Combining Deep Learning Matching and Traditional Keyword Search for Job Search

Henning Rode

Luigi Lorato, Eike Dehling, Vincent Slot, Mihai Rotaru

textkernel

Machine Intelligence for People and Jobs

About Textkernel

Founded in 2001

Headquartered in Amsterdam

> 125 employees

Machine Intelligence for
Matching People and Jobs

- AI and Machine Learning
- Semantic Search and Match
- Document Understanding
- Web Mining
- Big Data

International leader in AI for HR and Recruitment

More than 1000 clients worldwide

Part of the CareerBuilder group

Textkernel's Match

The traditional approach

From a Job Text to a Query

Sr. Optical Network Engineer - Central and East Regions

WWT has an optical network engineering position available on the Professional Services team. As a Sr. optical network engineer, you will be responsible for the entire deployment lifecycle of an optical installations including design, installation, validation, and support.

RESPONSIBILITIES:
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Textkernel's parser extracts from the text:

- Job title
- Education

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Textkernel's parser extracts from the text:

- Job title
- Education
- Experience years

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- Job title
- Education
- Experience years
- Skills

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Textkernel's parser extracts from the text:

- Job title
- Education
- Experience years
- Skills
- Etc...

Enriched with Search Knowledge (**synonyms, taxonomies**, etc.)

The extracted query is used to search among the parsed CVs.

From a Job Text to a Query

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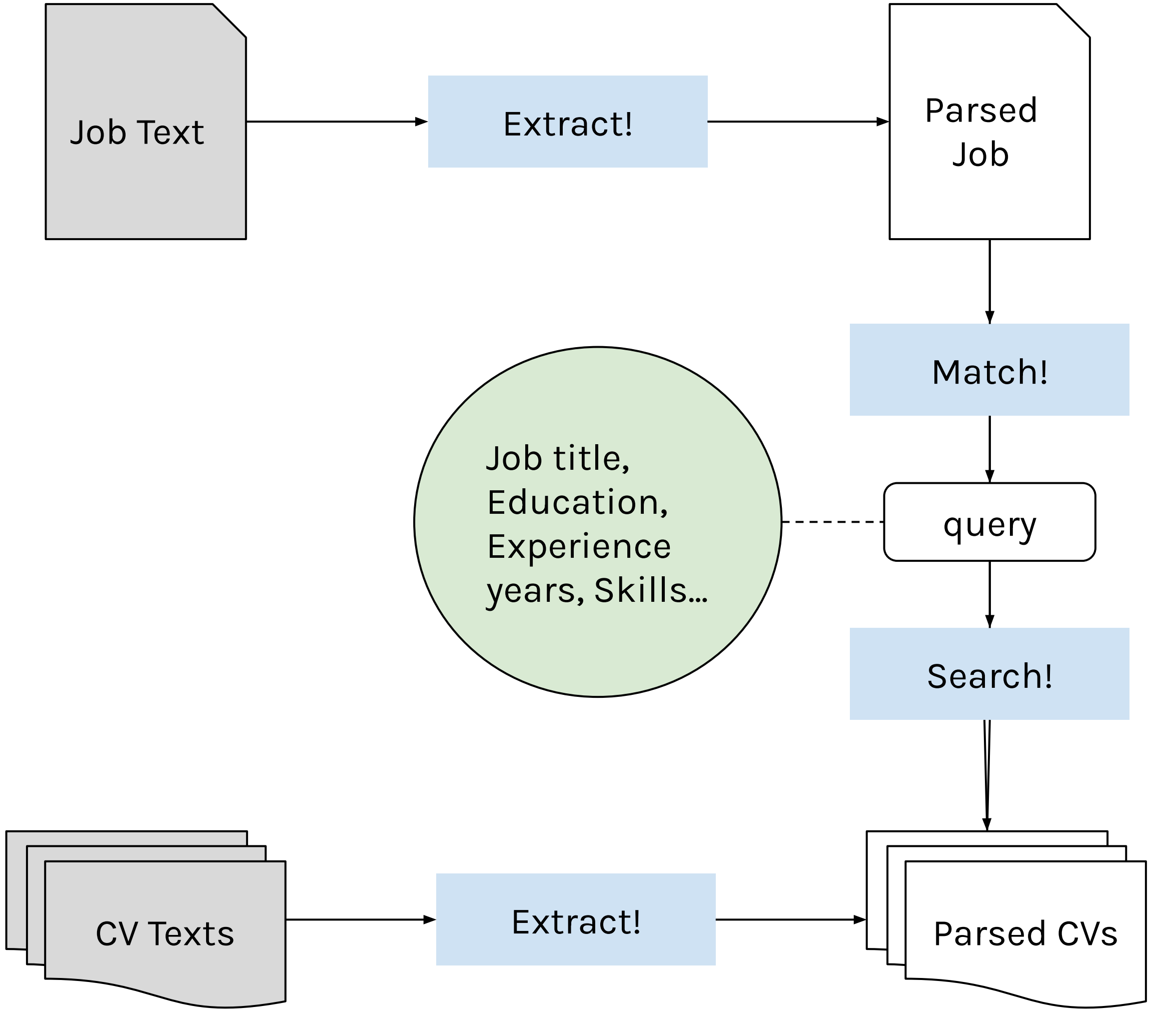
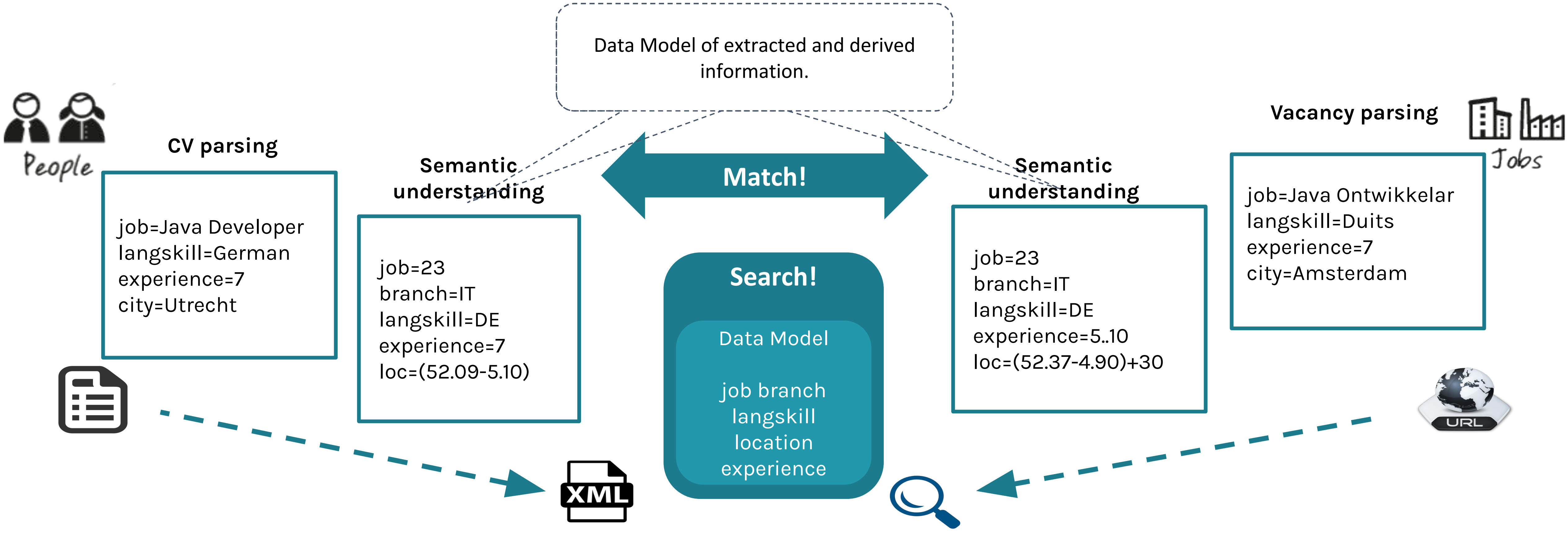


Job Text
Extract!
Parsed Job
Match!
Job title, Education, Experience years, Skills...
query
Search!
CV Texts
Extract!
Parsed CVs

Textkernel Match! Architecture Outline



Data Model of extracted and derived information.

CV parsing

job=Java Developer
langskill=German
experience=7
city=Utrecht

Semantic understanding

job=23
branch=IT
langskill=DE
experience=7
loc=(52.09-5.10)

Match!

Search!

Data Model

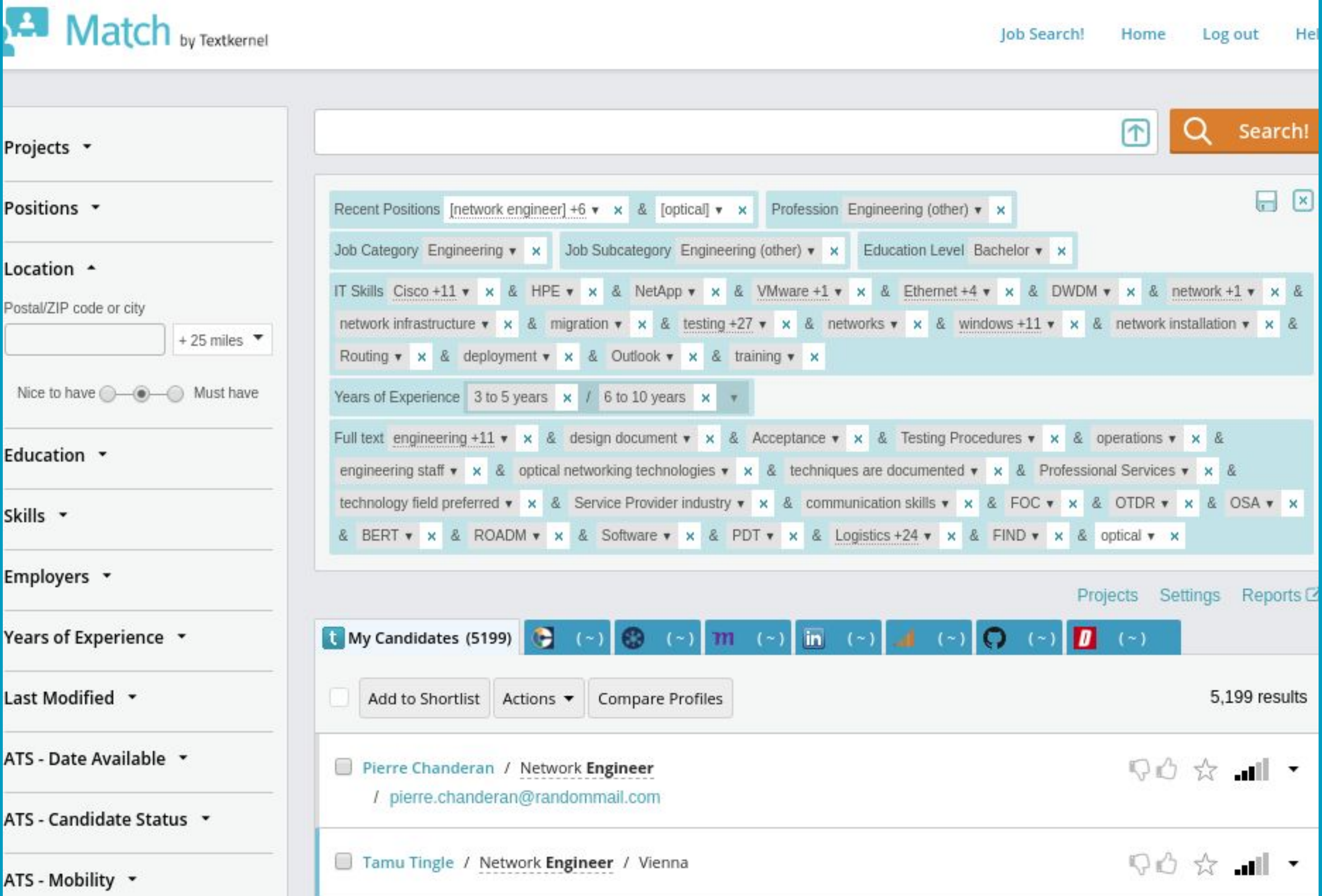
job branch
langskill
location
experience

Semantic understanding

job=23
branch=IT
langskill=DE
experience=5..10
loc=(52.37-4.90)+30

Vacancy parsing

job=Java Ontwikkelar
langskill=Duits
experience=7
city=Amsterdam


Match by Textkernel
Job Search!
Home
Log out
He
Projects
Positions
Location
Postal/ZIP code or city
+ 25 miles
Nice to have
Must have
Education
Skills
Employers
Years of Experience
Last Modified
ATS - Date Available
ATS - Candidate Status
ATS - Mobility
Search!
Projects
Settings
Reports
My Candidates (5199)
(~)
(~)
(~)
(~)
(~)
(~)
(~)
Add to Shortlist
Actions
Compare Profiles

Recent Positions [network engineer] +6 & [optical] — Profession Engineering (other)

Job Category Engineering — Job Subcategory Engineering (other) — Education Level Bachelor

IT Skills Cisco +11 & HPE & NetApp & VMware +1 & Ethernet +4 & DWDM & network +1 & network infrastructure & migration & testing +27 & networks & windows +11 & network installation & Routing & deployment & Outlook & training

Years of Experience 3 to 5 years / 6 to 10 years

Full text engineering +11 & design document & Acceptance & Testing Procedures & operations & engineering staff & optical networking technologies & techniques are documented & Professional Services & technology field preferred & Service Provider industry & communication skills & FOC & OTDR & OSA & BERT & ROADM & Software & PDT & Logistics +24 & FIND & optical

5,199 results

☐ Pierre Chanderan / Network **Engineer** / pierre.chanderan@randommail.com

☐ Tamu Tingle / Network **Engineer** / Vienna

Match query (AI)

Job title handling

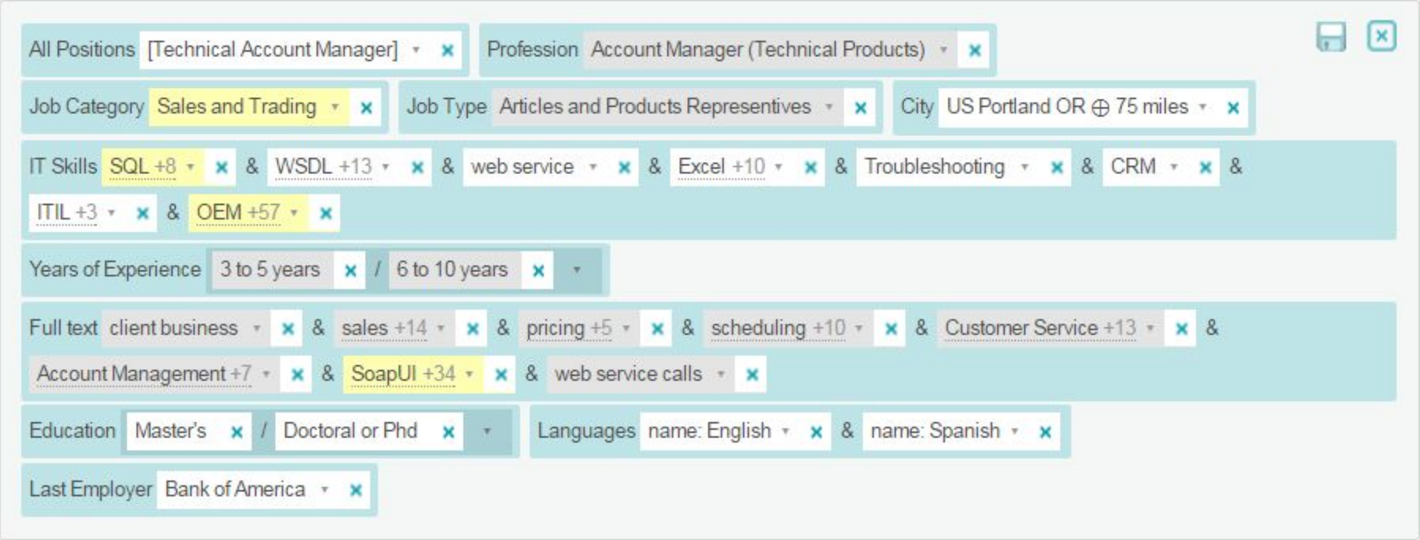
- ‘ **Project Manager**, Automotive’

Requiredness

- ‘ Knowledge of **Java** is **essential**’

Balancing

- Learning a Weighting model

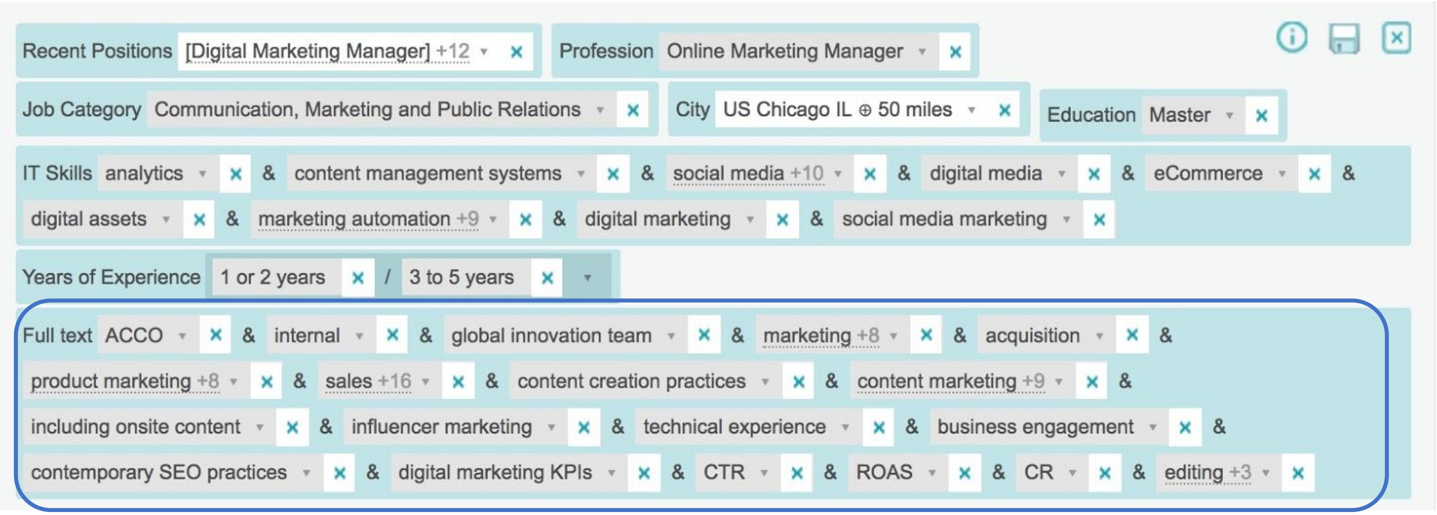


All Positions [Technical Account Manager]
Profession Account Manager (Technical Products)
Job Category Sales and Trading
Job Type Articles and Products Representives
City US Portland OR ⊕ 75 miles
IT Skills SQL +8 & WSDL +13 & web service & Excel +10 & Troubleshooting & CRM & ITIL +3 & OEM +57
Years of Experience 3 to 5 years / 6 to 10 years
Full text client business & sales +14 & pricing +5 & scheduling +10 & Customer Service +13 & Account Management +7 & SoapUI +34 & web service calls
Education Master's / Doctoral or Phd
Languages name: English & name: Spanish
Last Employer Bank of America

Important keyword extraction

Match in greater detail

- Java developer for *financial services*
- Open-world keyword extraction
  - Using gazetteers
  - And textual features



Recent Positions [Digital Marketing Manager] +12
Profession Online Marketing Manager
Job Category Communication, Marketing and Public Relations
City US Chicago IL ⊕ 50 miles
Education Master
IT Skills analytics & content management systems & social media +10 & digital media & eCommerce & digital assets & marketing automation +9 & digital marketing & social media marketing
Years of Experience 1 or 2 years / 3 to 5 years
Full text ACCO & internal & global innovation team & marketing +8 & acquisition & product marketing +8 & sales +16 & content creation practices & content marketing +9 & including onsite content & influencer marketing & technical experience & business engagement & contemporary SEO practices & digital marketing KPIs & CTR & ROAS & CR & editing +3

Perfect Match?

Perfect Match?
Not yet

Looking closer...

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Looking closer... at the results...

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CV

SUMMARY

Over 4 years of extensive experience in the field of Networking with excellent written and communication skills. Strong understanding of Cisco routers, firewalls and switches and in-depth understanding of networking concepts, TCP/IP and communication protocols in LAN / WAN environments.

WORK EXPERIENCE
2013 – Present Network Engineer

- Designed, deployed and maintain the **entire company's network** comprising of 6 branch offices, up to **500 employees.**
- Configured and managed Cisco routers, Firewalls, layer 2 switches, Wireless and Web-content filter
- Performed periodic upgrades on all network devices in a timely manner.

o Configured Voice VLANs and QoS for VoIP.
o DHCP, DNS, SMTP and Kiwi syslog servers on Windows 2008 r2 server.

Looking closer… at the results… and the job

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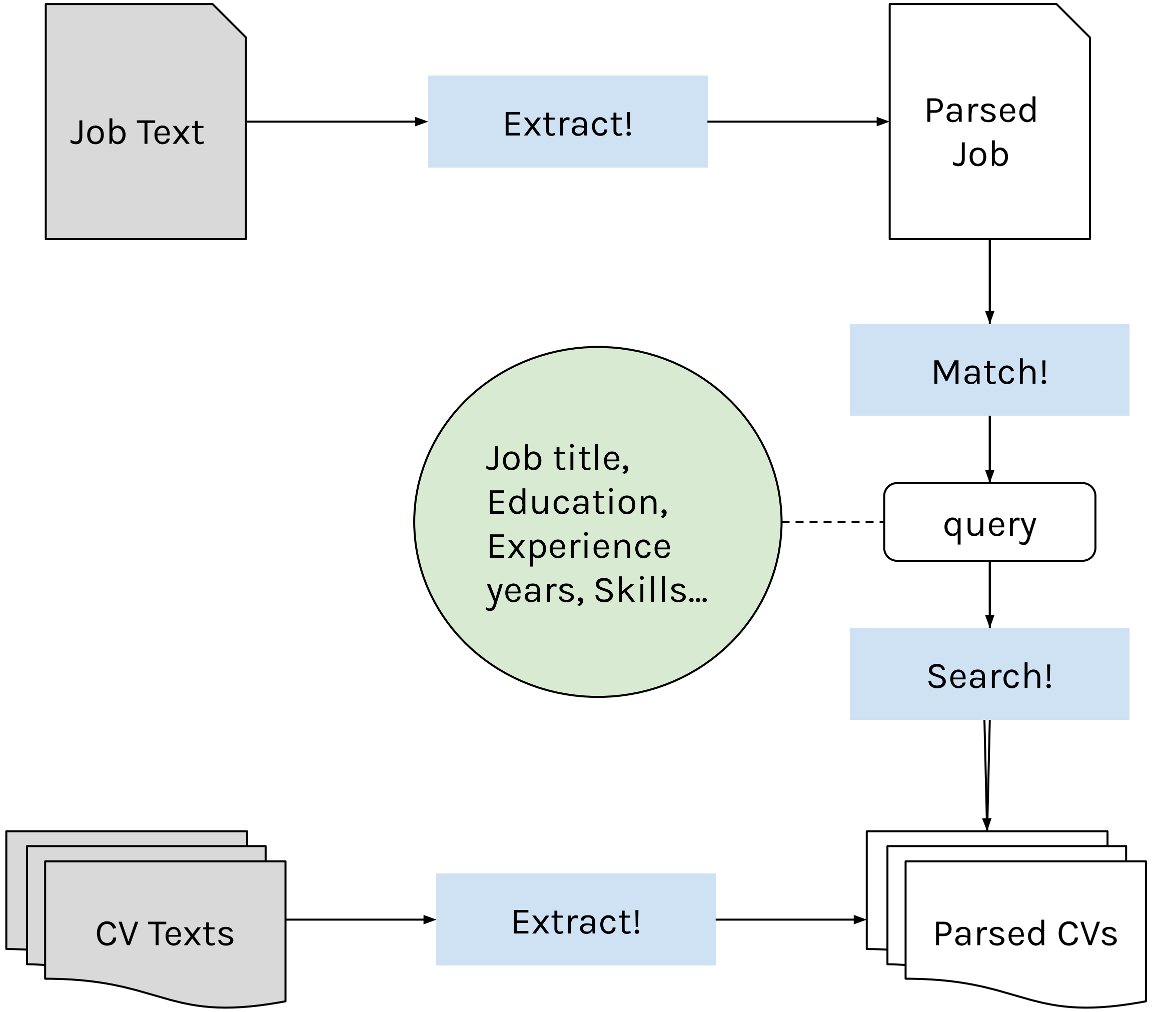
Limitations of the current approach

- **Complex pipeline:** impact of error propagation
    - job title extraction
    - taxonomy classification
    - synonyms
    - …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Job title, Education, Experience years, Skills…
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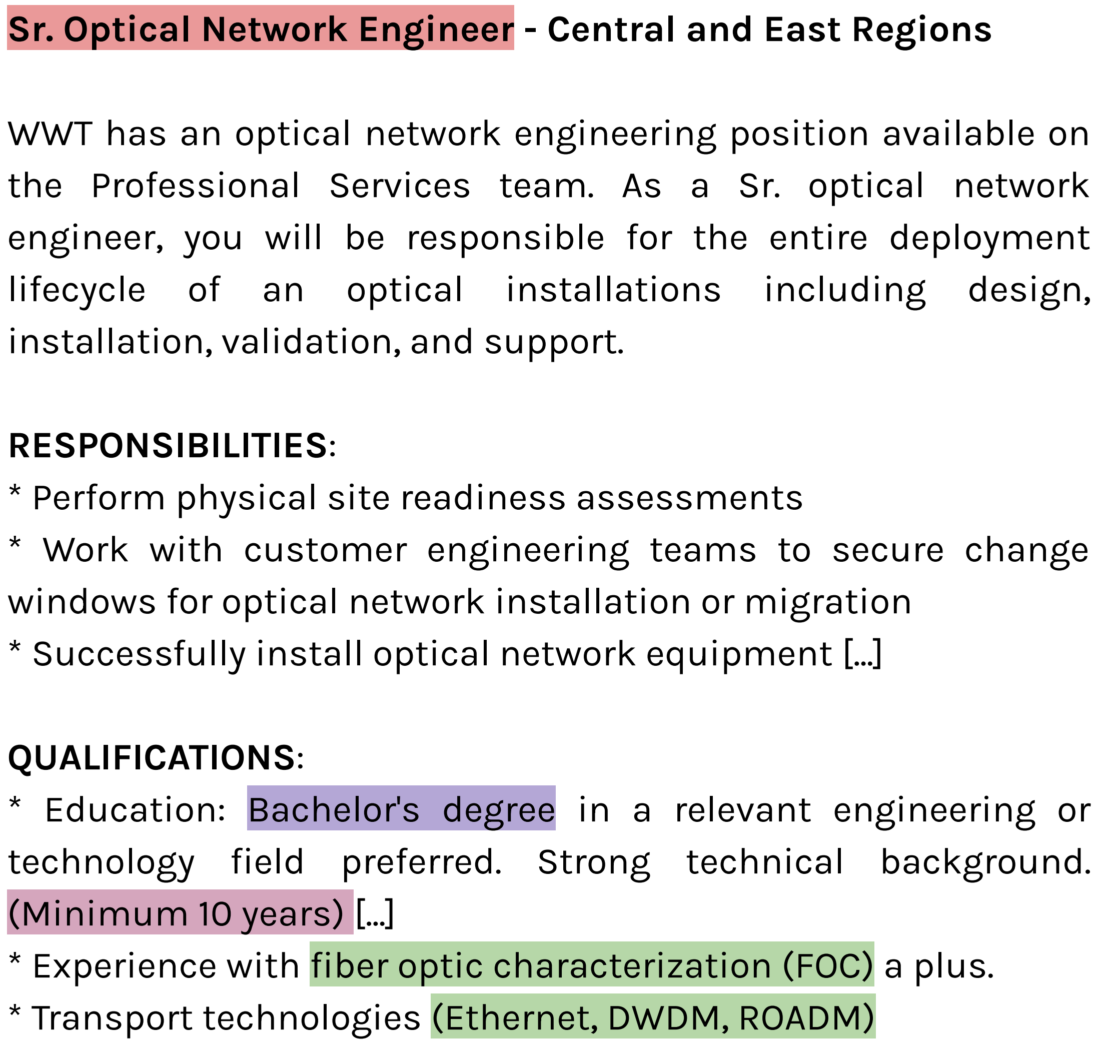

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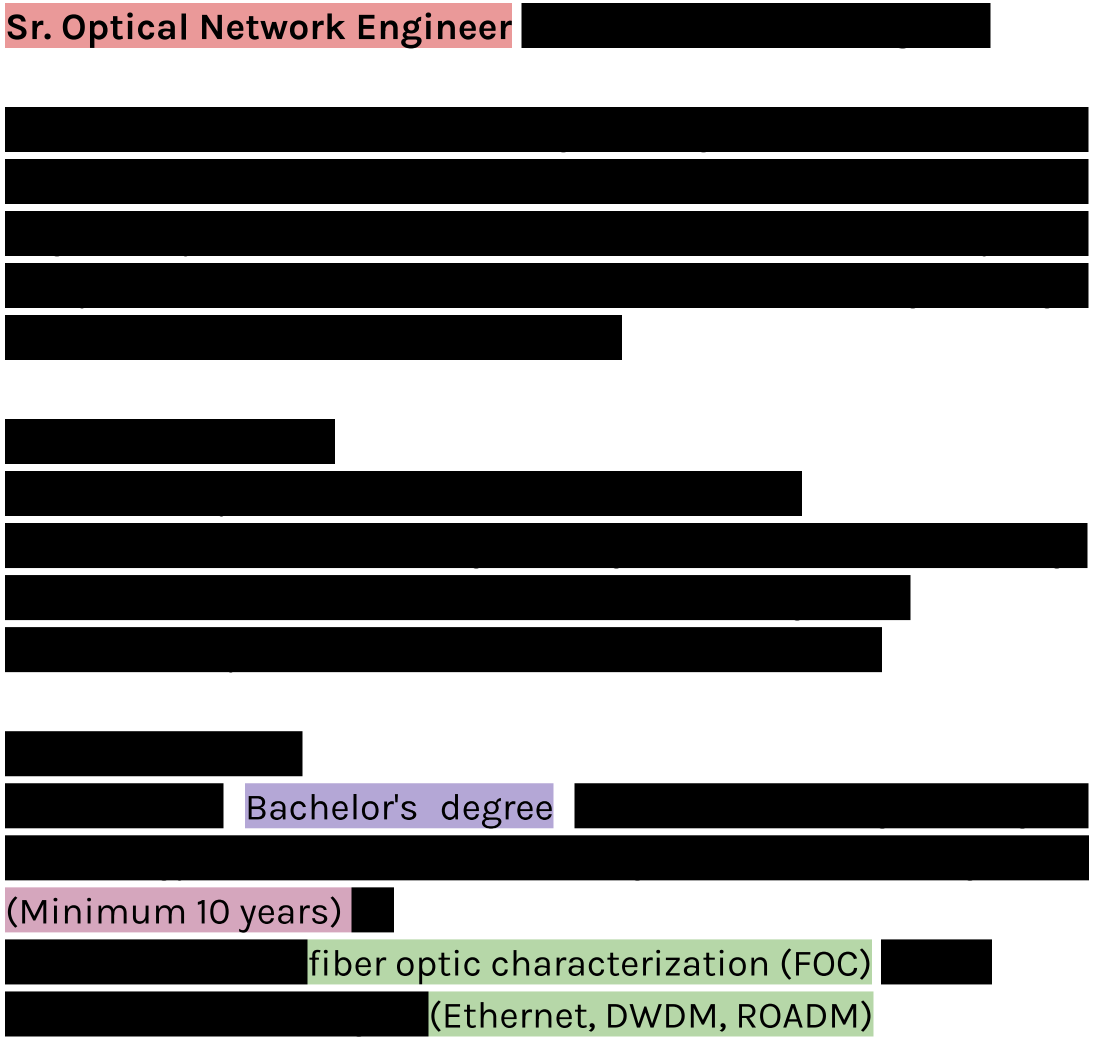

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[redacted]

[redacted]

[redacted]
[redacted] Bachelor's degree [redacted]
(Minimum 10 years) [redacted]
[redacted] fiber optic characterization (FOC) [redacted]
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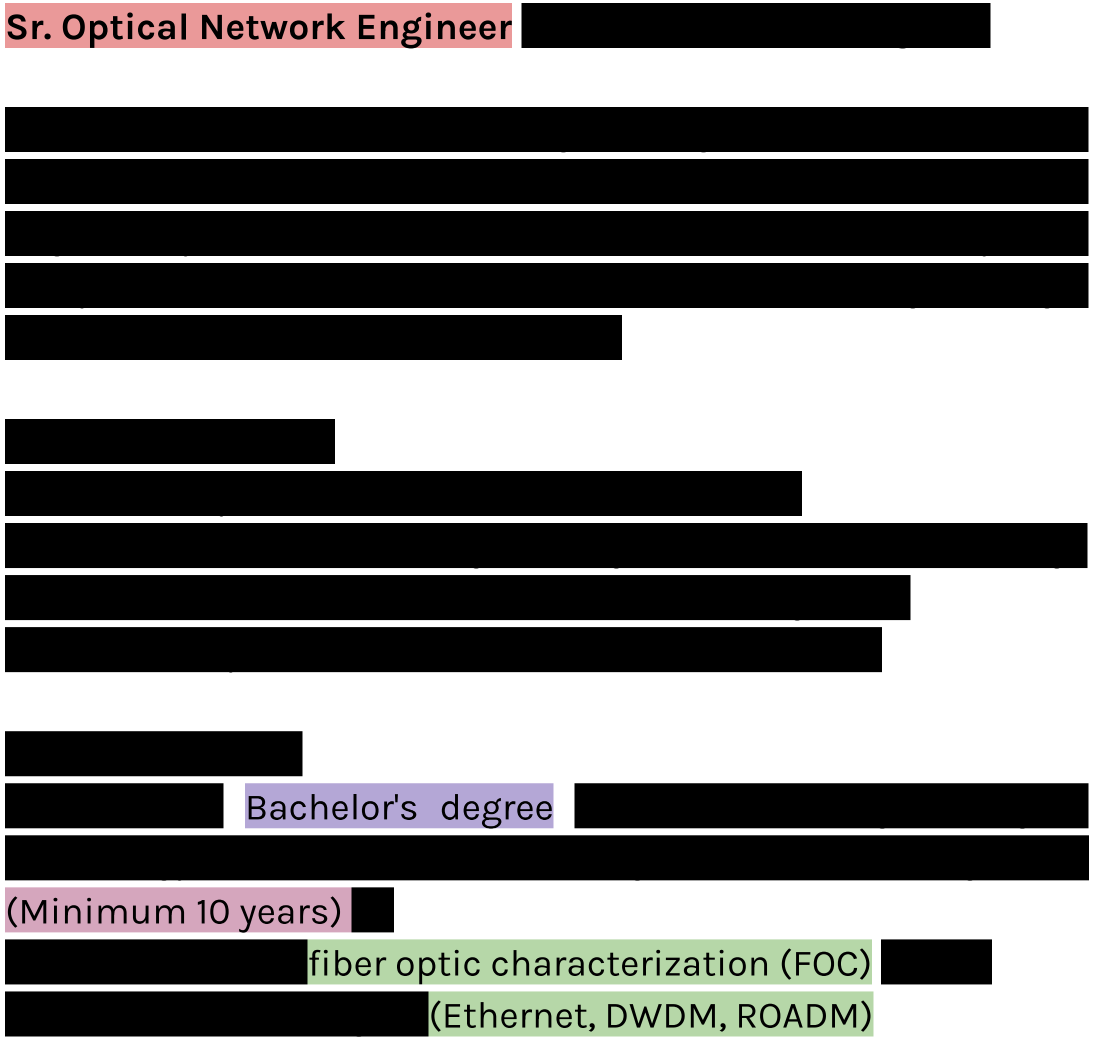
- **Fixed-term matching:** Stripping the text of semantic outside of extracted terms
  - Semantic of extracted terms also limited to synonyms and taxonomy
- **Skills:** Important, unimportant?
- **Other keywords:** too many unimportant



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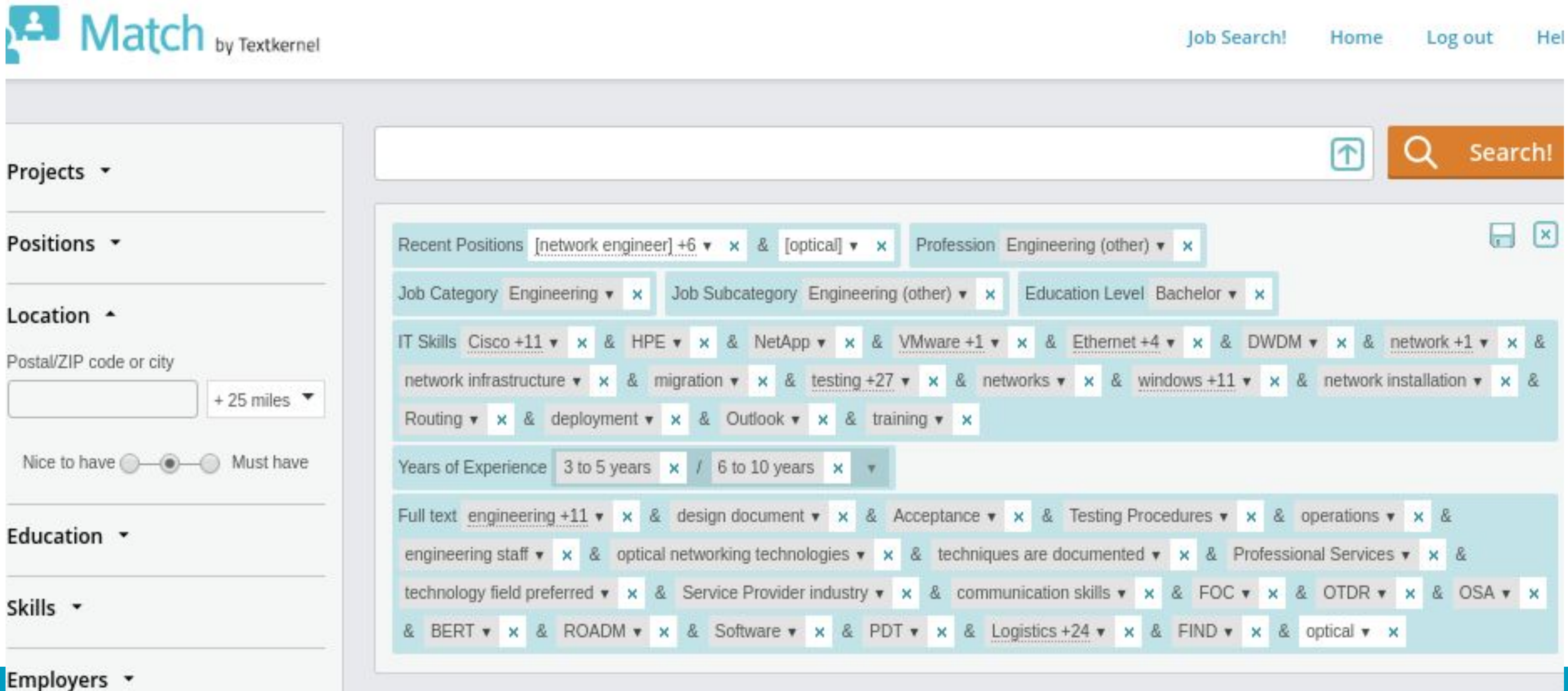
Limitations of the current approach

- **Overwhelming UX**


Match by Textkernel
Job Search!
Home
Log out
Hel
Search!
Projects
Positions
Location
Postal/ZIP code or city
+ 25 miles
Nice to have
Must have
Education
Skills
Employers

Recent Positions [network engineer] +6 ▾ × & [optical] ▾ ×
Profession Engineering (other) ▾ ×
Job Category Engineering ▾ ×
Job Subcategory Engineering (other) ▾ ×
Education Level Bachelor ▾ ×
IT Skills Cisco +11 ▾ × & HPE ▾ × & NetApp ▾ × & VMware +1 ▾ × & Ethernet +4 ▾ × & DWDM ▾ × & network +1 ▾ × & network infrastructure ▾ × & migration ▾ × & testing +27 ▾ × & networks ▾ × & windows +11 ▾ × & network installation ▾ × & Routing ▾ × & deployment ▾ × & Outlook ▾ × & training ▾ ×
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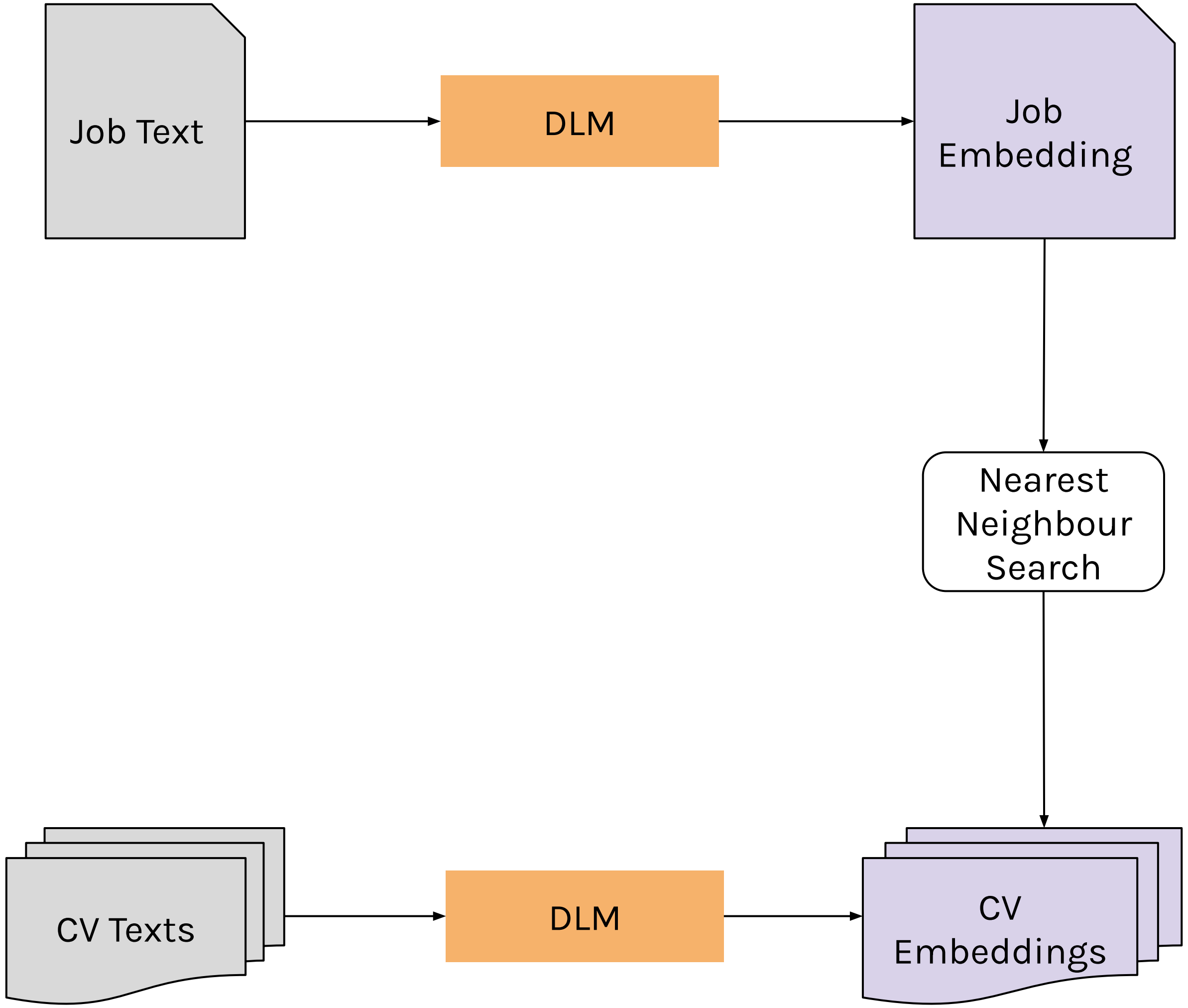
Deep Learning Matcher

The Neural IR approach

DL Matcher Architecture

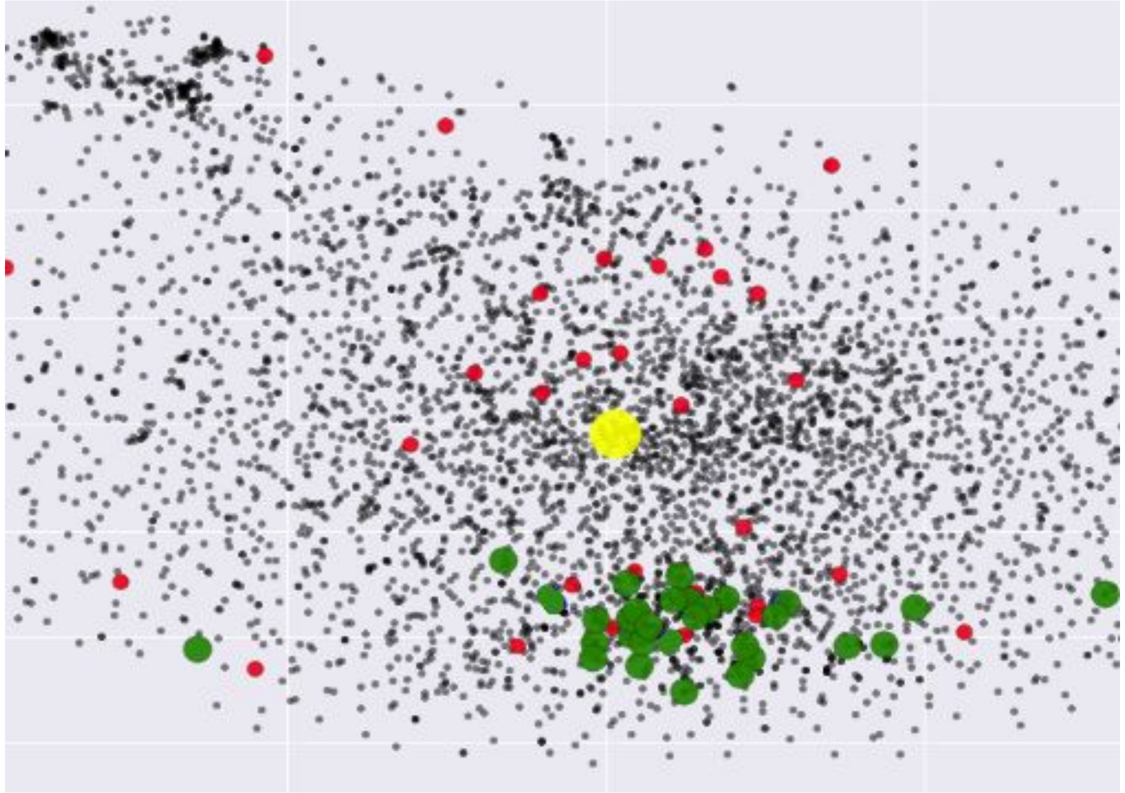
Can we build **document embeddings** from entire CVs and Job texts such that, within this continuous semantic space, looking for good matching jobs for a CV becomes a **nearest neighbor search**?


Job Text
DLM
Job Embedding
Nearest Neighbour Search
CV Texts
DLM
CV Embeddings

Could we use Doc2Vec? ... Not really

T-SNE plot of Doc2Vec representation of:

Job Irrelevant CVs Relevant CVs



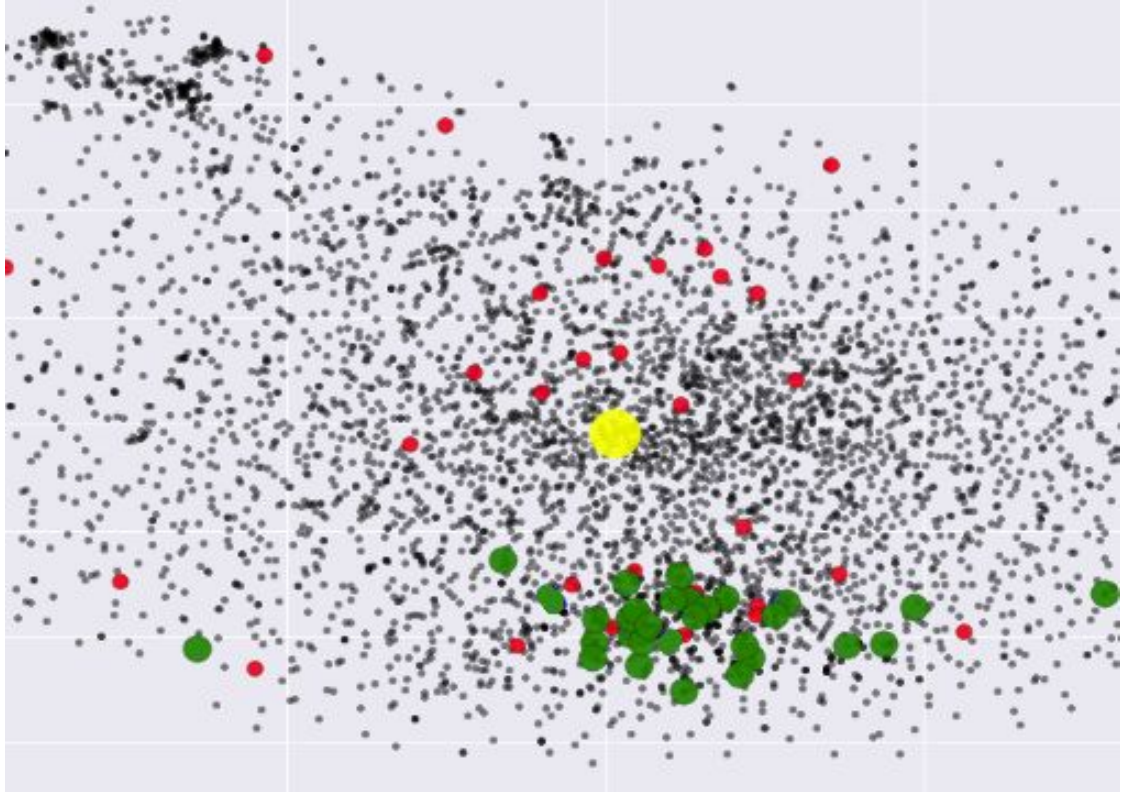
Doc2Vec: **Word2Vec** for documents creating a single embedding for a document.

- Relevant CVs are close to each other
- But far from the job

Could we use Doc2Vec? ... Not really

T-SNE plot of Doc2Vec representation of:

Job Irrelevant CVs Relevant CVs



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What's the problem?

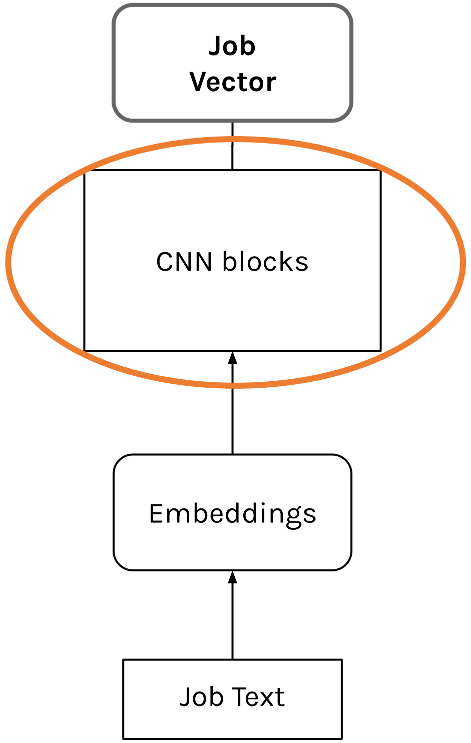
- Embeddings represent general language model
- Job and CV texts use different language:
  - E.g. ' *You should be familiar with ...*' vs ' *I have experience with ...*'
  - Company information vs Personal Information
  - ....
- Differences get picked up in Doc2Vec

Starting from Word Embeddings can we capture only the relevant information for matching Jobs to CVs?

Extracting what’s relevant

Idea: *Learn representation in shared space of CV and Job texts such that* ***Relevant*** *CVs are close to the Job and* ***Irrelevant*** *CVs are far.*

- Convolutional Neural Networks extract from the Word Embeddings of the text the relevant parts



Job Vector
CNN blocks
Embeddings
Job Text

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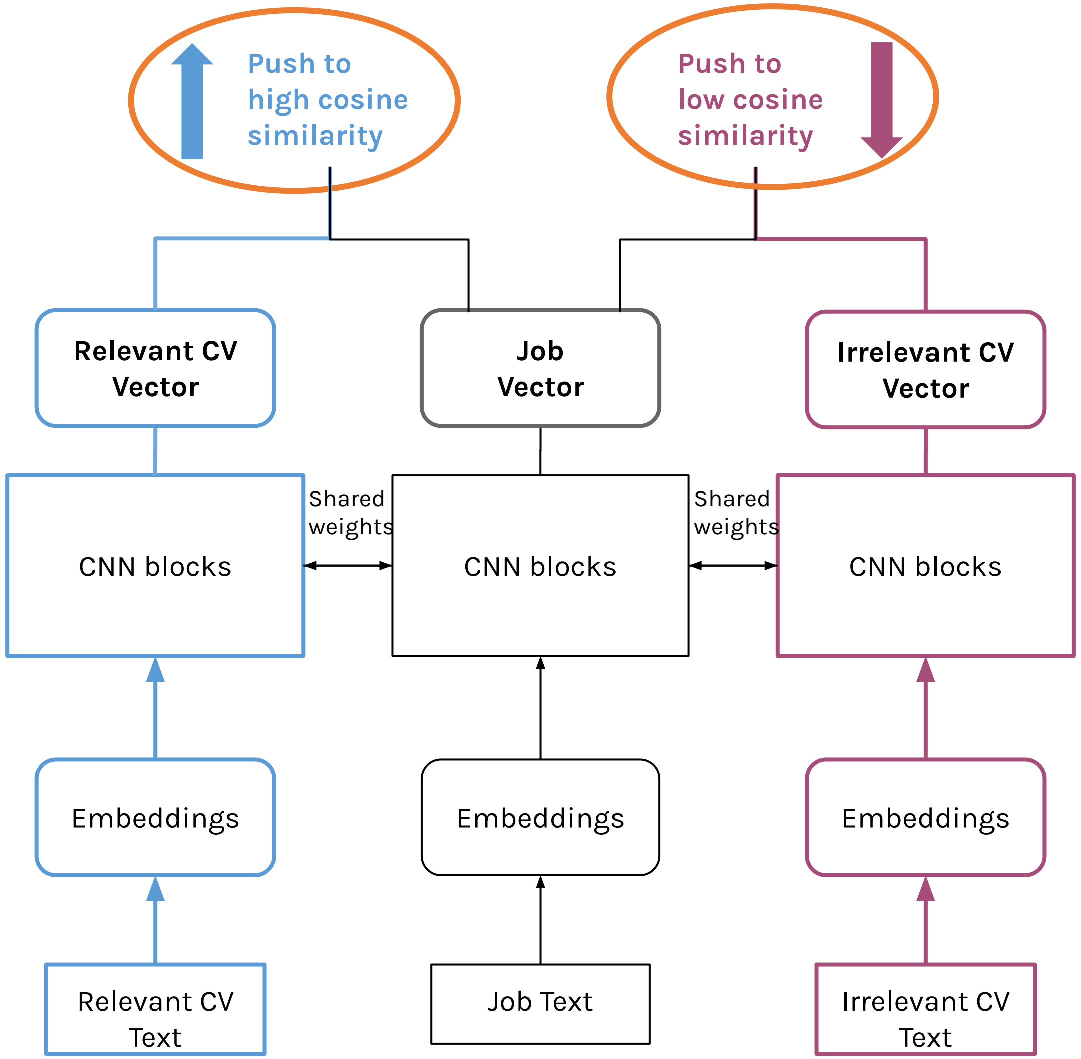
Push to high cosine similarity
Push to low cosine similarity
Relevant CV Vector
Job Vector
Irrelevant CV Vector
CNN blocks
Shared weights
CNN blocks
Shared weights
CNN blocks
Embeddings
Embeddings
Embeddings
Relevant CV Text
Job Text
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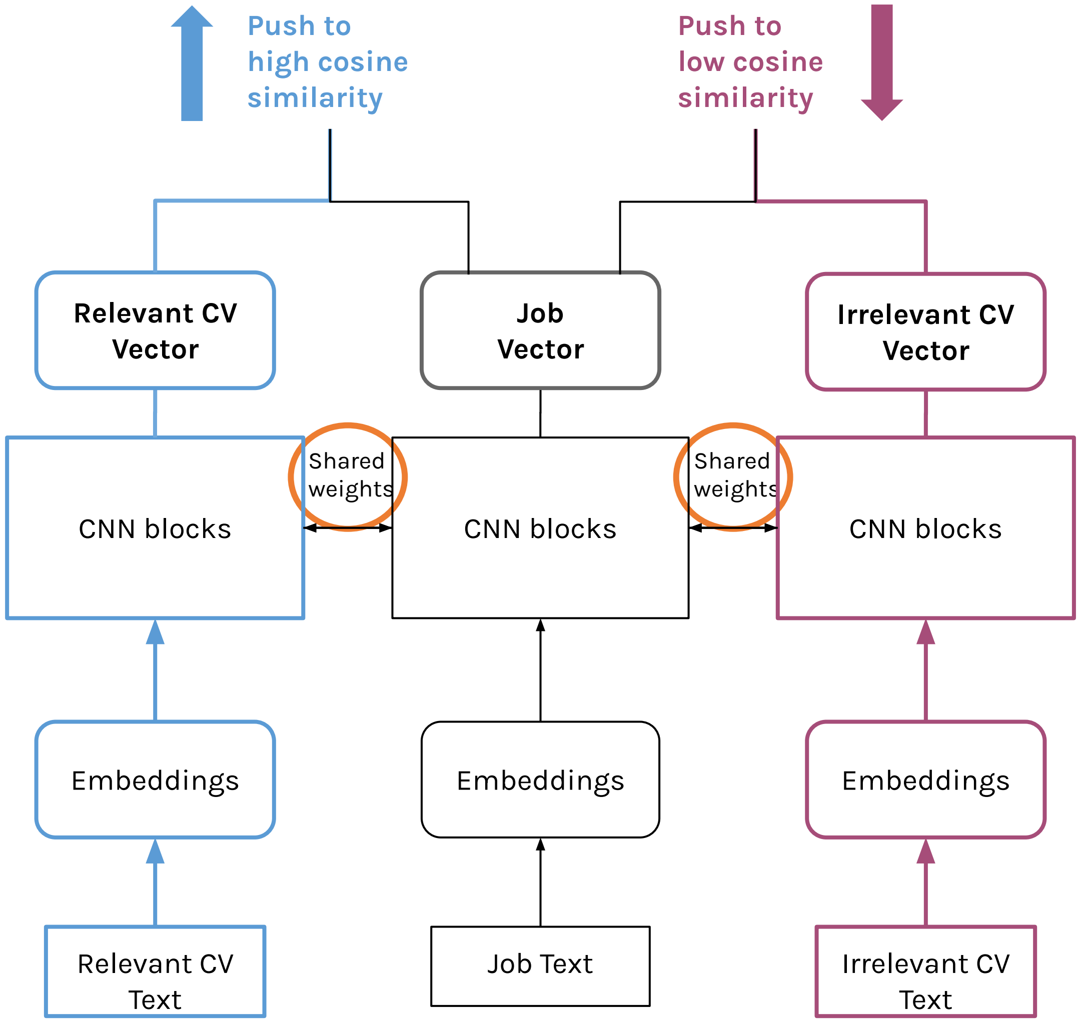
- Sharing the weights forces to extract only the shared relevant information for matching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Relevant CV Text
Job Text
Irrelevant CV Text

That sounds great!
But where do we get the data?

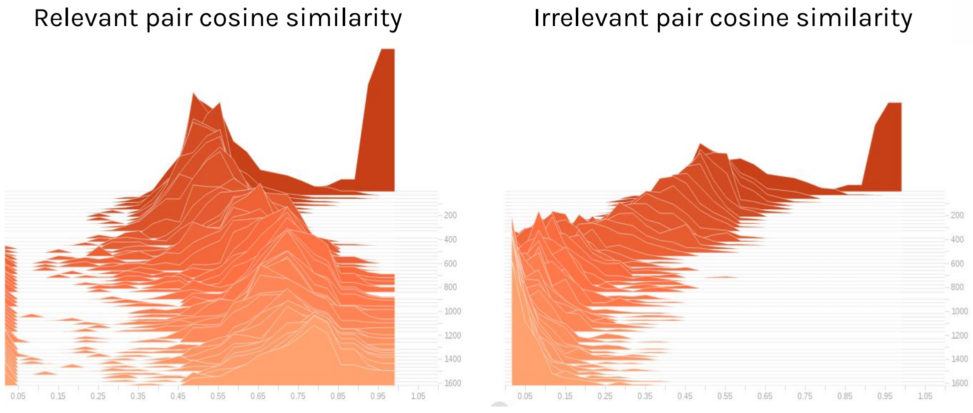
Data

We train the model using Application data

- 10 Millions CV-Job application pairs
  - CV-Job pair **relevant** if it was a real application
  - Randomly sample **irrelevant** CV-Job pairs

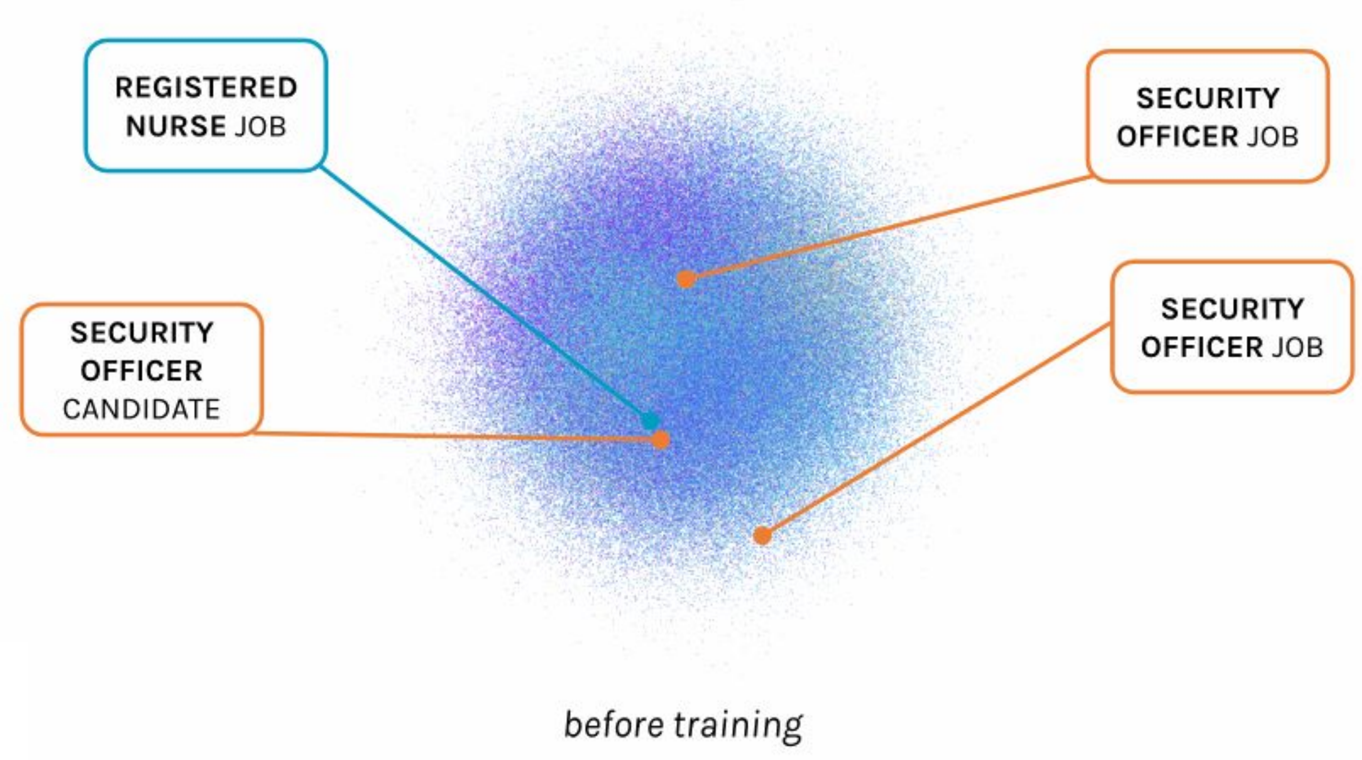
Training

Using the application data we can now model the Job/CV vector space as we need and get job-meaningful neighbourhoods


Relevant pair cosine similarity

Irrelevant pair cosine similarity

Cosine similarity of Relevant and Irrelevant pair during training


REGISTERED NURSE JOB
SECURITY OFFICER JOB
SECURITY OFFICER JOB
SECURITY OFFICER CANDIDATE

before training

Looking at our Optical Network Engineer again…

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...and at the most relevant candidate for DLM...

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CV

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* A dynamic professional in Telecommunication Engineering (SDH) in the field of O & M for Fiber Optics Communication Sector.

EXPERIENCE
Jan '04-2010 - Till Date with Unimax Telecom Pvt. Ltd. as a Network Engineer (O & M) Company Name: Unimax Telecom Pvt. Ltd,

* Installation & Commissioning of SDH, TDM & Ethernet equipment like STM-1.STM-4 & STM-16.Fault finding in OFC Maintenance of OFC equipments & other accessories.
* Knowledge of NMS (Tejas Networks), fault identification and rectification.
* Coordinating with the team in installing indoor and outdoor SDH, Ethernet & TDM equipment.
* External alarm monitoring and escalation of electrical works.
* Responsible for operation & maintenance of MAN network of TTSL both for equipments and fiber. [...]

…and at the parts of text it finds most important

Job ad

Sr. Optical Network Engineer - Central and East Regions

WWT has an optical network engineering position available on the Professional Services team. As a Sr. optical network engineer, you will be responsible for the entire deployment lifecycle of an optical installations including design, installation, validation, and support.

RESPONSIBILITIES:

* Perform physical site readiness assessments

* Work with customer engineering teams to secure change windows for optical network installation or migration

* Successfully install optical network equipment [...]

QUALIFICATIONS:

* Education: Bachelor's degree in a relevant engineering or technology field preferred. Strong technical background. (Minimum 10 years) [...]

* Experience with fiber optic characterization (FOC) a plus.

* Transport technologies (Ethernet, DWDM, ROADM)

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Evaluation

We compared the **DLM** with the **traditional Match**

- Look at 100 jobs
- and at the Top 5 CVs returned

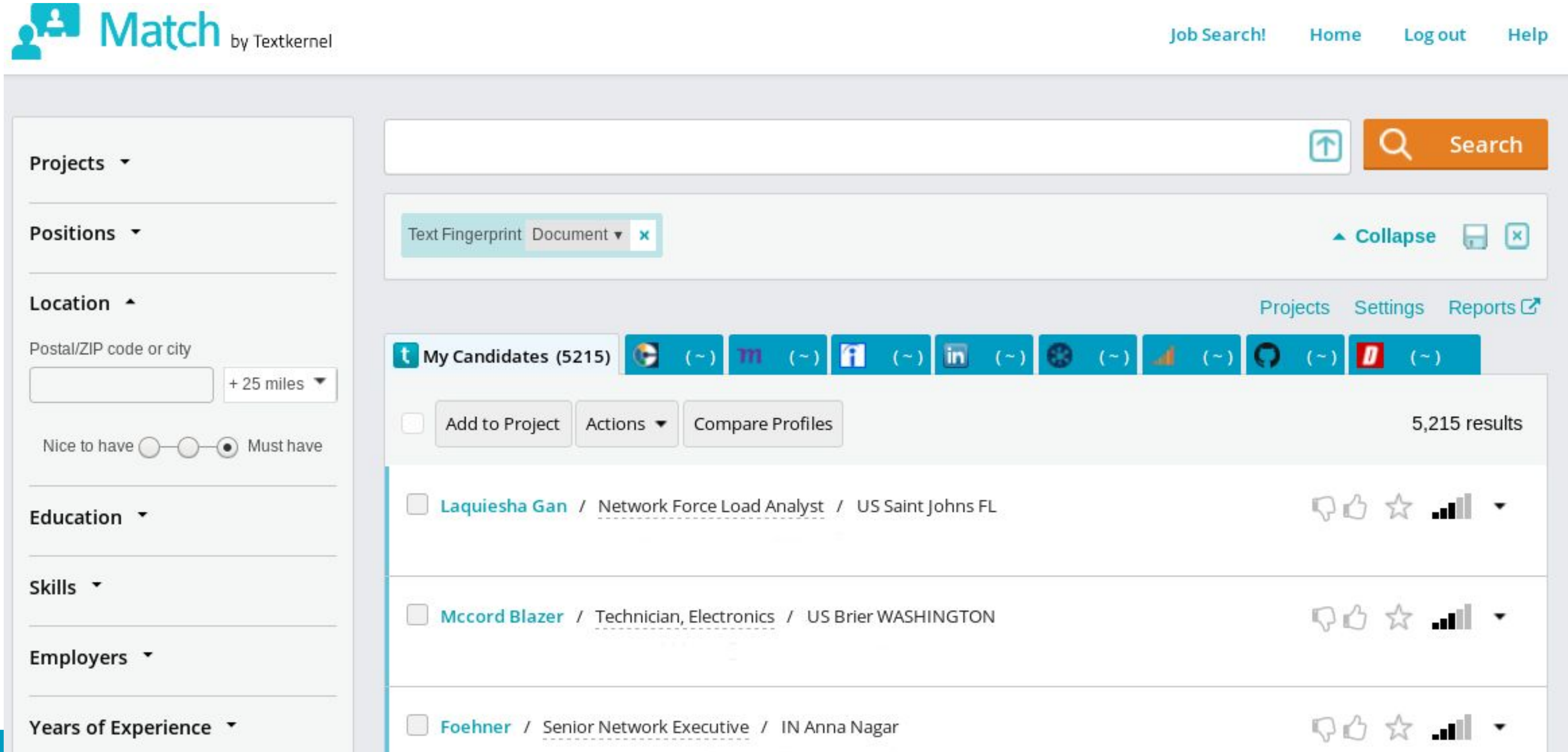
What we got…

DLM is

33%

less likely to return irrelevant results

UX Limitations of the Approach

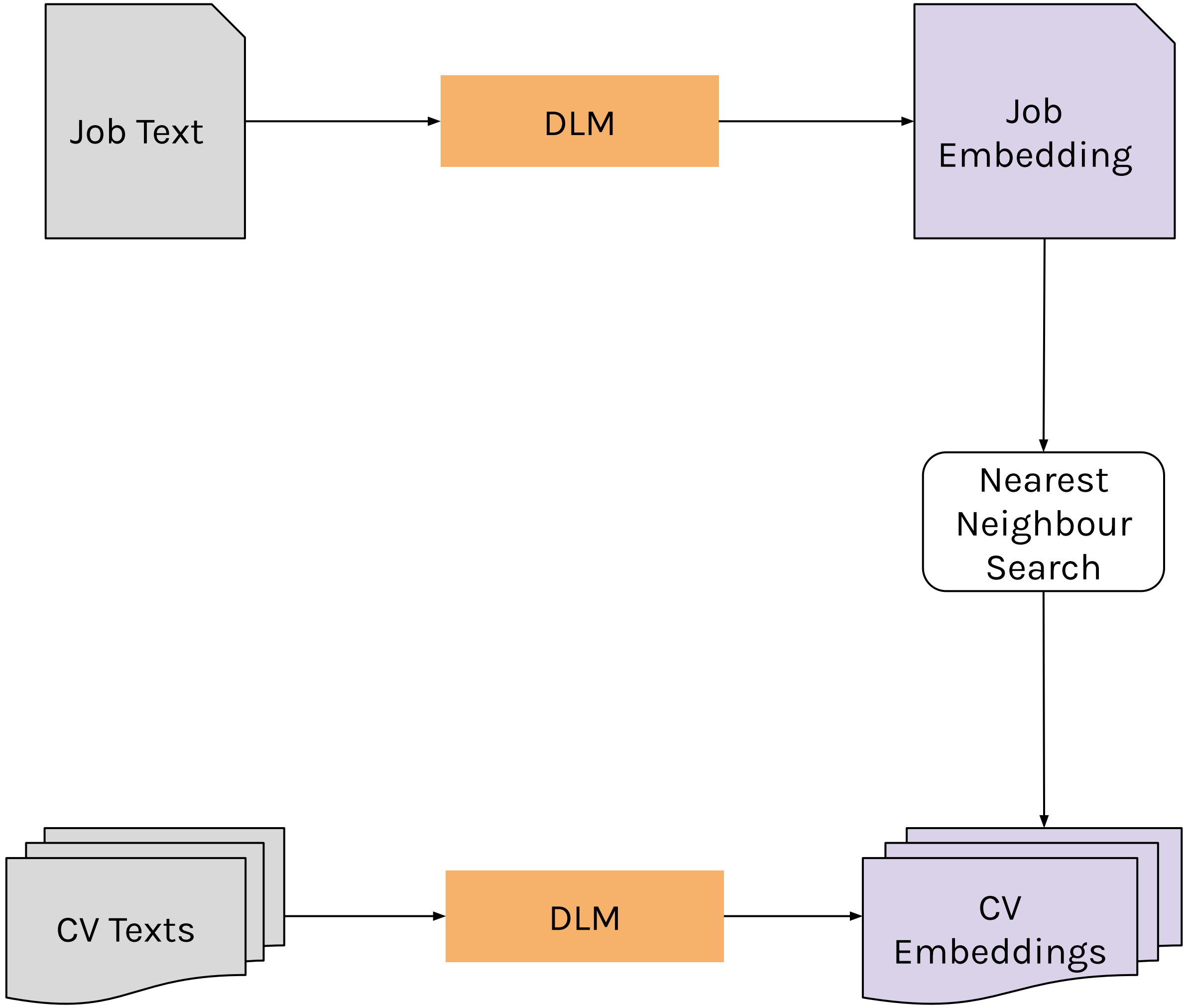

Match by Textkernel
Job Search!
Home
Log out
Help
Projects
Positions
Location
Postal/ZIP code or city
+ 25 miles
Nice to have
Must have
Education
Skills
Employers
Years of Experience
Search
Text Fingerprint
Document
Collapse
Projects
Settings
Reports
My Candidates (5215)
(~)
(~)
(~)
(~)
(~)
(~)
(~)
(~)
Add to Project
Actions
Compare Profiles

5,215 results

- ☐ Laquiesha Gan / Network Force Load Analyst / US Saint Johns FL
- ☐ Mccord Blazer / Technician, Electronics / US Brier WASHINGTON
- ☐ Foehner / Senior Network Executive / IN Anna Nagar

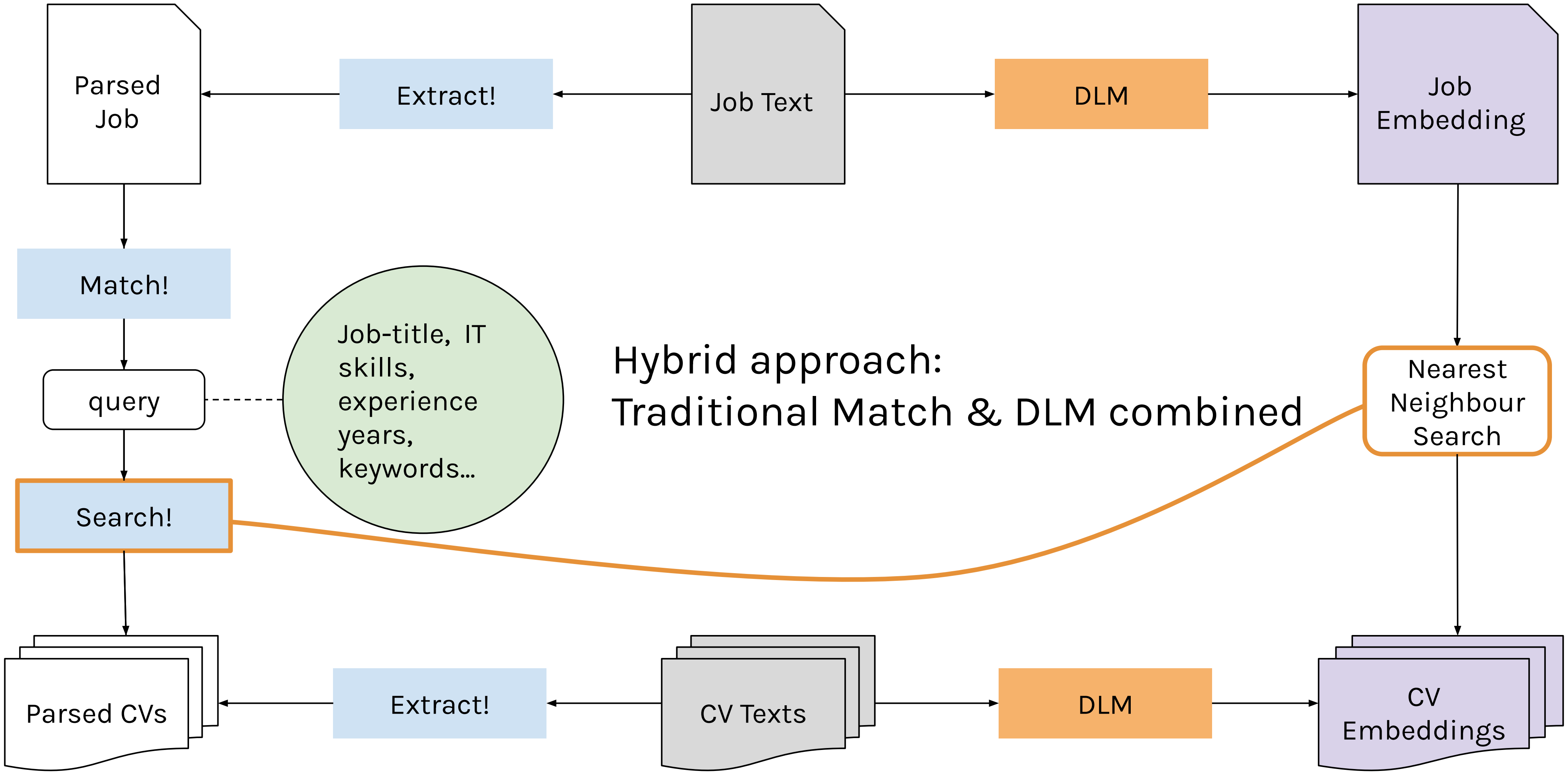
The importance of being Explainable

- **Explainability:** User needs to have a clear understanding of the reason why they're seeing certain results.
- **Refinability:** User needs to be able to modify the generated query as preferred.
- **Control:** Having a faceted search system for filtering or searching on meta-data is crucial.


Job Text
DLM
Job Embedding
Nearest Neighbour Search
CV Texts
DLM
CV Embeddings

Combining DL Matching and Keyword Search

The importance of being Explainable



Parsed Job

Extract!

Job Text

DLM

Job Embedding

Match!

query

Job-title, IT skills, experience years, keywords…

Hybrid approach:
Traditional Match & DLM combined

Nearest Neighbour Search

Search!

Parsed CVs

Extract!

CV Texts

DLM

CV Embeddings

In an ideal world

Query:

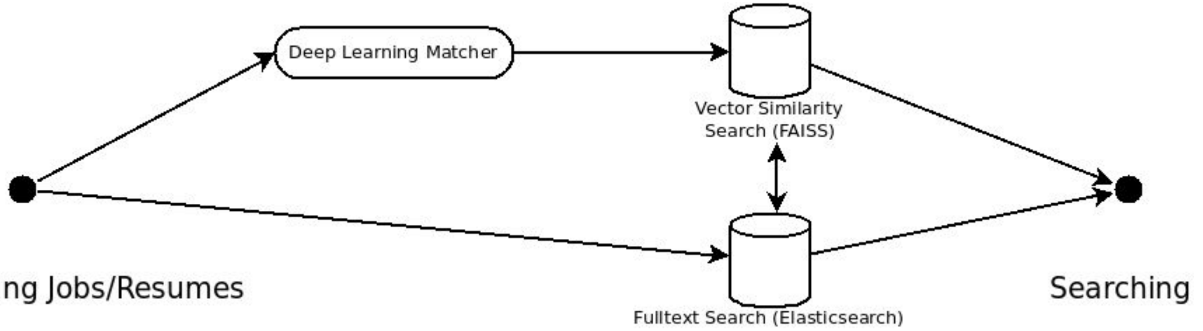
- Jobtitle = ‘ Software Engineer’
- Skills = ‘ Java’ , ‘ Elasticsearch’ , ‘ Python’
- Experience > 5 years
- Vector = (0.0, 0.3, 0.6, 0.0, 0.4, …) [512 dimensions]

The challenge

- Combine search approaches
  - Fulltext & facets
  - Vector similarity

- Challenge
  - Search engine => text (‘ software engineer’)
  - Vector similarity => numbers (0.0, 0.3, 0.6, 0.0, 0.4, …)
  - Reranking vs. Score combination

Approach 1: Keep it separate / Rerank



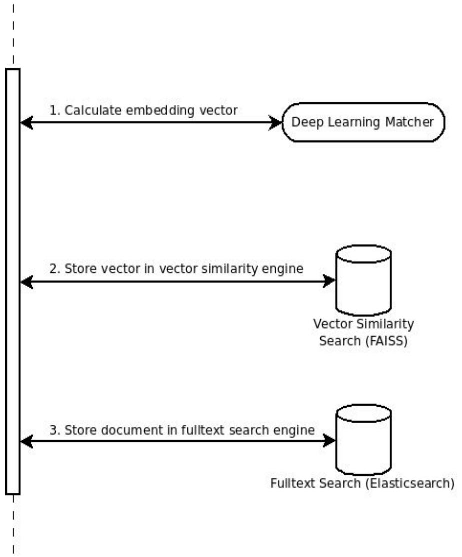
Deep Learning Matcher

Vector Similarity Search (FAISS)

Fulltext Search (Elasticsearch)

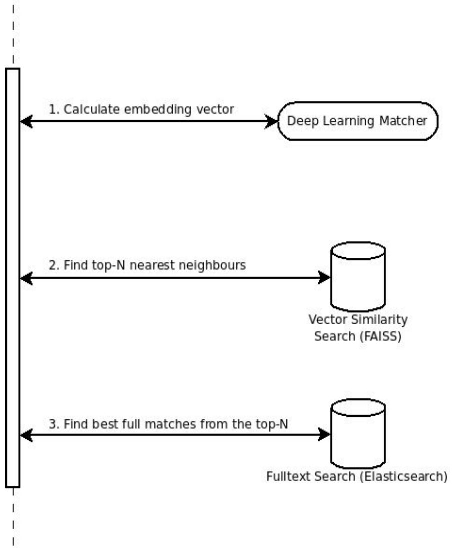
Indexing Jobs/Resumes

Searching



Indexing Jobs

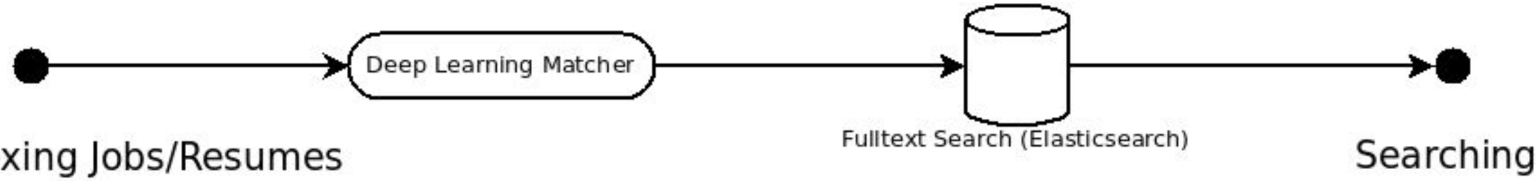
1. Calculate embedding vector — Deep Learning Matcher
2. Store vector in vector similarity engine — Vector Similarity Search (FAISS)
3. Store document in fulltext search engine — Fulltext Search (Elasticsearch)



Searching for relevant Jobs

1. Calculate embedding vector — Deep Learning Matcher
2. Find top-N nearest neighbours — Vector Similarity Search (FAISS)
3. Find best full matches from the top-N — Fulltext Search (Elasticsearch)

Approach 2 : All-in-one



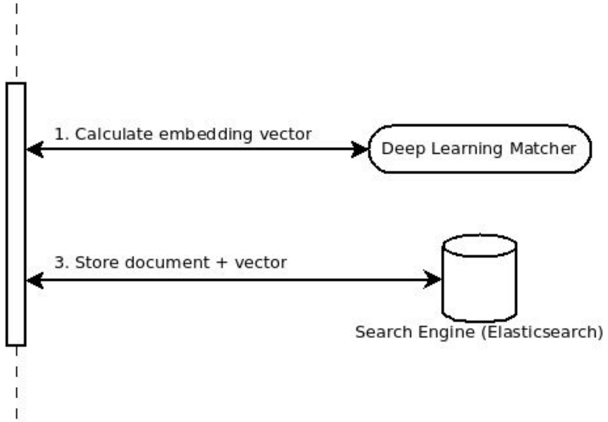
Deep Learning Matcher

Fulltext Search (Elasticsearch)

Indexing Jobs/Resumes

Searching

Indexing Jobs



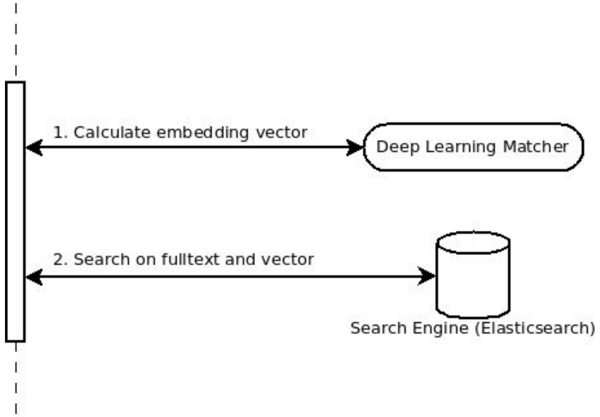
1. Calculate embedding vector

Deep Learning Matcher

3. Store document + vector

Search Engine (Elasticsearch)

Searching relevant Jobs



1. Calculate embedding vector

Deep Learning Matcher

2. Search on fulltext and vector

Search Engine (Elasticsearch)

Pro's / Con's

Separated	**All-in-one**
Pro's ● Off-the-shelf software ● Less engineering	Pro's ● Simpler searching / indexing ● More robust ● Allows for score combination rather than only reranking approaches
Con's ● More parts, more complexity ● Complex two-phase search with difficult data transfer (execution speed) ● Need to keep both systems synchronized, updates!	Con's ● Need to engineer efficient vector-similarity in a search engine

Why Reranking is bad

1. Identify candidates by Keyword Search, rerank by DLM
    - Losing control:
        - only possible to add filters,
        - no way to add keywords, skills, job titles that would influence the ranking

2. Identify candidates by DLM, rerank by Keyword Search
    - Efficiency: Cannot prune search space by facet filters
    - Losing the fine-grained DLM relatedness score

Score Combination

Problem: Typical IR scoring functions (e.g. BM25) have no defined score range

- Textkernel scoring plugin guarantees [0 - 1] scores
- Score combination then is matter of weighting

Efficient nearest neighbour search in ES

Open Source Development to the rescue…

- Developed own ES plugin for vector-similarity search with reduced dimensionality -> losing precision
- Since ES 7.3: https://www.elastic.co/blog/text-similarity-search-with-vectors-in-elasticsearch allowing high-dimensional vector search
- It’s still limited in applicability and gets hopefully soon further extended

Meanwhile…

DL network is used to improve conventional architecture

- Improve quality of synonym knowledge
  - Check closeness of synonyms in vector space to filter out inappropriate ones
  - Build average CV embedding model for each skill, suggest skills with close embedding model.

- Job title normalization
  - Pre-filter: Make sure the normalized job title is also close in vector space. Mainly reducing embarrassing errors.

The End

Any questions?

Further Deep Learning Match Research

Applications are not symmetrical:

- Same job
- Promotion
- Side step

Tag application data accordingly before learning.

- ignore promotion and side steps for learning the network to create embeddings.
- Promotion or Side-step models could be useful still for better matching.

Multilingual Fingerprints

Using existing knowledge to map English model to other languages, creating synthetic learning data.