

Mining the Technical Skills of Open Source Developers

João Eduardo Montandon



“Our civilization runs on software.”

— Bjarne Stroustrup

Banking



Traveling



Media & Social



Transport



Telecoms



Shopping



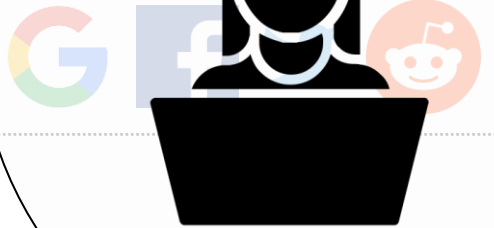
Banking



Traveling



Media & Social



Telecoms



Transport



Shopping





“Software development is a human
centric activity, which makes
developers the most important asset
of software companies.”

DeMarco, T. and Lister, T. (1999). *Peopleware:
Productive Projects and Teams*.

*“Our [Facebook’s] policy is literally to hire as many **talented engineers** as we can find.”*

— Mark Zuckerberg

*“**Hiring well** is the most important thing in the universe.”*

— Valve Corporation

Where do we find the
right people?

Where do we find them? ...

The screenshot shows Dan Abramov's GitHub profile. At the top, there are navigation tabs for Overview, Repositories (248), Projects, and Packages. The profile picture is on the left, followed by his name 'Dan Abramov' and handle 'gaearon'. Below that is a bio: 'Working on @reactjs. Co-author of Redux and Create React App. Building tools for humans.' There are 'Follow' and '...' buttons. Below the bio, it says '63.2k followers · 171 following · 1.4k'. There are links for '@facebook', 'dan.abramov@me.com', and 'http://twitter.com/dan_abramov'. A 'Highlights' section shows 'Arctic Code Vault Contributor' and '1 discussion answered'. The main content area is titled 'Pinned' and shows six repository cards: 'facebook/react', 'facebook/create-react-app', 'react-dnd/react-dnd', 'reduxjs/redux', 'reduxjs/redux-devtools', and 'paularmstrong/normalizr'. Each card displays the repository name, description, and statistics for JavaScript, TypeScript, stars, and forks. At the bottom, it says '3,391 contributions in the last year' and shows a calendar heatmap with a legend for 'Less' and 'More' contributions.

GitHub!

60M
new repositories*

56M
new users*

* In 2020, only!

Where do we find them? ...

Overview Repositories **248** Projects Packages

Pinned

- facebook/react**
A declarative, efficient, and flexible JavaScript library for building user interfaces.
JavaScript ☆ 162k 🍴 32.4k
- facebook/create-react-app**
Set up a modern web app by running one command.
JavaScript ☆ 85.4k 🍴 21k
- react-dnd/react-dnd**
Drag and Drop for React
TypeScript ☆ 15.1k 🍴 1.6k
- reduxjs/redux**
Predictable state container for JavaScript apps
TypeScript ☆ 55.1k 🍴 14.5k
- reduxjs/redux-devtools**
DevTools for Redux with hot reloading, action replay, and customizable UI
TypeScript ☆ 11.8k 🍴 903
- paularmstrong/normalizr**
Normalizes nested JSON according to a schema
JavaScript ☆ 19.8k 🍴 803

3,391 contributions in the last year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Mon													
Wed													
Fri													

Learn how we count contributions. Less More

GitHub!

60M
new repositories*

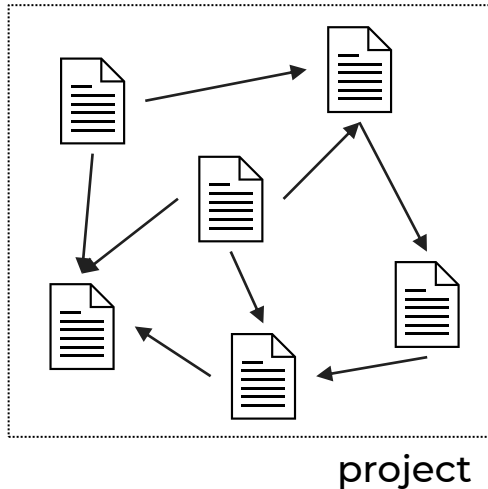
56M
new users*

* In 2020, only!

How do we choose the
right people?

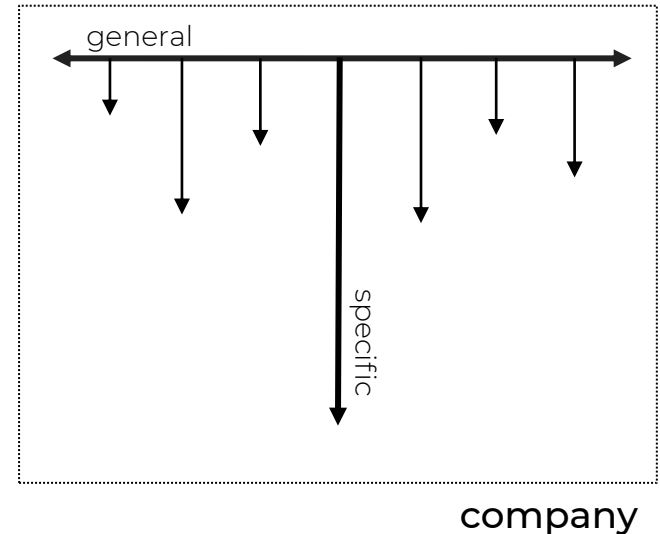
The Literature Perspective

Right people: The ones that better align with the project



The Industry Perspective

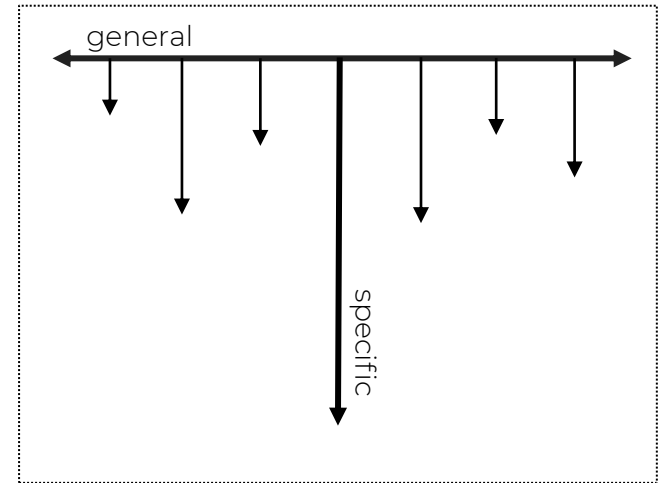
Right people: The ones that better align with the company



The Industry Perspective

**OUR
FOCUS**

Right people: The ones that better align with the company



company

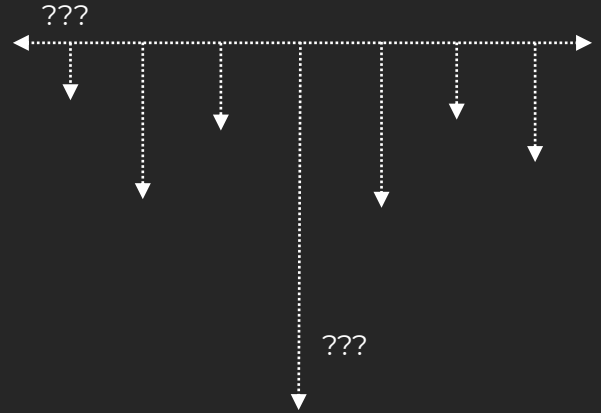
Our proposal is...

To investigate methods and techniques to effectively identify technical skills of software developers

Our goals

- Understand which skills and abilities are more required by IT companies when looking for new professionals.
- Investigate methods and techniques to identify expertise elements in a deep perspective (3rd party libraries).
- Investigate methods and techniques to identify expertise elements in a broad perspective (technical roles).

What Skills do IT Companies look for in New Developers?



What kind of skills are the industry interested in?

Technologies

python javascript odoo

Job description

About the role:

Odoo is the ERP used by ██████████ and is written in Python. As the roll-out of Odoo through-out the organisation is nearing completion, it is now necessary to build out our own in-house Python team, so we are not reliant on Odoo consultants for making changes in our Odoo setup. The Python Developer will be incredibly organized, enthusiastic, confident, and a great communicator.

Your responsibilities include:

- Implement the required modules to operate Odoo for ██████████
- Support the integration according to stakeholders' requirements.
- Assist and train other stakeholders for their usage of Odoo.
- Mentor other Python developers within the team.

About you:

You are:

- Initiative-taking; you are self-motivated, a doer, and can drive projects from start to finish
- A leader; you have a proven ability to inspire, energize and mobilize a team towards a goal
- A team-player; you are comfortable working with different styles and believe (like us) that together we achieve much more than alone
- Driven; you are used to working hard to achieve a goal you care about and running several projects in parallel
- A great communicator; you are comfortable in communicating in English both written and oral, including leading meetings, selling your ideas and storytelling

You have:

- Minimum of 3 years as a software engineer
- 2+ years Python experience
- Knowledge of best engineering practices in agile software development: architectural paradigms, code reviews, branching, task management, documentation, testing
- Thorough experience of REST & API practices
- In-depth knowledge of database design and optimization
- Excellent written and verbal communication skills in English
- Ability to work well with teams effectively without supervision

We'd be extra impressed if you also have:

- Javascript and Nodejs knowledge
- ERP knowledge or willing to learn the ERP Odoo

What we expect
from you

Technologies

python javascript odoo

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Soft Skills



Technologies

python javascript odoo

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You have:

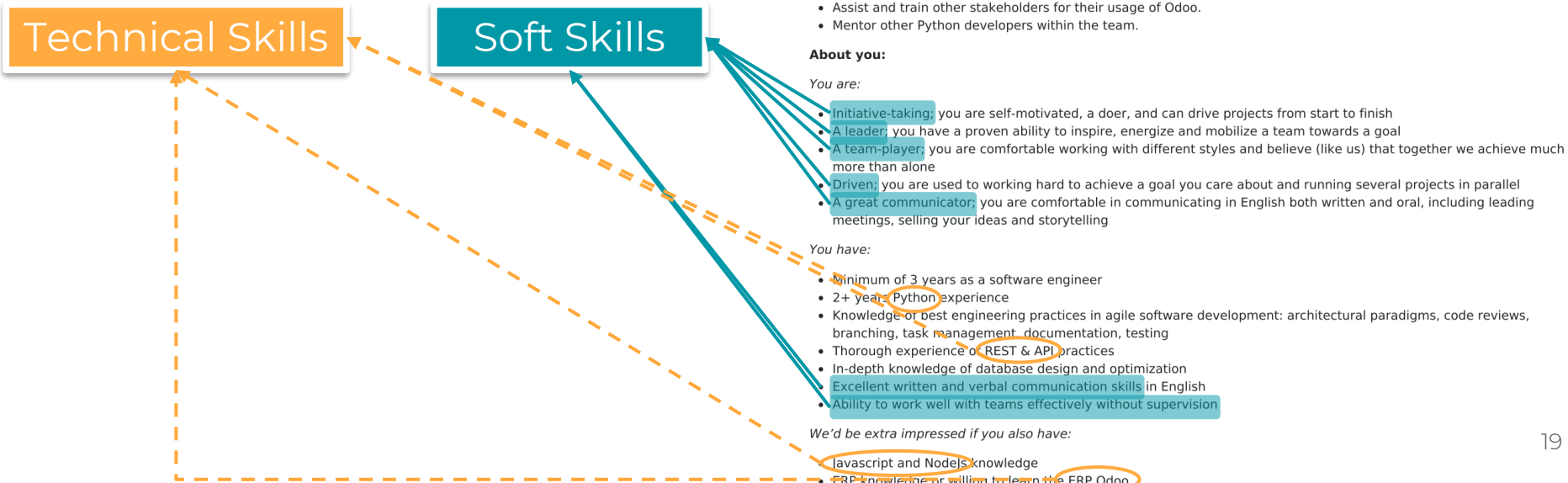
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- **Excellent written and verbal communication skills** in English
- **Ability to work well with teams effectively without supervision**

We'd be extra impressed if you also have:

- **Javascript and NodeJS** knowledge
- **ERP** knowledge or willing to learn the ERP Odoo

Technical Skills

Soft Skills



Our study: Technical Skills

20,968

Job posted in 2019

14

pre-defined roles

67K ⁽²⁸²⁾

Technical skills
occurrences

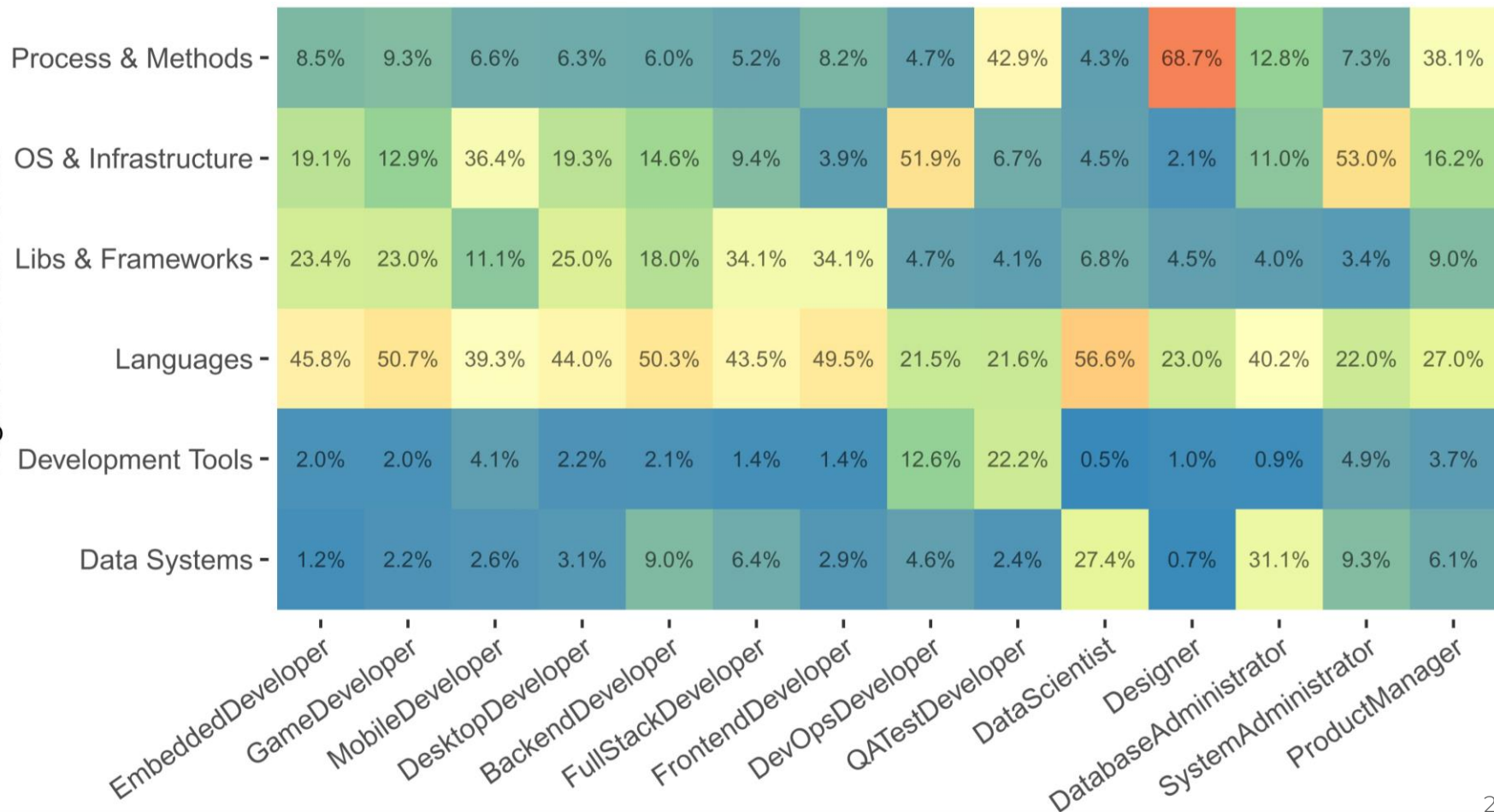
Technologies

python javascript odoo

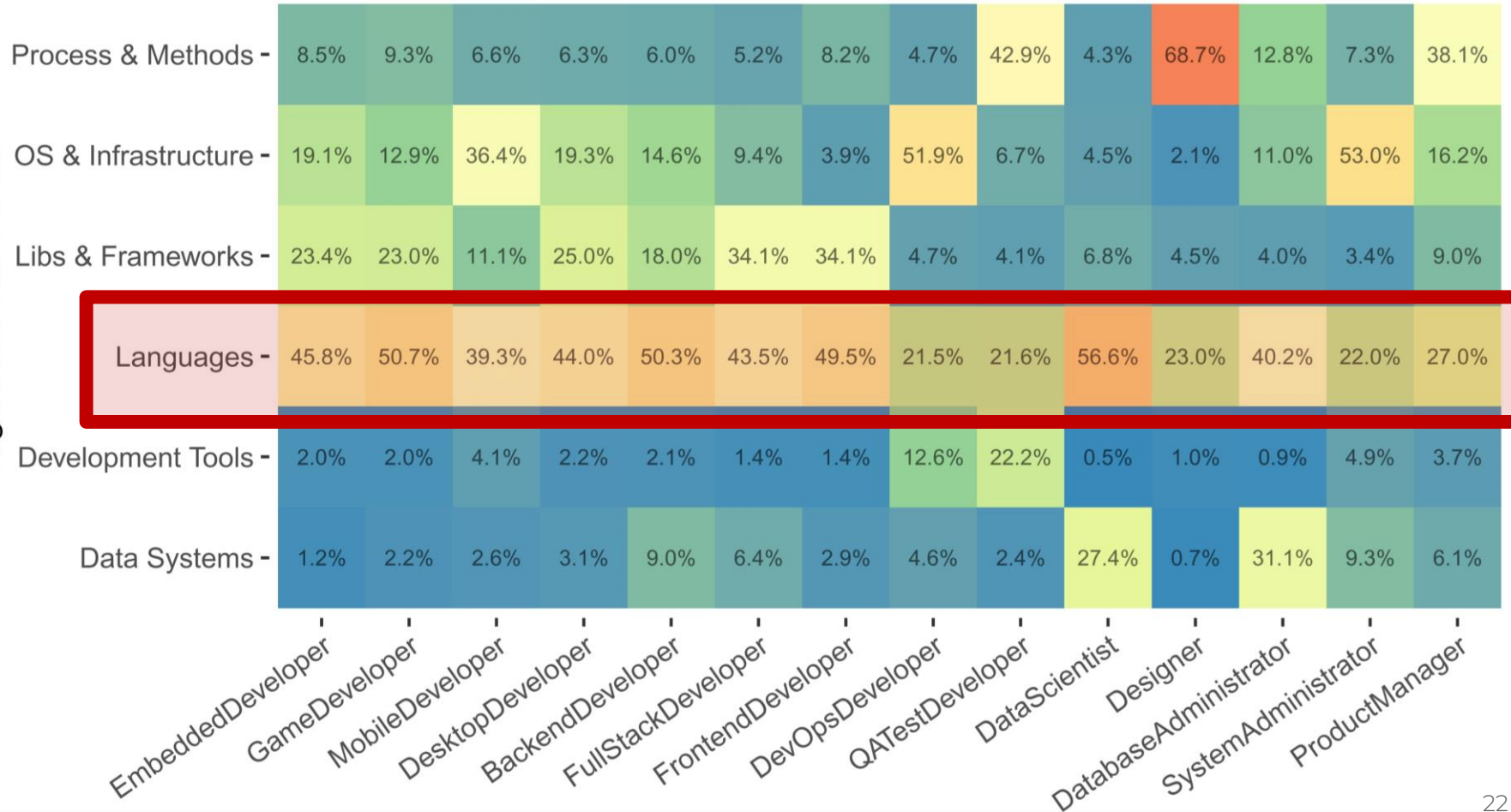
6

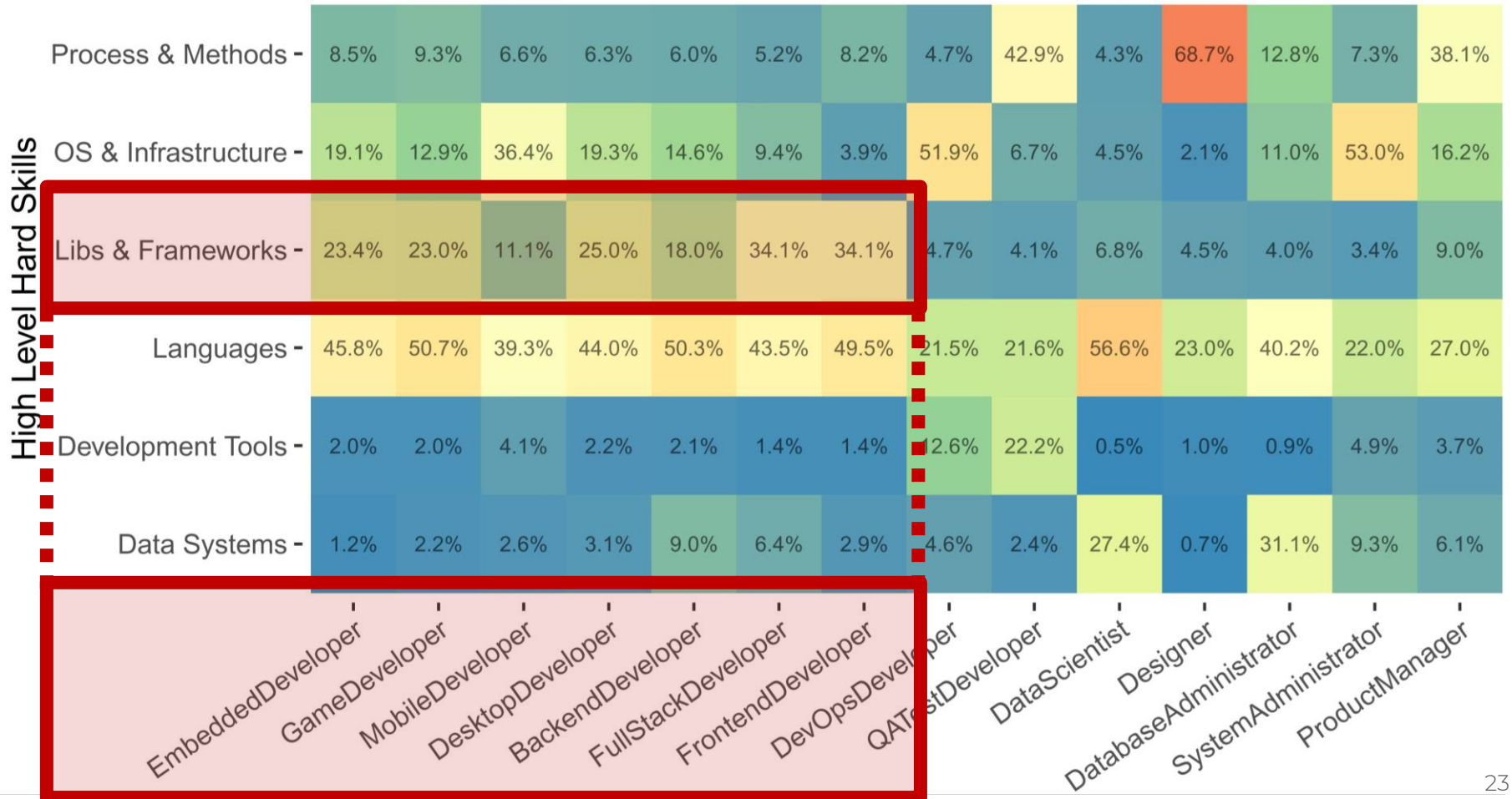
High level
technical skills

High Level Hard Skills



High Level Hard Skills





Our study: Soft Skills

376

Opportunities
randomly selected

3

Researchers manually
annotated sentences

1,530

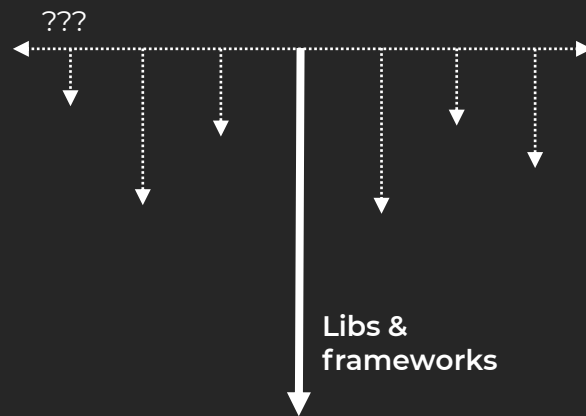
Sentences annotated

- Excellent written and verbal **communication skills** in English
- Ability to **work well with teams** effectively without supervision

Takeaway

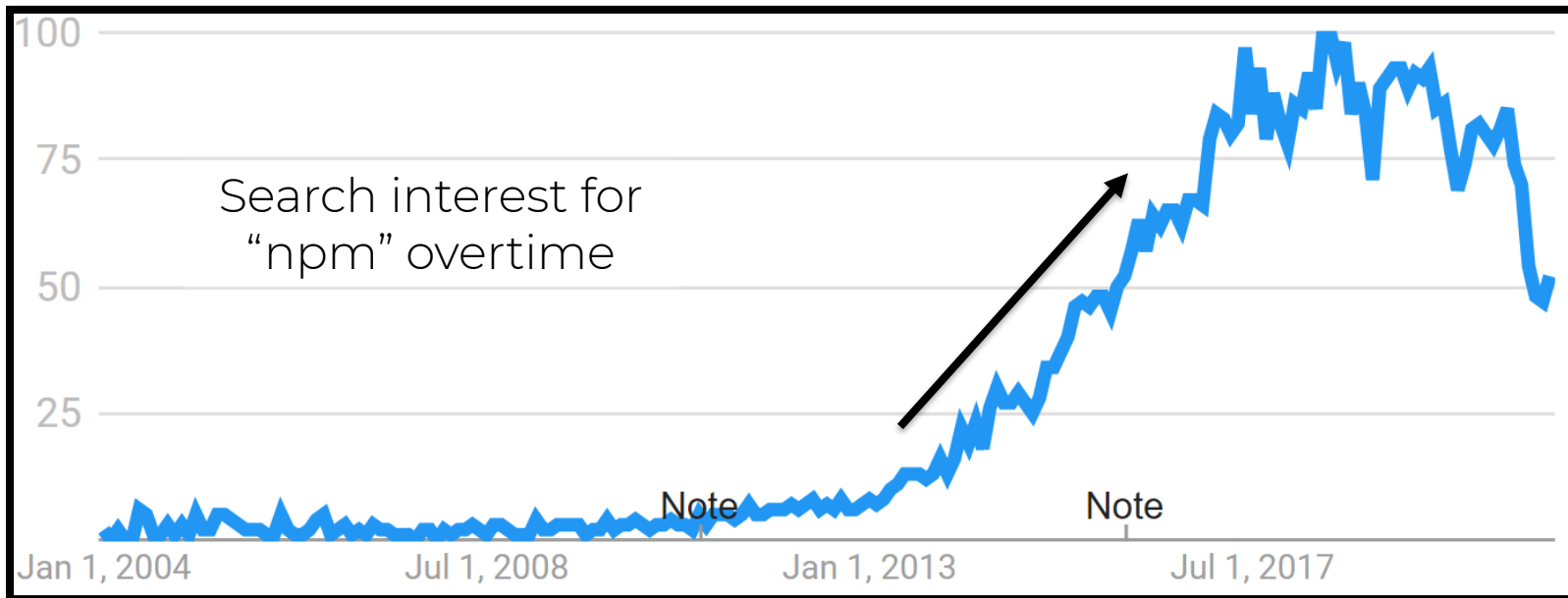
- Developer-based positions do require expertise in 3rd party components
- Programming languages skills are needed across all roles
- Soft skills: teamwork and communication do matter!

Identifying Experts in Software Libraries and Frameworks among GitHub Users





Software development
increasingly relies on
3rd party software
components



Investigate data-driven methods to identify developers'
expertise level on 3rd party libraries

H =

When maintaining a piece of code, developers gain expertise on frameworks and libraries

- **RQ.1:** How accurate are [supervised] machine learning classifiers when used to identify library experts?
- **RQ.2:** Which features best distinguish library experts?

Our Ground-Truth

Library	Description	#Dev.
ReactJS	Fronted library used to build user interfaces	8,742
MongoDB	Official JavaScript driver for MongoDB	454
socket.io	Real-time communication library	608



Our Ground-Truth

*Could you please rank your expertise on [target library]
in a scale from 1 (novice) to 5 (expert)?*

ReactJS

2,185

mails

19%

418

answers

MongoDB

454

mails

15%

68

answers

socket.io

608

mails

15%

89

answers

ReactJS

MongoDB

socket.io

2,185

mails

19%

418

answers

575

mails

68

answers

608

mails

15%

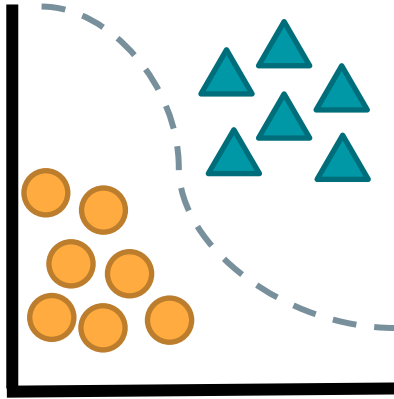
89

answers

Developers!

Dimension	Description	Features
Volume	Amount of code written by developer using the library	Commits CommitsClientFiles CommitsImportLibrary CodeChurn CodeChurnClientFiles Imports
Frequency	Amount of time a developer has used the library	DaysSinceFirstImport DaysSinceLastImport DaysBetweenImports AvgDaysCommitsClientFiles AvgDaysCommitsImportLibrary
Breadth	Quantify the situations the library was used	Projects ProjectsImport

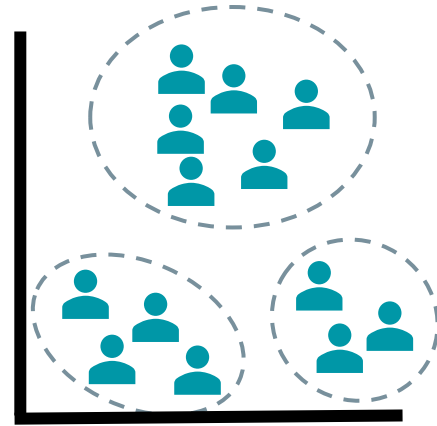
RQ.1



Random Forest & SVM

- ❖ 3 classes: All three libraries
- ❖ 5 classes: ReactJS

RQ.2



KMeans

- ❖ 3 classes: ReactJS & MongoDB
- ❖ 5 classes: socket.io

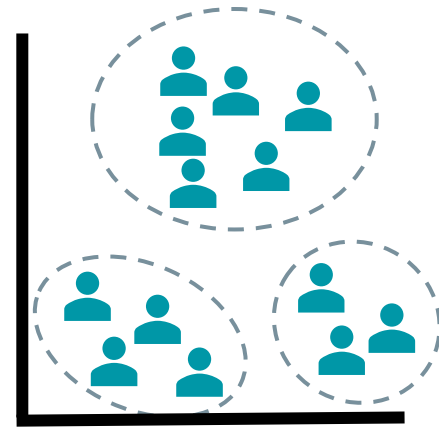
RQ.1

In this presentation,
we will focus here

Random Forest & SVM

- ❖ 3 classes: All three
- ❖ 5 classes: ReactJS

RQ.2



KMeans

- ❖ 3 classes: ReactJS & MongoDB
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RQ.2

Cluster	% Novices	% Intermediate	% Experts	# Devs
FACEBOOK/REACT				
C1	0.03	0.23	0.74	97
C2	0.12	0.28	0.60	129
C3	0.18	0.27	0.55	192
MONGODB/NODE-MONGODB				
C1	0.12	0.24	0.65	17
C2	0.21	0.43	0.36	14
C3	0.35	0.35	0.30	37
SOCKETIO/SOCKET.IO				
C1	0.00	0.25	0.75	4
C2	0.29	0.36	0.36	28
C3	0.33	0.33	0.33	15
C4	0.50	0.40	0.10	30
C5	0.67	0.33	0.00	12

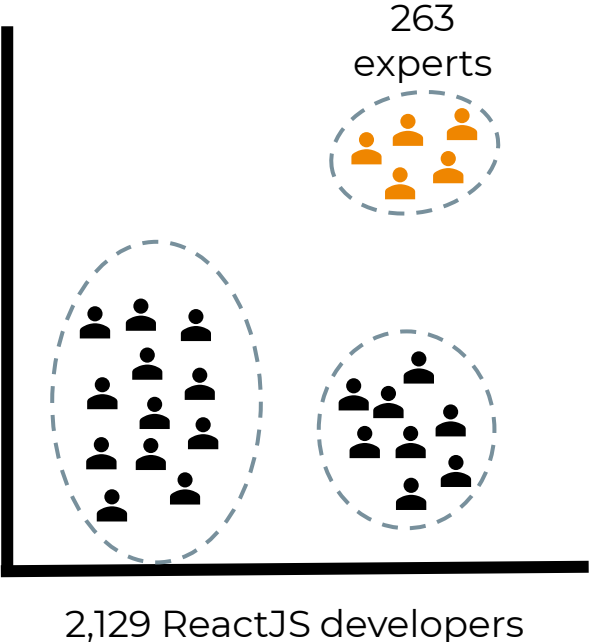
RQ.2

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C2	↓ 0.12	0.28	↑ 0.60	129
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MONGODB/NODE-MONGODB				
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C5	↓ 0.67	0.33	↑ 0.00	12

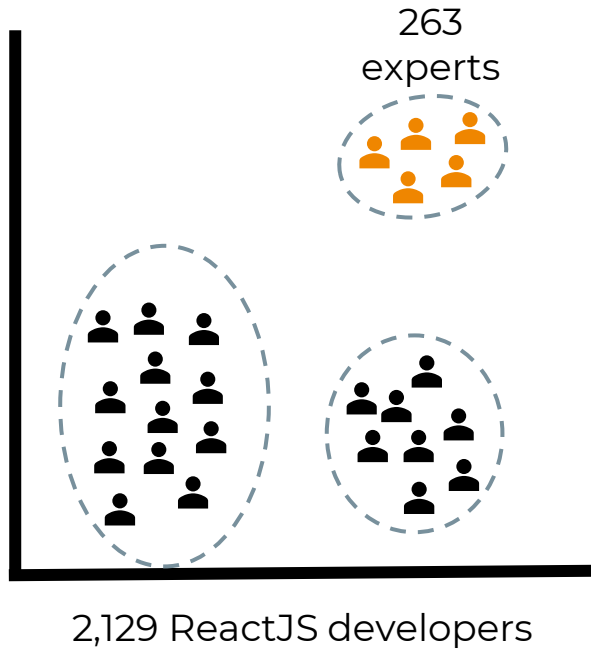
RQ.2

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C4	0.50	0.40	0.10	30
C5	0.67	0.33	0.00	12

LinkedIn Triangulation



LinkedIn Triangulation



Senior Developer at [redacted] (React)
Czech Republic

Connect

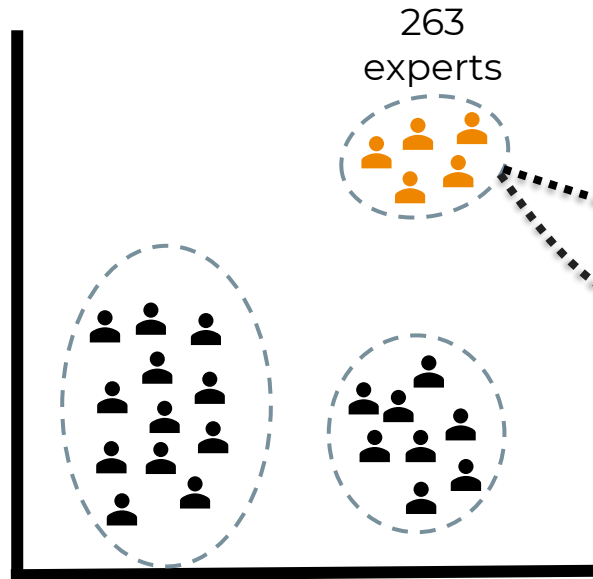
⇒ Recently doing mainly
React, redux, redux-saga, webpack

⇒ Summary of other skills:
Java, Spring, Hibernate, Vaadin, Maven
Javascript, Dojo, Ext.Js, Gatsbyjs
Css, Less, Sass, Bootstrap
User Interface design, User Experience basics
PHP, Python, LaTeX
MySQL, PostgreSQL
Git
Neural Networks, Evolutionary Computing, Cellular Automata, Data Mining

⇒ I know a bit about:
Angular, npm, NodeJs, ExpressJs, Liferay, Atomic Design, Gradle, Gulp, Psychology, People Management, GraphQL

160 LinkedIn profiles

LinkedIn Triangulation



2,129 ReactJS developers

Senior Developer at [Redacted] (React)
Czech Republic

⇒ Recently doing mainly React, redux, redux-saga, webpack

⇒ Summary of other skills:
Java, Spring, Hibernate, Vaadin, Maven
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Neural Networks, Evolutionary Computing, Cellular Automata, Data Mining

⇒ I know a bit about:
Angular, npm, NodeJs, ExpressJs, Liferay, Atomic Design, Gradle, Gulp, Psychology, People Management, GraphQL

72%
Explicitly
Mentioned
ReactJS

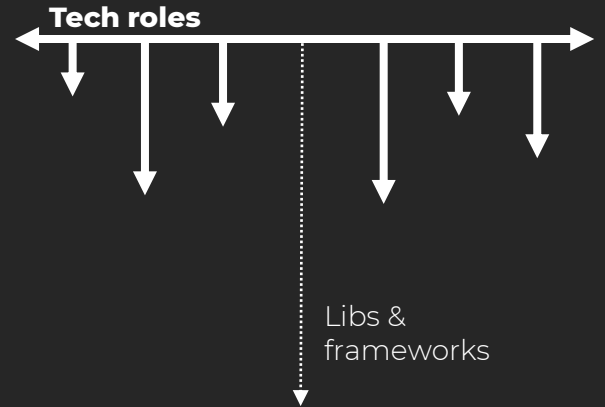
160 LinkedIn profiles

Takeaway



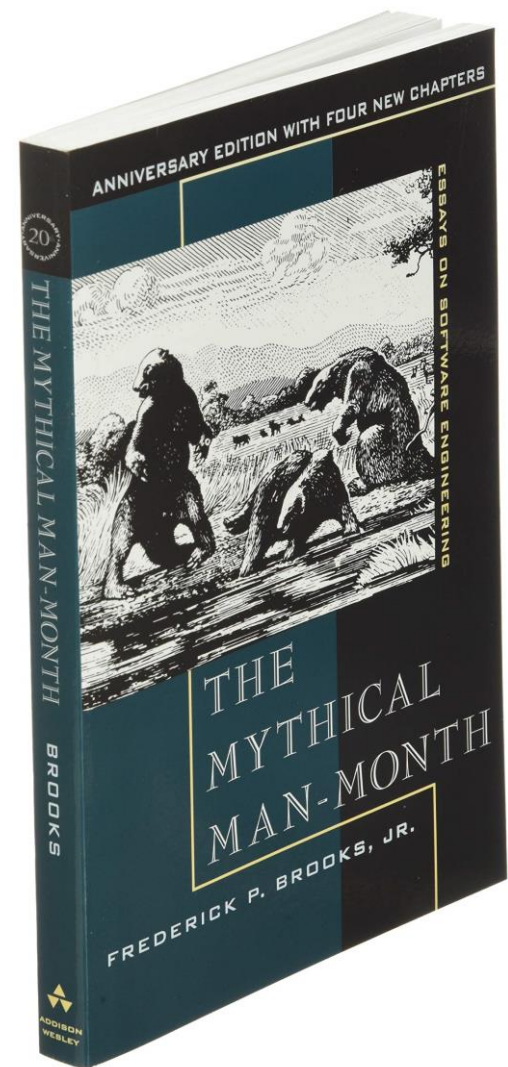
- Exploratory analysis can identify groups of experts based on the selected features
- We found clusters dominated by experts
(↑Experts + ↓Novices)

Mining The Technical Roles of GitHub Users



THE SURGICAL TEAM

*“Mills proposes that each segment of a large job be tackled by a team, but that the **team be organized like a surgical team** [...]”*



Technical roles are one of the first information used by companies when hiring new developers

Full-Stack JavaScript Developer - Contract or Full-Time (100% Remote)

Timedoctor.com LLC - No office location

Remote

reactjs node.js javascript vue.js

DevOps Engineer

Tessian - London, UK

£45k - 80k | Equity Visa sponsor Paid relocation

docker ansible linux sysadmin terraform

Sr. Backend Engineer (Data Onboarding)

ADARA, Inc. - Palo Alto, CA

Visa sponsor

cloud python api google-cloud-platform

Sr Full Stack Developer - Java, Spring ,ReactJS

Modus Create - No office location

Remote

java spring spring-mvc reactjs

Identify the technical roles played by developers using information available in OSS platforms.

H =

The technologies that developers master define
their technical roles

- **RQ.1:** How accurate are ML classifiers on identifying developers' technical roles?
- **RQ.2:** What are the most relevant features to distinguish technical roles?
- **RQ.3:** Do technical roles influence each other during classification?
- **RQ.4:** How effectively can we identify full-stack developers?

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- **RQ.3:** Do technical roles influence each other during classification?
- **RQ.4:** How effectively can we identify full-stack developers?*

Our Ground Truth

1. Selected developers from Stack Overflow with GitHub profiles
2. Filtered the ones self-ascribed in the following roles: **Backend**, **Frontend**, **DevOps**, **DataScience**, **Mobile**, and **FullStack***.

Profile Activity Developer Story

Meta user Network profile

10 answers 0 questions ~4k people reached

Barcelona, Espanya

stackoverflow.com

Member for 3 years, 3 months

3 profile views

Last seen Aug 12 at 8:34

144 REPUTATION

9

Communities (2)

- Stack Overflow 144
- Software Engineering 1

Top network posts

We respect a laser-like focus on one topic.

Top tags (19)

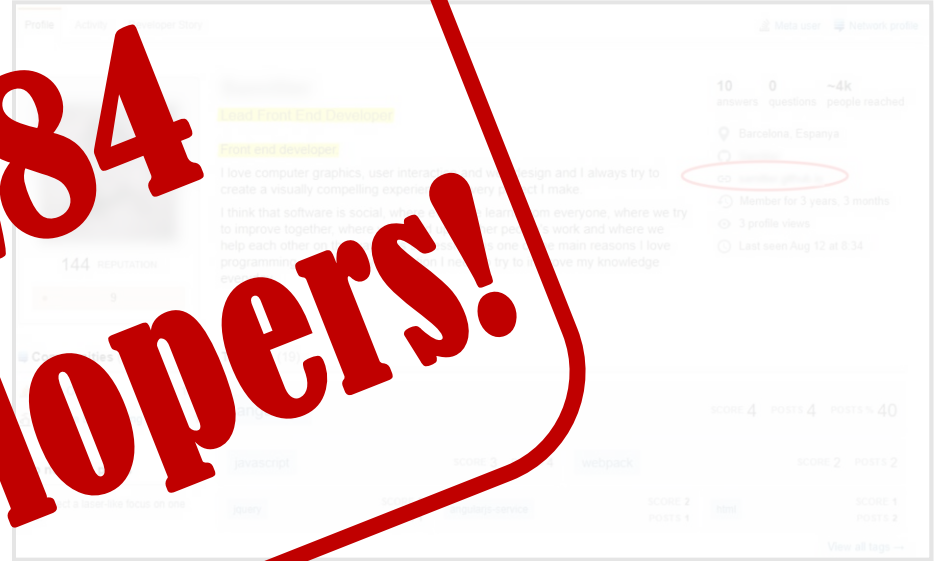
angularjs	SCORE 4	POSTS 4	POSTS % 40
javascript	SCORE 3	POSTS 4	
webpack	SCORE 2	POSTS 2	
jquery	SCORE 2	POSTS 1	
angularjs-service	SCORE 2	POSTS 1	
html	SCORE 1	POSTS 2	

View all tags →

Our Ground Truth

- Selected developers from Stack Overflow with GitHub profiles
- Filtered the ones self-ascribed in the following roles: **Backend, Frontend, DevOps, DataScience**

**2,284
Developers!**



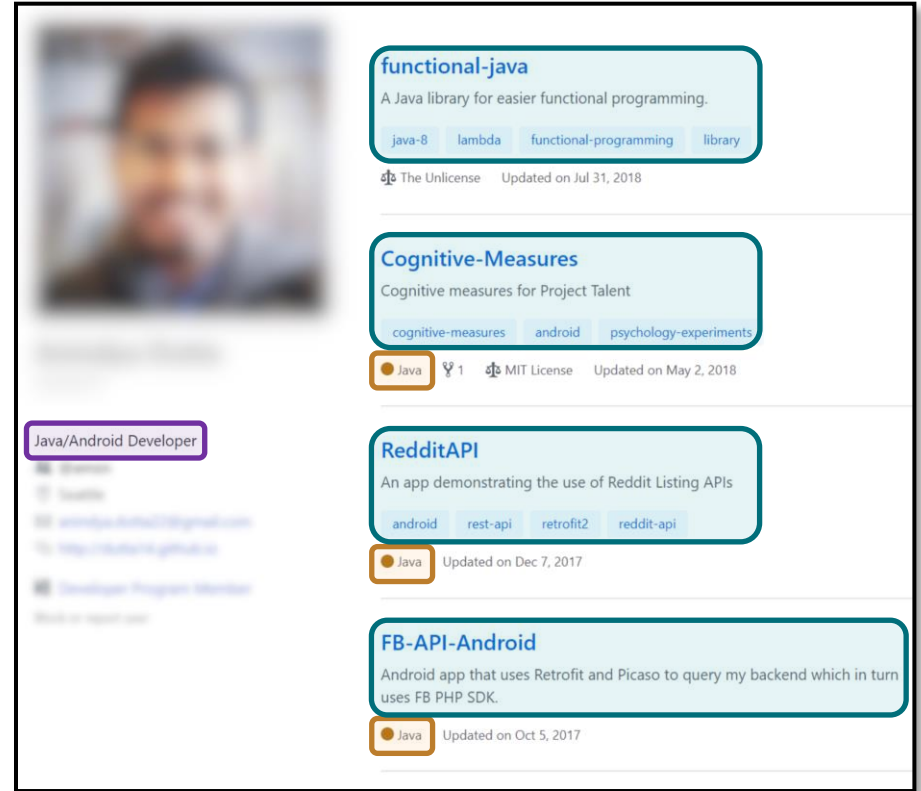
Our Feature Set

■ Programming Language

■ Short Bio

■ Projects' names, topics & descriptions

■ 3rd party dependencies



The screenshot displays a developer profile page with a blurred profile picture and a bio section. The bio includes the text "Java/Android Developer" highlighted with a purple box. Below the bio, there are four project cards, each with a title, description, tags, license, and update date:

- functional-java**: A Java library for easier functional programming. Tags: java-8, lambda, functional-programming, library. License: The Unlicense. Updated on Jul 31, 2018.
- Cognitive-Measures**: Cognitive measures for Project Talent. Tags: cognitive-measures, android, psychology-experiments. License: MIT License. Updated on May 2, 2018.
- RedditAPI**: An app demonstrating the use of Reddit Listing APIs. Tags: android, rest-api, retrofit2, reddit-api. License: MIT License. Updated on Dec 7, 2017.
- FB-API-Android**: Android app that uses Retrofit and Picasso to query my backend which in turn uses FB PHP SDK. License: MIT License. Updated on Oct 5, 2017.

Our Feature Set

■ Programming Language

■ Short Bio

■ Projects' names, topics & descriptions

■ 3rd party dependencies

**1,567
features!**



(RQ.1 & RQ.4) How accurate are ML classifiers in identifying technical roles?

Role	Precision	Recall	F1
FullStack*	0.99	0.71	0.83
Backend	0.87	0.63	0.73
Frontend	0.86	0.89	0.87
Mobile	0.80	0.34	0.47
DevOps	0.75	0.06	0.11
DataScience	0.86	0.62	0.71
Overall	0.88	0.69	0.77

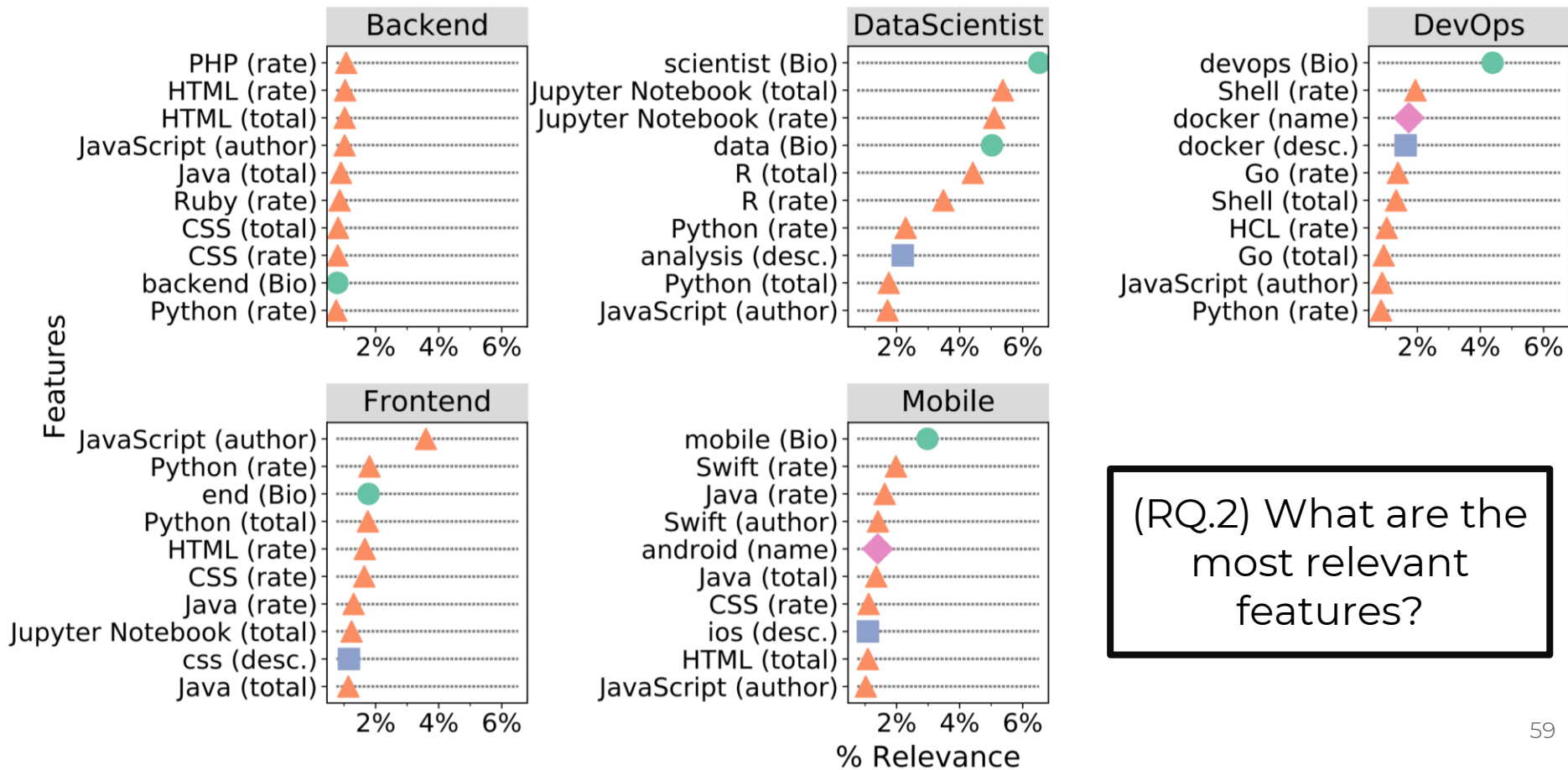
0.89

AUC

* RQ.4, only

Category

● Bio ▲ Language ■ Rep. Description ◆ Rep. Name



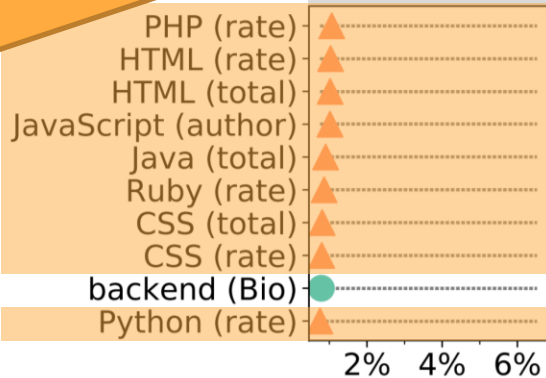
(RQ.2) What are the most relevant features?

38 out of 50

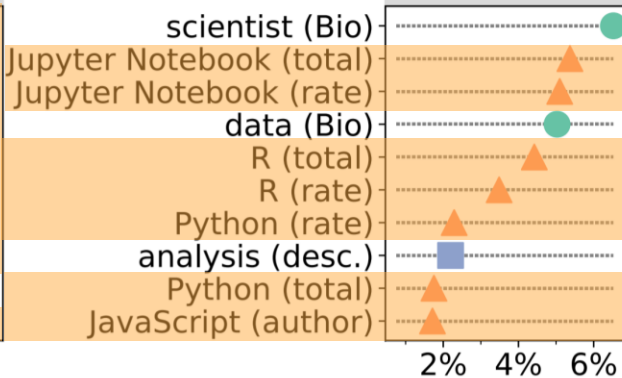
Category

● Bio ▲ Language ■ Rep. Description ◆ Rep. Name

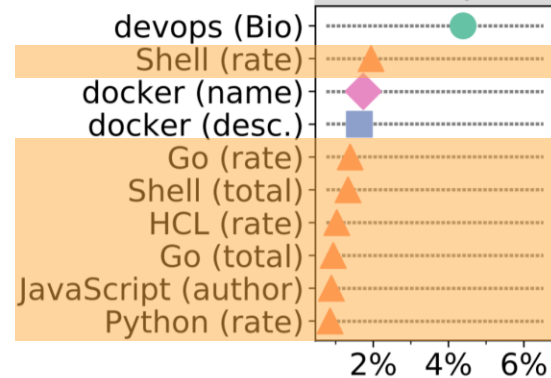
Backend



DataScientist

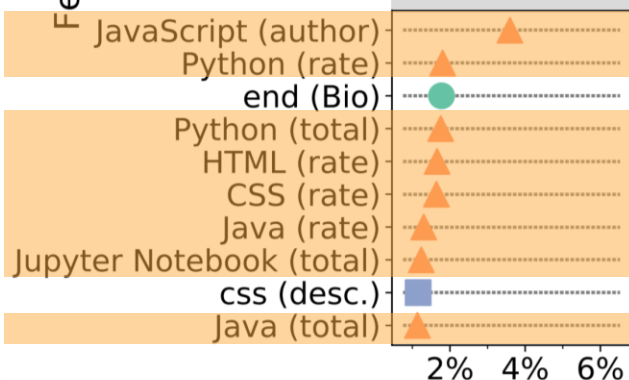


DevOps

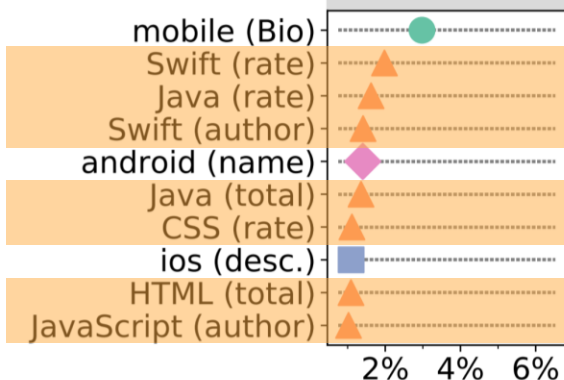


Features

Frontend



Mobile



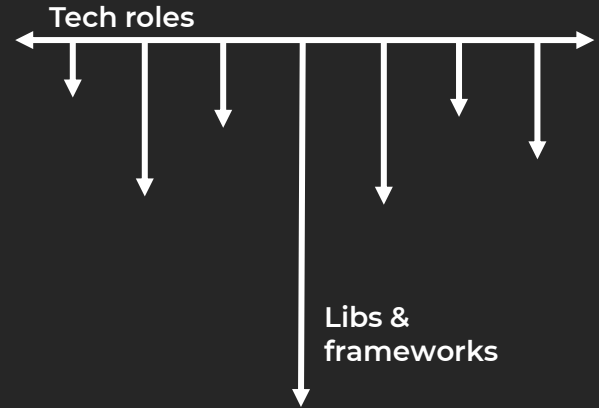
% Relevance

(RQ.2) What are the most relevant features?

Takeaway

- We show that it is possible to identify major technical roles from developers
- Features associated to PLs are relevant for all roles

Conclusions & Future Work

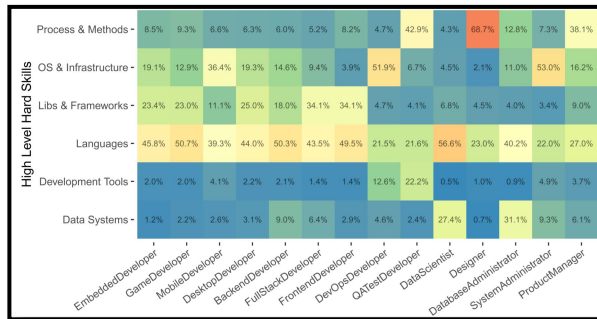


In this thesis...

We extensively analyzed data-driven methods and techniques to **leverage software developers' profiles**

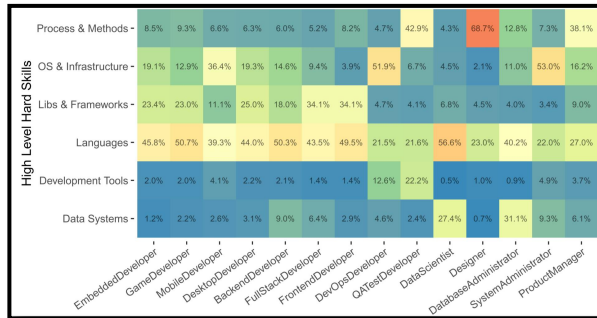
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In this thesis...

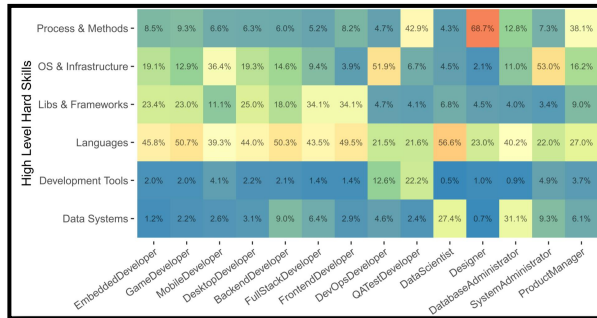
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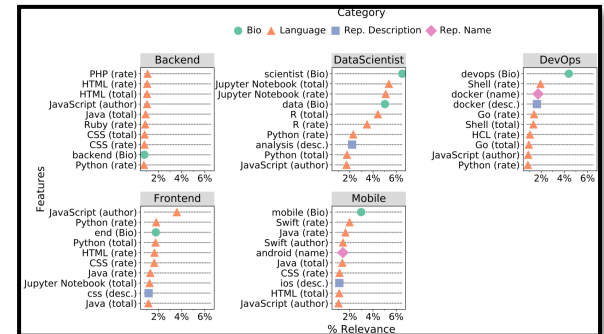
Cluster	% Novices	% Intermediate	% Experts	# Devs
FACEBOOK/REACT				
C1	0.03	0.23	0.74	97
C2	0.12	0.28	0.60	129
C3	0.18	0.27	0.55	192
MONGODB/NODE-MONGODB				
C1	0.12	0.24	0.65	17
C2	0.21	0.43	0.36	14
C3	0.35	0.35	0.30	37
SOCKETIO/SOCKET.IO				
C1	0.00	0.25	0.75	4
C2	0.29	0.36	0.36	28
C3	0.33	0.33	0.33	15
C4	0.50	0.40	0.10	30
C5	0.67	0.33	0.00	12

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C4	0.50	0.40	0.10	30
C5	0.67	0.33	0.00	12



Our Contributions

- ✓ A map of technical and soft skills more required by the IT industry
- ✓ Ground truth with expertise information of 575 developers
- ✓ A method based on low-level data to identify specific expertise information (libs & frameworks)
- ✓ A method based on coarse-grained features to detect general expertise elements (technical roles)

Future Work

1. Expand soft skills analysis
2. Study technical expertise in PLs
3. 3rd party libs in other ecosystems



Publications

1. J. E. Montandon, L. L. Silva, M. T. Valente. **Identifying Experts in Software Libraries and Frameworks among GitHub Users**. MSR, 2019.
2. J. E. Montandon, C. Politowski, L. L. Silva, M. T. Valente, F. Petrillo, Y. Guéhéneuc. **What Skills do IT Companies look for in New Developers? A Study with Stack Overflow Jobs**. IST, 2021.
3. J. E. Montandon, M. T. Valente, L. L. Silva. **Mining the Technical Roles of GitHub Users**. IST, 2021.

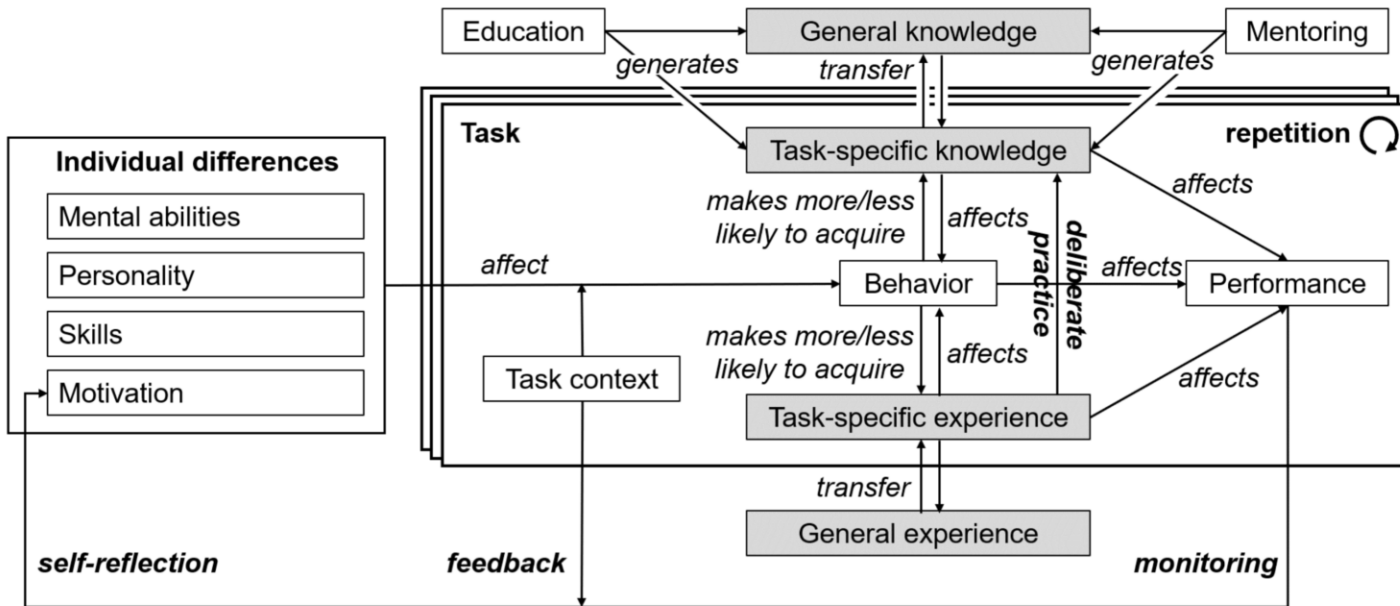
Mining the Technical Skills of Open Source Developers

João Eduardo Montandon

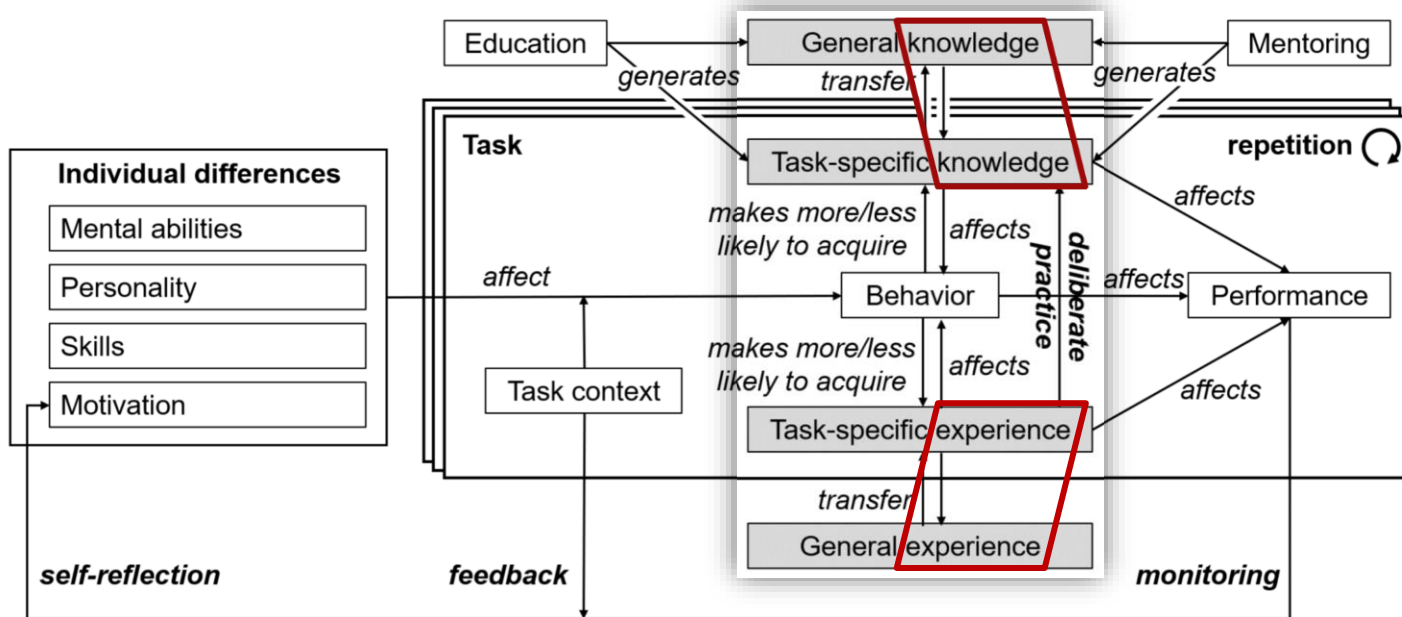
The Importance of Expertise

*“**Expertise** then refers to the **characteristics, skills,** and **knowledge** that distinguish experts from novices and less experienced people.”*

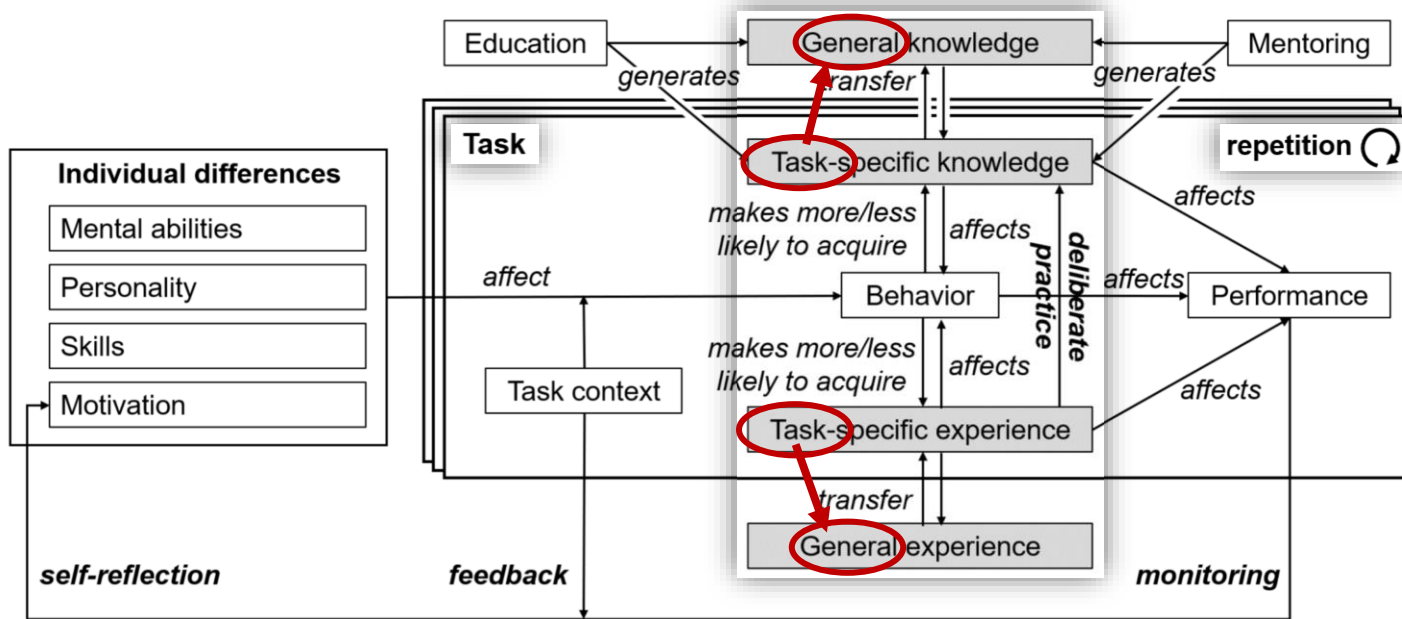
The Cambridge Handbook of Expertise and Expert Performance, K. A. Ericsson, 2012



Towards a Theory of Software Development Expertise, Baltes and Diehl, 2018



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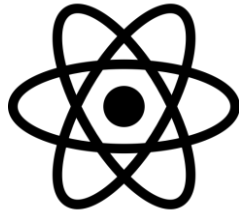


Towards a Theory of Software Development Expertise, Baltes and Diehl, 2018

Out of 1,839 job offers...



215
jobs



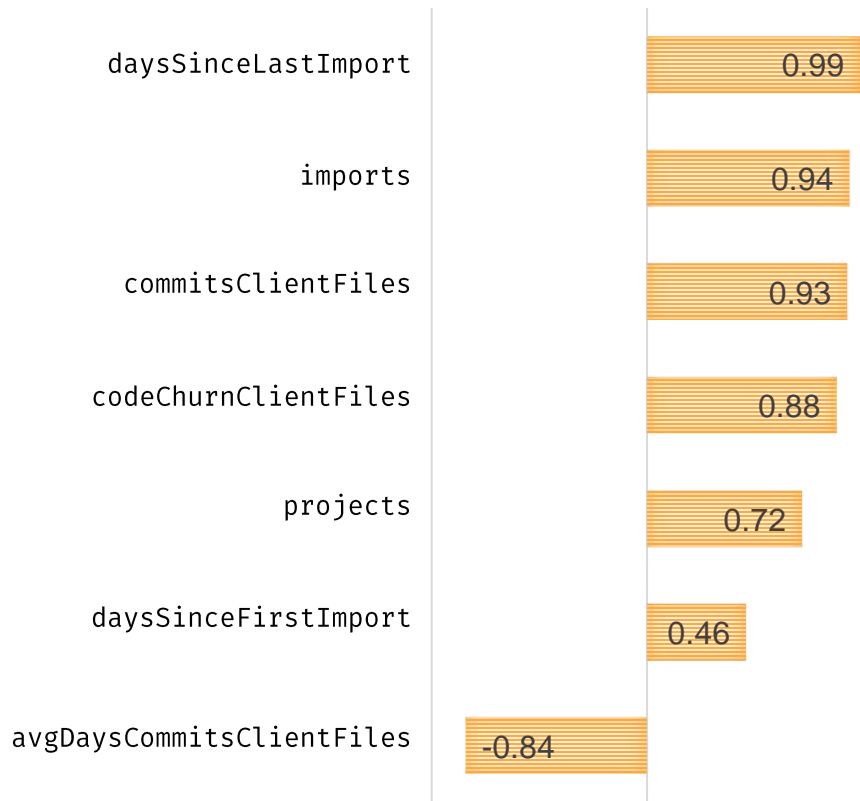
372
jobs



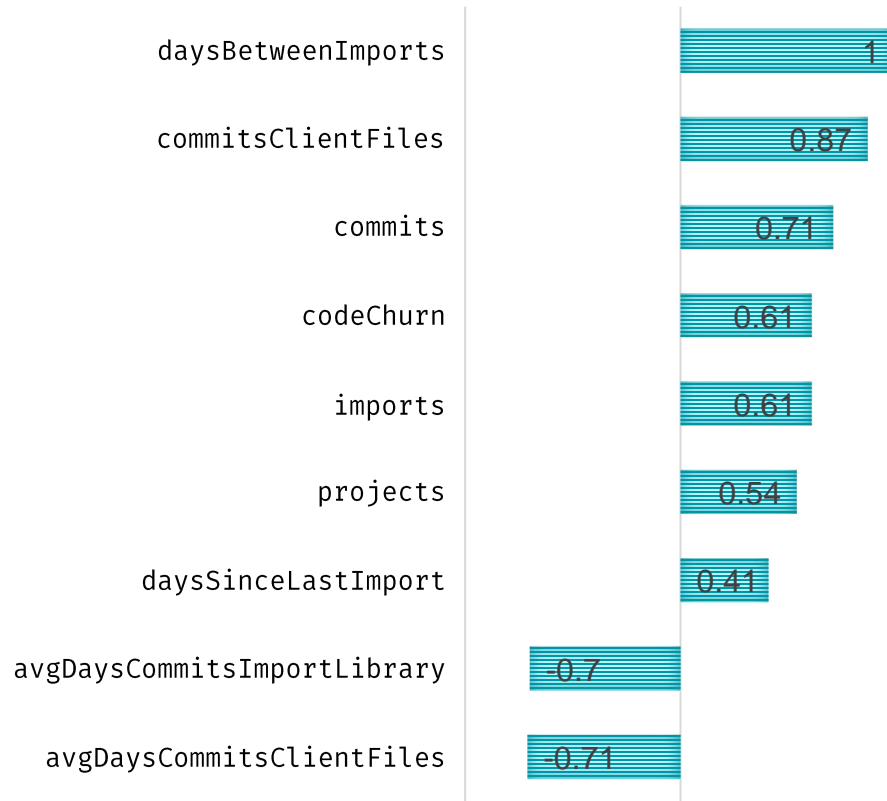
135
jobs

722 (39%)

ReactJS



MongoDB



(RQ.1) How accurate are ML classifiers in identifying technical roles?

Role	Precision	Recall	F1
Backend	0.62	0.12	0.18
Frontend	0.77	0.78	0.77
Mobile	0.78	0.38	0.51
DevOps	0.70	0.13	0.20
DataScience	0.86	0.66	0.74
Overall	0.77	0.49	0.59

0.71

AUC

(RQ.4) The FullStack Dataset

*“Being a **Full-Stack** developer [...] means that you are able to **work on both sides**”*

2,284

FullStack dataset

+783

Backend + Frontend
developers

(RQ.4) How effectively can we identify full-stack developers?

Role	Precision	Recall	F1
FullStack	0.99	0.71	0.83
Backend	0.87 (+0.25)	0.63 (+0.51)	0.73 (+0.55)
Frontend	0.86 (+0.09)	0.89 (+0.11)	0.87 (+0.10)
Mobile	0.80 (+0.03)	0.34 (-0.04)	0.47 (-0.04)
DevOps	0.75 (+0.05)	0.06 (-0.07)	0.11 (-0.09)
DataScience	0.86 (0.00)	0.62 (-0.04)	0.71 (-0.03)
Overall	0.88 (+0.11)	0.69 (+0.20)	0.77 (+0.18)

0.89 (+0.18)
AUC

(RQ.4) How effectively can we identify full-stack developers?

Role	Precision	Recall	F1
FullStack	0.99	0.71	0.83
Backend	0.87 (+0.25)	0.63 (+0.51)	0.73 (+0.55)
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0.89 (+0.18)
AUC