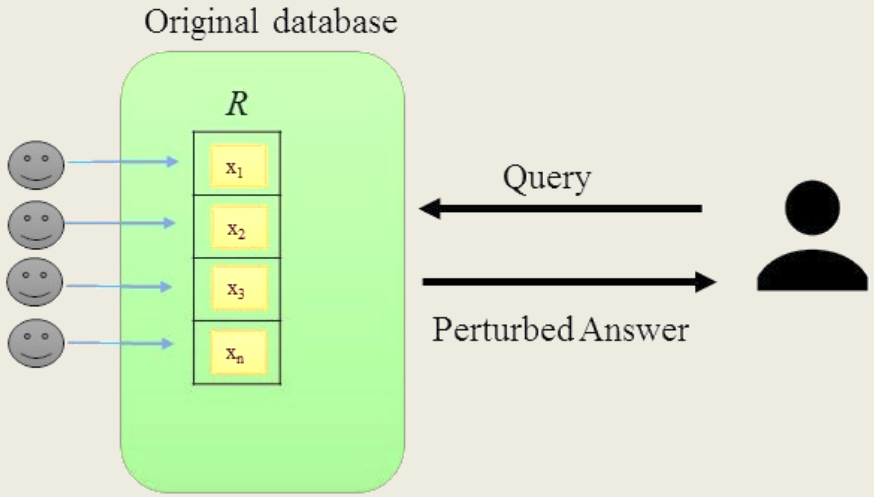
Records with no consent

Comprehensiveness

Accuracy

Privacy


Original database
R
x1
x2
x3
xn
Privatization
Synthetic database
V
x1'
x2'
x3'
xn'
Full access


Original database
R
x1
x2
x3
xn
Query
Perturbed Answer

Privacy Preserving Data Access

Anonymization

Removal of personally identifying information

Prone to linkage attack

Anonymization

Queries over Large Sets

Anonymization

Forcing all queries to be over large sets

Anonymization

Prone to differencing attacks

Anonymization

Queries over Large Sets

Query Auditing

Anonymization

Queries over Large Sets

Auditing the sequence of queries and refusing disclosive answers

Anonymization

Queries over Large Sets

Refusing to answer some queries is itself disclosive

Anonymization

Queries over Large Sets

Refusing to answer some queries is itself disclosive

Auditing can be computationally infeasible

Anonymization

Queries over Large Sets

Query Auditing

Differential Privacy

Learning useful information about a population

Learning almost nothing about an individual

Differential privacy ensures that the same conclusions will be reached independent of whether any individual is **present in** or **absent from** the data set.

Definition 1. *A randomized algorithm* M *is* ϵ*-differentially private if for all* $S \subset Range(M)$ *and for all* $x, y \in domain(M)$ *such that* $\|x - y\| \leq 1$*:* $Pr[M(x) \in S] \leq exp(\epsilon)Pr[M(y) \in S]$.

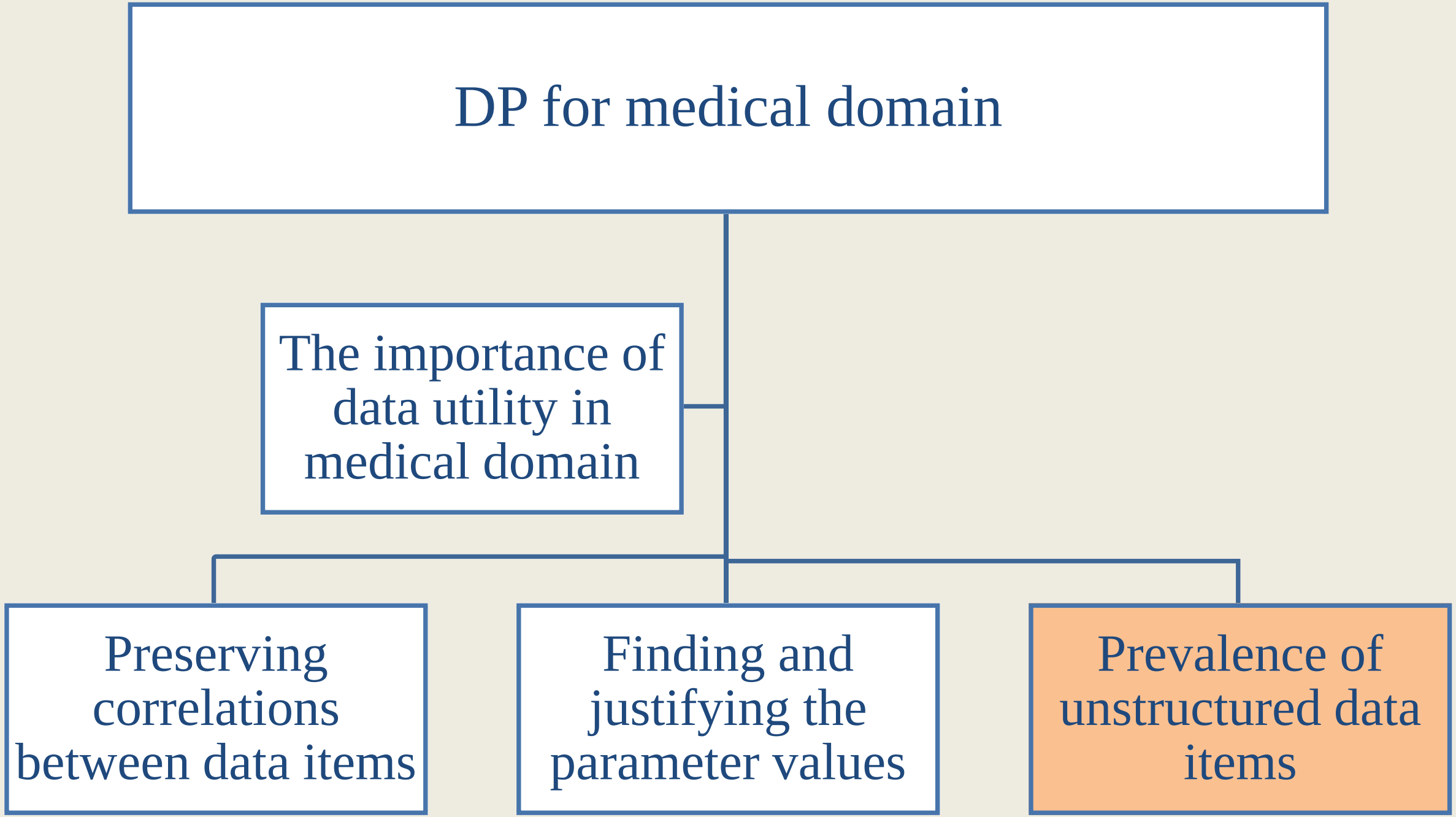
Desirable properties of differential privacy

Provides a measure to compute the privacy loss

Immune to post processing

No assumptions about an adversary's background knowledge

Applying Differential Privacy to Optometry Records


DP for medical domain
The importance of data utility in medical domain
Preserving correlations between data items
Finding and justifying the parameter values
Prevalence of unstructured data items

DP for medical domain

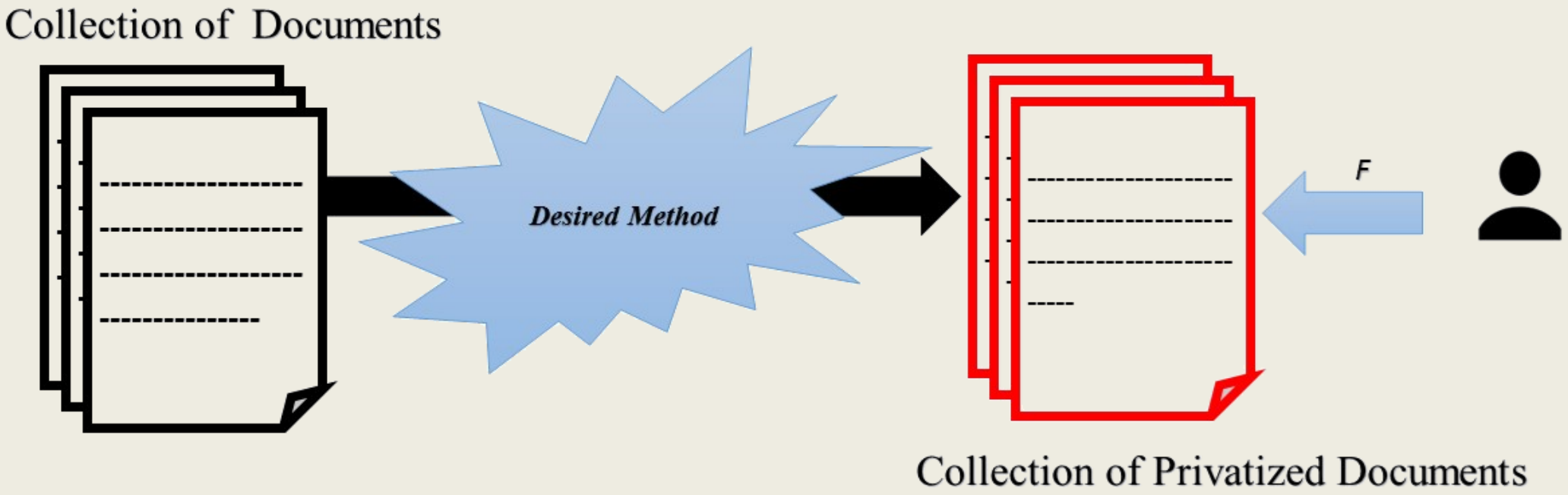
The importance of data utility in medical domain

Preserving correlations between data items

Finding and justifying the parameter values

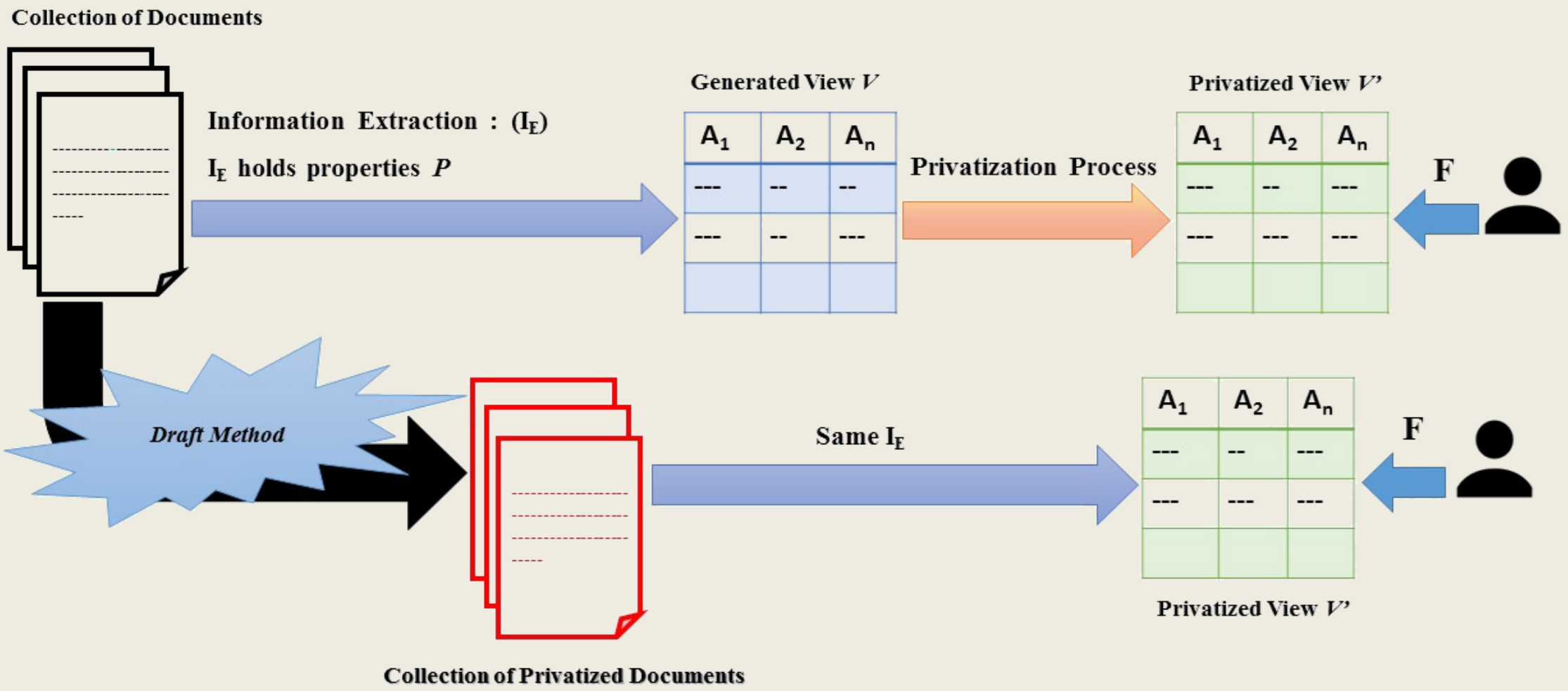
Proposing a solution to apply an appropriate variant of DP to text

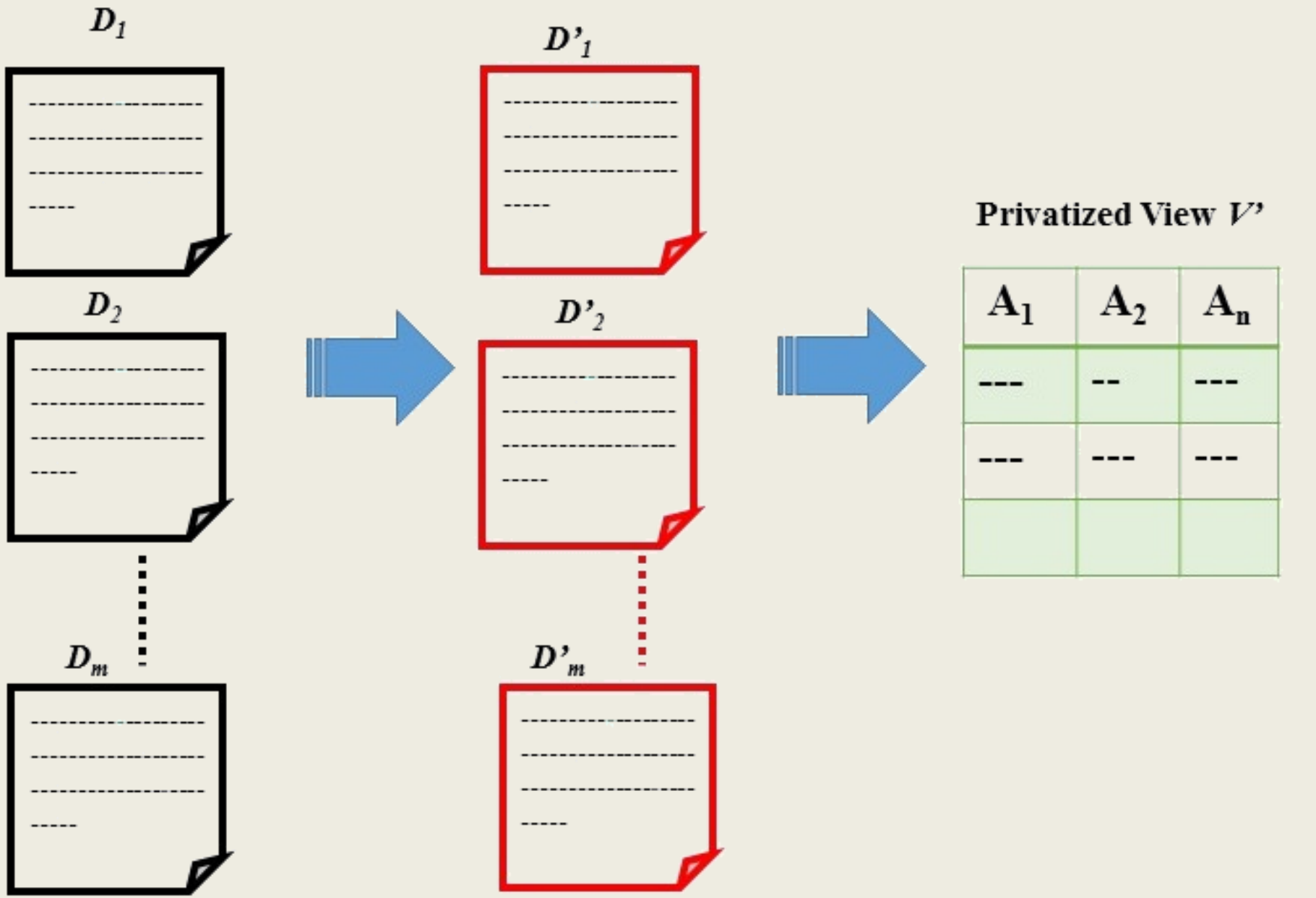
The problem statement


Collection of Documents
Desired Method
F
Collection of Privatized Documents

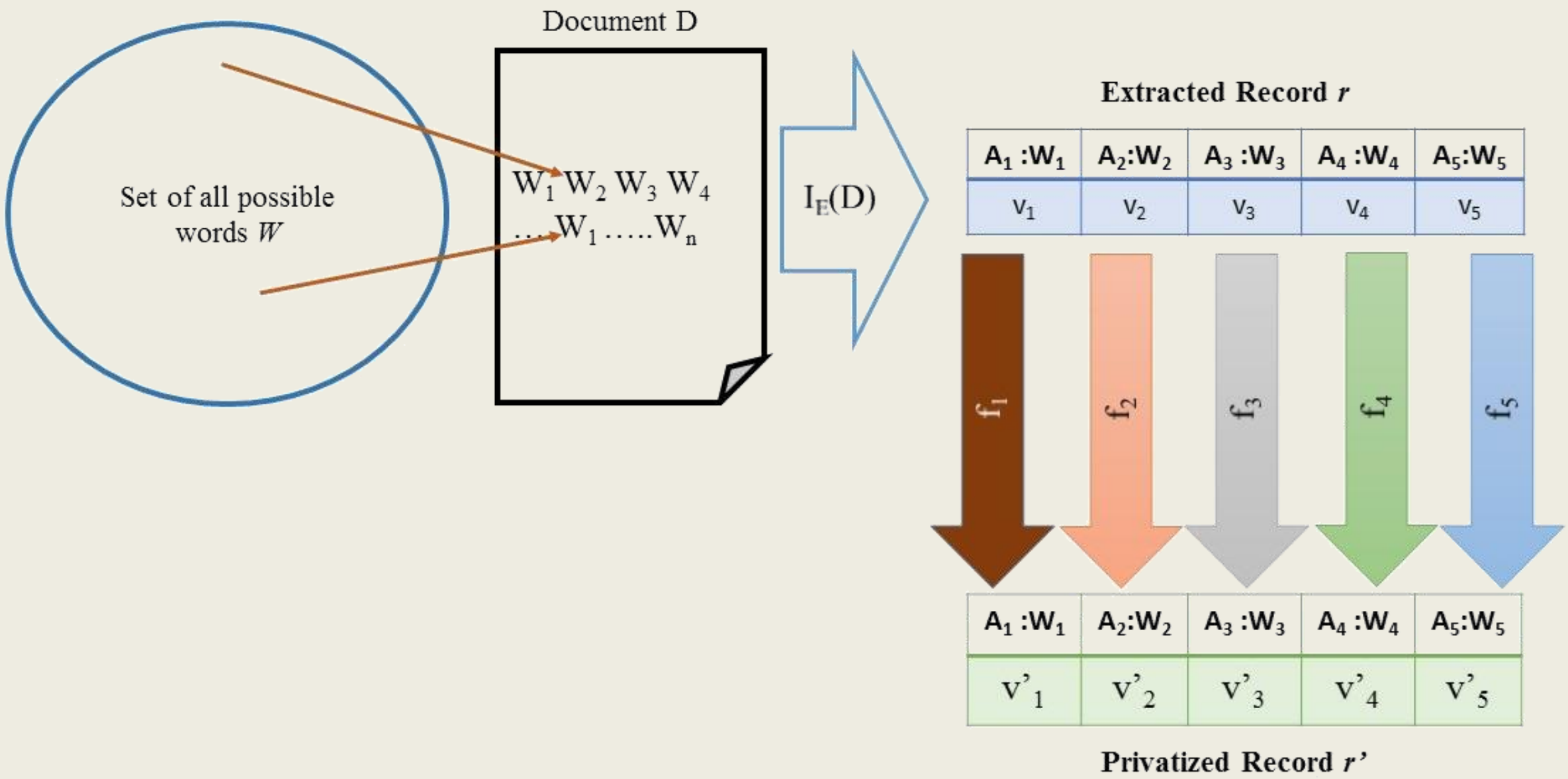
Information Extraction

Automatic extraction of structured information such as entities and relationships between entities from unstructured sources.


Collection of Documents
Information Extraction : (I_E)
I_E holds properties P
Generated View V
A_1 A_2 A_n
Privatization Process
Privatized View V'
F
Draft Method
Same I_E
Collection of Privatized Documents
Privatized View V'


D_1
D_2
D_m
D'_1
D'_2
D'_m
Privatized View V'
A_1
A_2
A_n
Owner
Semi-Trusted Party
Not-Trusted Party

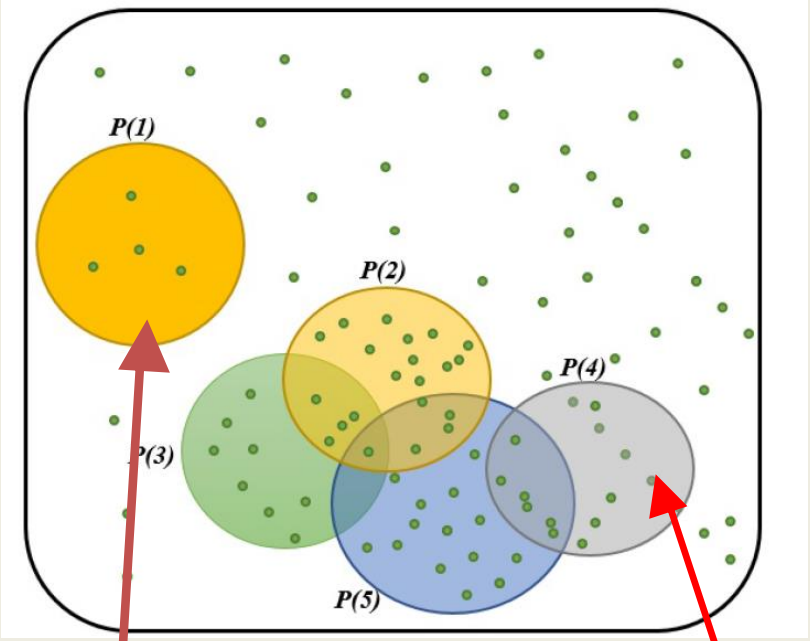
Characteristics of Information Extraction algorithms


Document D
Set of all possible words W
W1 W2 W3 W4
….W1 …..Wn
IE(D)
Extracted Record r
A1 :W1
A2:W2
A3 :W3
A4 :W4
A5:W5
v1
v2
v3
v4
v5
f1
f2
f3
f4
f5
A1 :W1
A2:W2
A3 :W3
A4 :W4
A5:W5
v'1
v'2
v'3
v'4
v'5
Privatized Record r'

- ***Strict Extractor***
  if $\{v_1, v_2, ..., v_{\mathcal{T}}\} \subseteq \{w_1, w_2, w_3, ..., w_{\mathcal{N}}\}$.
  An Information Extraction algorithm is *Strict Extractor* if the set of extracted values in a record is a subset of words appearing in the corresponding document.

  Let $P_D(j) \subseteq \{p | w_p = v_j\}$, i.e., a subset of positions in $D =< w_1, w_2, ..., w_{\mathcal{N}} >$ where $w_p = v_j$ (the position(s) from which v_j is extracted).

Document D



Extracted Record *r*

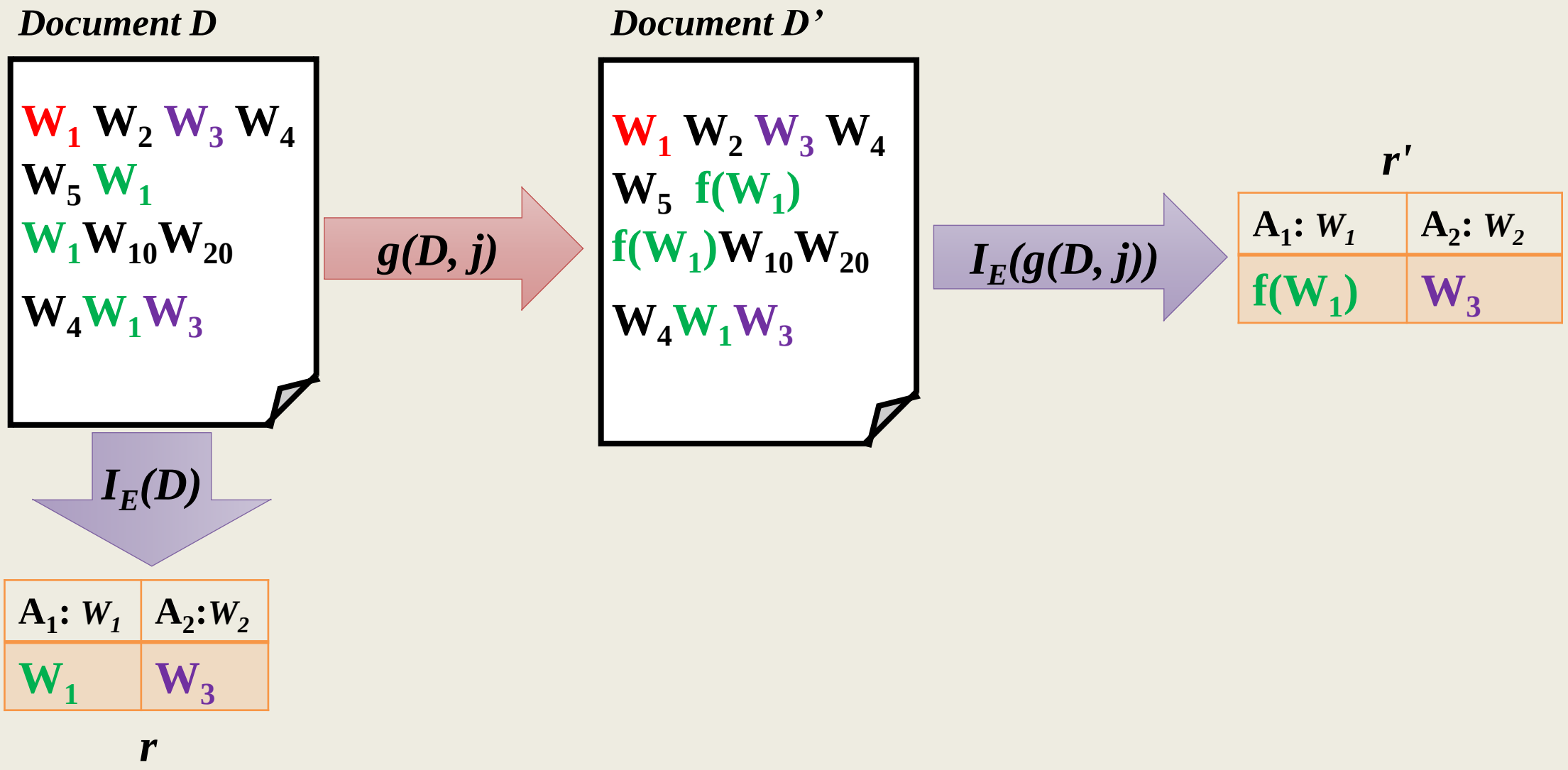
$A_1 : W_1$	$A_2 : W_2$	$A_3 : W_3$	$A_4 : W_4$	$A_5 : W_5$
v_1	v_2	v_3	v_4	v_5

- ***Stable Extractor***
  Let $g(D, j) =< w'_1, w'_2, w'_3, ..., w'_{\mathcal{N}} >$ where:

$$w'_k = \begin{cases} f_j(w_k), & \text{if } k \in P_D(j) \ . \\ w_k, & \text{otherwise.} \end{cases} \tag{2}$$

  An Information Extraction algorithm is *Stable* if $\forall\ j \in [1 \ldots \mathcal{T}]\ P_D(j) = P_{g(D,j)}(j)$ and $I_E(g(D, j)) = r'(j)$.

  A *Stable Extractor* satisfies two conditions. First, $P_D(j)$ does not change when running the algorithm over a legitimately generated document, i.e., $g(D, j)$. Second, changing values in appropriate positions in a specific document affects only the expected attribute in the extracted record.


Document D
W1 W2 W3 W4
W5 W1
W1W10W20
W4W1W3
g(D, j)
Document D'
W1 W2 W3 W4
W5 f(W1)
f(W1)W10W20
W4W1W3
IE(g(D, j))
r'
A1: W1
A2: W2
f(W1)
W3
IE(D)
A1: W1
A2:W2
W1
W3
r

- ***Computable Extractor***

$$if \begin{cases} P_D(j) \text{ is explicit(given) for all } j \in [1 \dots \mathcal{T}], \text{ and} \\ P_D(j) \text{ and } P_D(j') \text{ are pairwise disjoint for all } j, j' \in [1 \dots \mathcal{T}]. \end{cases} \tag{3}$$

Theorem. *For any function* $I_E : \mathcal{D} \to R$ *having the aforementioned properties, there exists an algorithm* $A(F, P_D(j))$ *such that for an arbitrary set of functions* $F = \{f_i | f_i : W_i \to W_i,\ i \in [1 \ldots \mathcal{T}]\}$ *and any document* $D \in \mathcal{D}$, $A(F, P_D(j))$ *produces* $D_F^{\mathcal{P}}$ *in such way that,* $F(I_E(D)) = I_E(D_F^{\mathcal{P}})$.

Claim. *For any function* I_E *having the aforementioned properties, Algorithm 1 produces* $D_F^{\mathcal{P}}$ *in such a way that* $F(I_E(D)) = I_E(D_F^{\mathcal{P}})$.

Input: F, $\{\ P_D(j)\ | j \in [\ 1 \ldots \mathcal{T}]\}$

Output: $D_F^{\mathcal{P}}$

for $j \in [1 \ldots \mathcal{T}]$ **do**

  for *every* i *in* $P_D(j)$ **do**

    substitute $w_i \in D$ with $f_j(w_i)$

  end

end

return $D_F^{\mathcal{P}}$

Algorithm 1: PrivateGen

Work still in progress …

Loosening assumptions:

- The assumption of independence between extracted attributes
- Having access to very limited information about the internal processes of the IE algorithm

Generalizing the proposed properties to cover common Information Extraction algorithms

Designing advanced algorithms to generate D’

Proposing property verification algorithms

Considering more complex relations between documents, individuals, and extracted records

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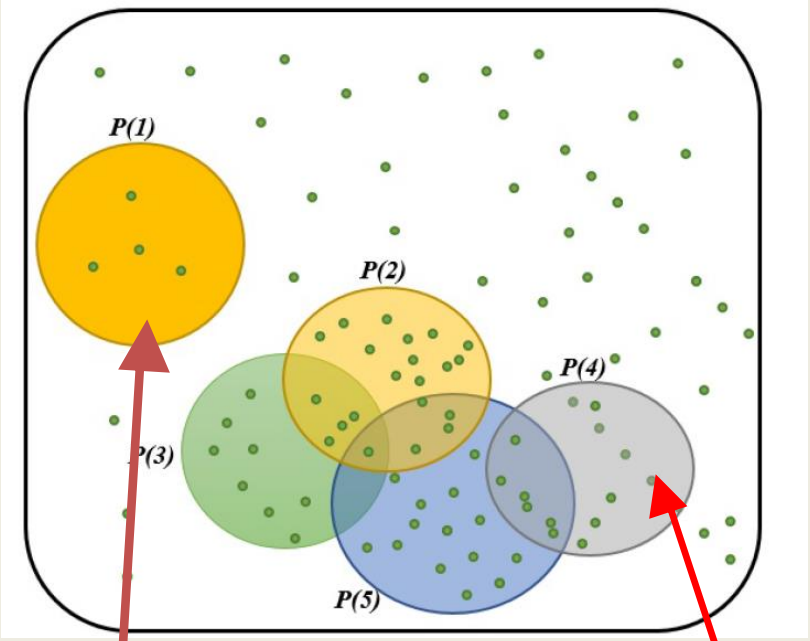

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Let $P_D(j) \subseteq \{p|w_p = v_j\}$, i.e., a subset of positions in $D =< w_1, w_2, ..., w_{\mathcal{N}} >$ where $w_p = v_j$. Let $Q_D(j) \subseteq \{p|p \in [1 \ldots \mathcal{N}]\}$, i.e., a subset of positions in D. $C(Q_D(j))$ represents constraints for $Q_D(j)$ such as:

$$C(Q_D(j)) = \begin{cases} \text{Domain constraints} \\ \text{Inter-relation such as } q_1(w_i, w_j) = q_2(w_k) \\ \text{Value costraints such as } w_i = q(D) \ . \end{cases} \tag{5}$$

Rule-Based Information Extraction

Rule Representation

Patterns → Actions

It was not immediately clear whether Trump had given final approval to the latest staff shakeup, but one of the officials said the president asked for the plan to be put together. Tillerson's long-rumored departure would end a troubled tenure for the former Exxon Mobil Corp chief executive who has been increasingly at odds with Trump over policy challenges such as North Korea and under fire for his planned cuts at the State Department. Tillerson was reported in October to have privately called Trump a "moron," something which the secretary of state sought to dismiss.

That followed a tweet by Trump a few days earlier that Tillerson should not waste his time by seeking negotiations with North Korea over its nuclear and missile program. Trump asked John Kelly, the White House chief of staff, to develop the transition strategy and it has already been discussed with other officials, one administration source said.

- [x] Date
- [x] Location
- [ ] Lookup
- [x] Organization
- [x] Person
- [ ] Sentence
- [ ] SpaceToken
- [ ] Split
- [ ] Token
- [ ] Unknown

▶ Original markups

Type	Set	Start	End	Id	Features
Organization		259	275	673	{matches=[673, 579, 485], orgType=unknown, rule=OrgXEnding, ruleFinal=OrgFinal}
Organization		259	275	579	{matches=[673, 579, 485], orgType=unknown, rule=OrgXEnding, ruleFinal=OrgFinal}
Organization		259	275	485	{matches=[673, 579, 485], orgType=unknown, rule=OrgXEnding, ruleFinal=OrgFinal}
Location		368	379	674	{locType=country, matches=[674, 580, 486, 677, 583, 489], rule=Location1, ruleFinal=LocFinal}
Location		368	379	580	{locType=country, matches=[674, 580, 486, 677, 583, 489], rule=Location1, ruleFinal=LocFinal}
Location		368	379	486	{locType=country, matches=[674, 580, 486, 677, 583, 489], rule=Location1, ruleFinal=LocFinal}
Organization		423	439	675	{matches=[675, 581, 487], orgType=government, rule=GazOrganization, ruleFinal=OrgFinal}
Organization		423	439	581	{matches=[675, 581, 487], orgType=government, rule=GazOrganization, ruleFinal=OrgFinal}
Organization		423	439	487	{matches=[675, 581, 487], orgType=government, rule=GazOrganization, ruleFinal=OrgFinal}
Date		468	475	676	{kind=date, matches=[676, 582, 488], rule=GazDate, ruleFinal=DateOnlyFinal}
Date		468	475	582	{kind=date, matches=[676, 582, 488], rule=GazDate, ruleFinal=DateOnlyFinal}
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Person		762	772	678	{firstName=John, gender=male, kind=fullName, matches=[678, 584, 490], rule=PersonLocAmbig, ruleFinal=PersonFinal, surname=K
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Organization		778	789	585	{matches=[679, 585, 491], orgType=government, rule=GazOrganization, ruleFinal=OrgFinal}
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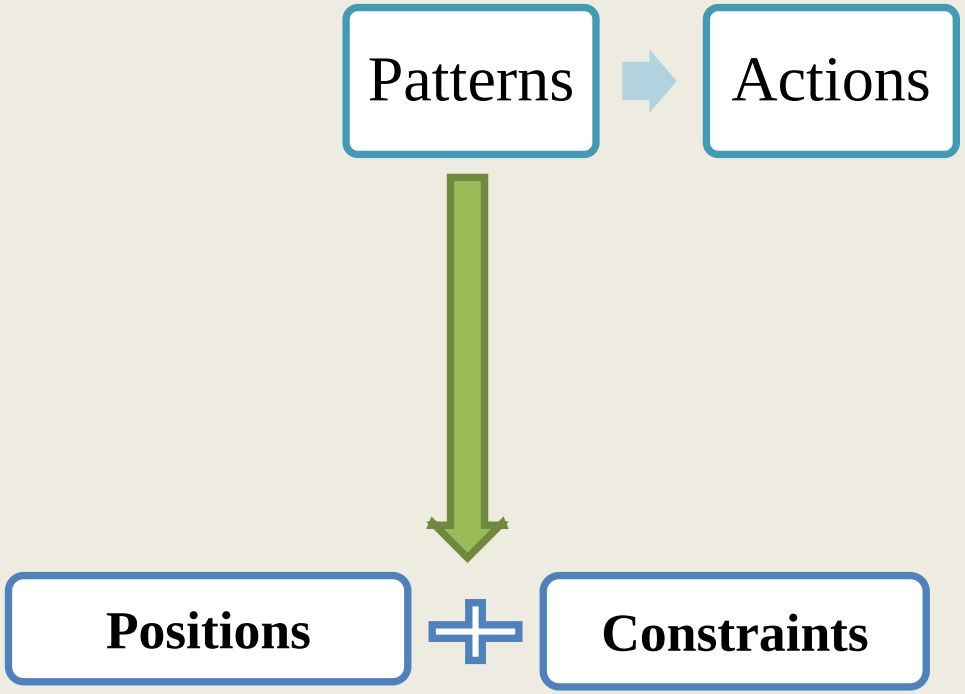
Patterns
Actions
Positions
Constraints

References

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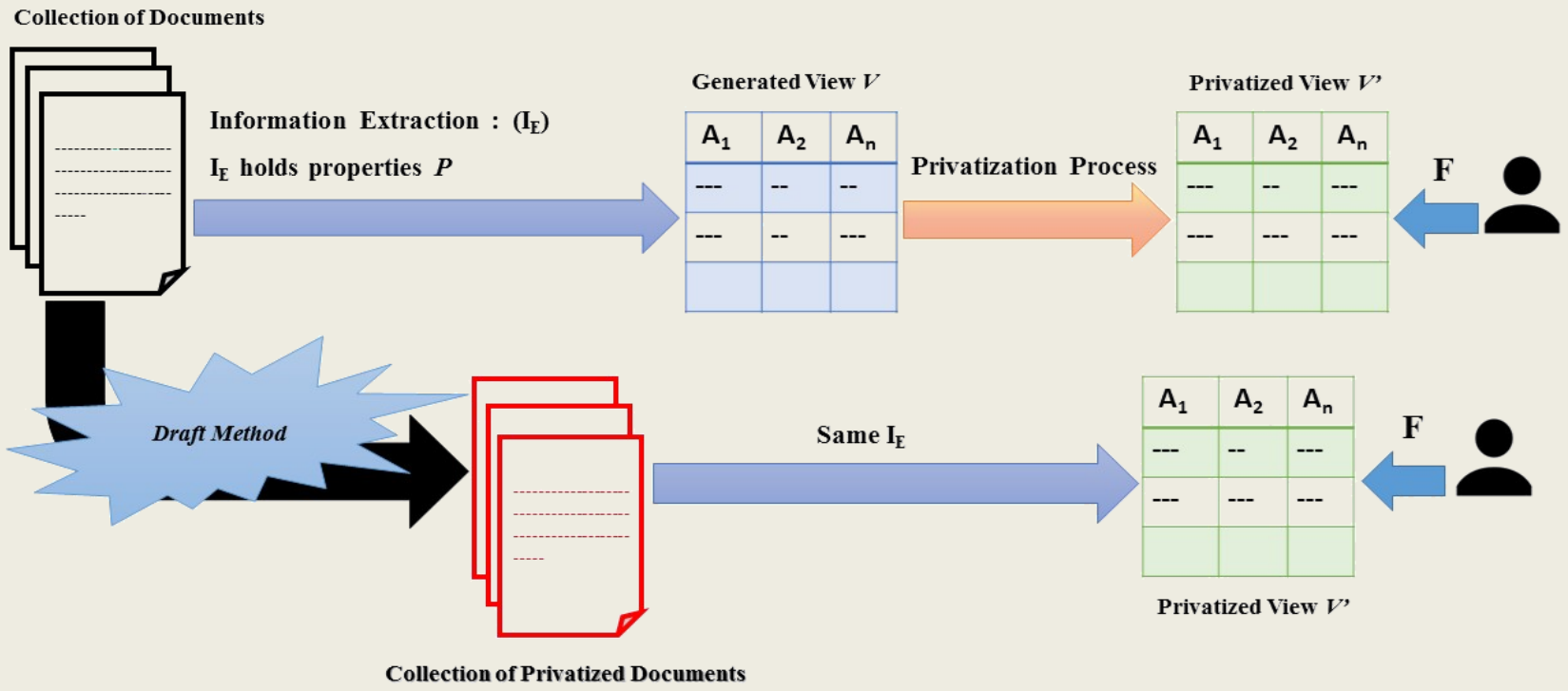
Thanks


Collection of Documents
Information Extraction : (I_E)
I_E holds properties P
Generated View V
A_1 A_2 A_n
Privatization Process
Privatized View V'
F
Draft Method
Same I_E
Collection of Privatized Documents
Privatized View V'