



# Supporting Business Document Workflows via Collection-Centric Information Foraging with Large Language Models

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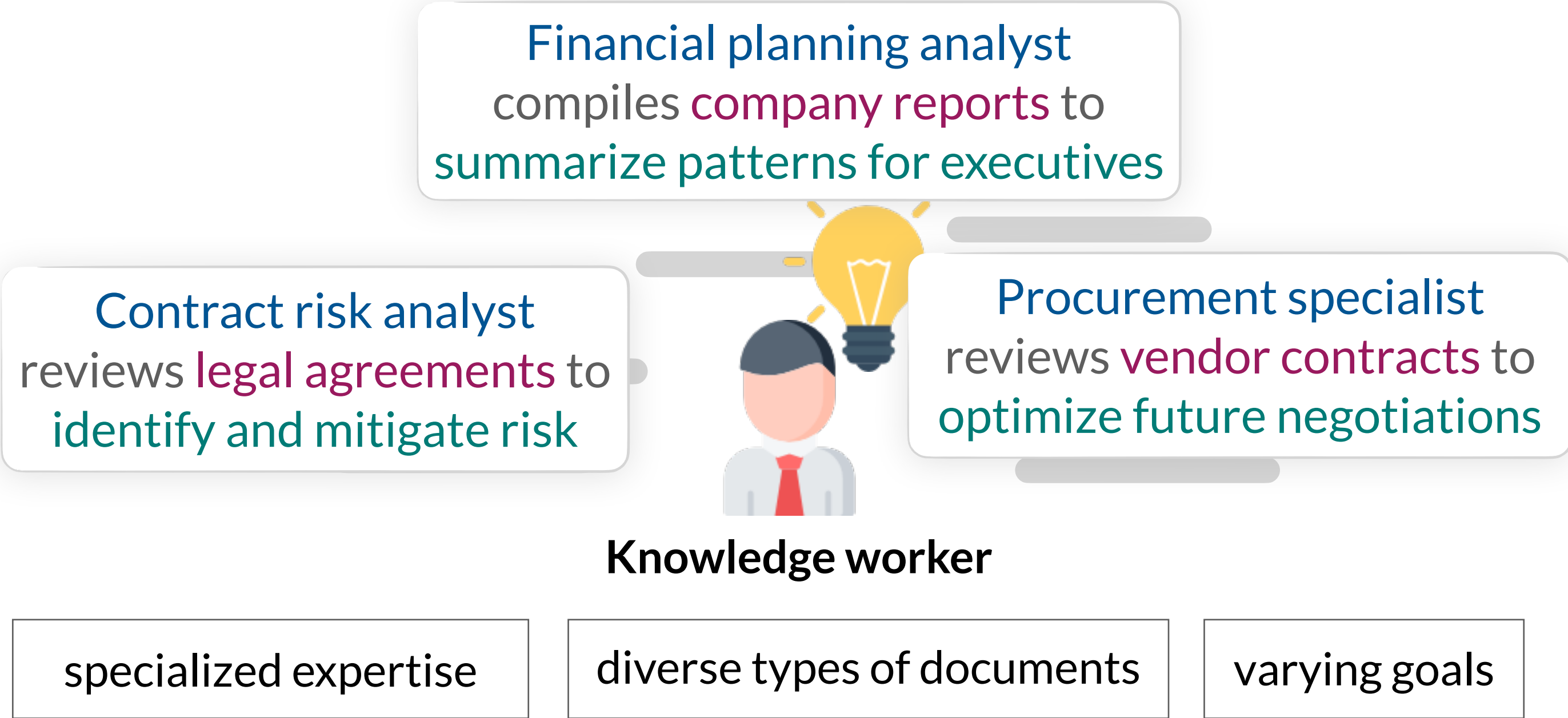
University of Washington

Nedim Lipka, Tong Sun, Alexa Siu

Adobe Research



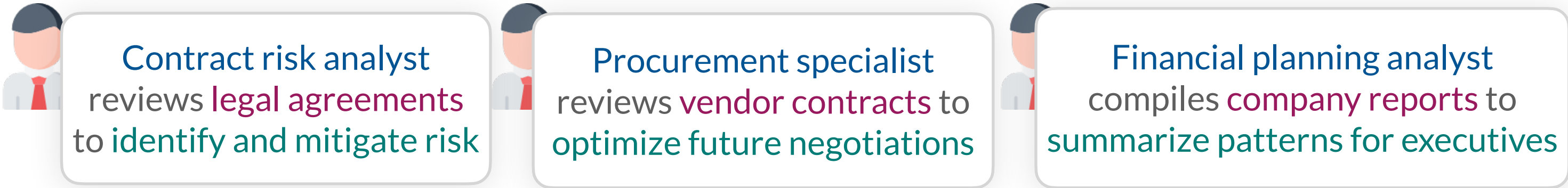
# Deriving insights from information within long documents



# Understanding current processes via formative interviews



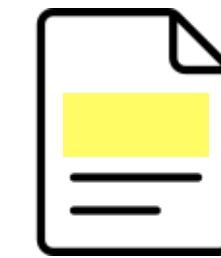
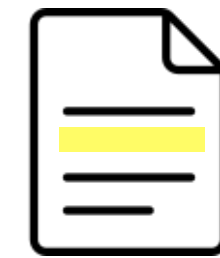
We interviewed 12 knowledge workers across various business areas



- What types of documents do you most frequently work with?
- What challenges do you face in your current workflows?
- What tools do you use to support your work?



# Collecting and comparing relevant information from many documents is hard!



## Challenges

- Large volume of documents
- Linear information extraction. Process is repetitive, tedious, and error-prone.
- Comparison and synthesis across documents lacks scaffolding
- Minimal tool support, at most single doc tools











## Challenges

- Large volume of documents
- Linear information extraction. Process is repetitive, tedious, and error-prone.
- Comparison and synthesis across documents lacks scaffolding
- Minimal tool support, at most single doc tools

**How can we design human-AI systems to support knowledge workers in efficiently and reliably collecting and analyzing information across many documents?**



**Explorer** Add files

- 10 Document(s)
-  Aegis\_Group
-  CrystalClear\_2
-  EcoGuard\_Cleaning
-  Harmony\_House
-  Nature\_Touch\_Cleaners
-  Pristine\_Pro\_Clean
-  Pro\_Cleaning\_3
-  SparkleSweep\_Cleaner
-  UrbanScrubs
-  Zenith\_Shine\_Solution

 Notebook  Table

What do you want to accomplish? Set Goal

Clear cells

+  Start writing or press '/' for AI.

# Collection-centric information foraging via **actions**

## Scaffolded natural language queries

**Ask** Each Document **Does this candidate have experience with ...**

Doc 1	Yes, this candidate has experience ...
Doc 2	No, this candidate does not have experience ...

**Search** programming experience

Doc 1	"experience with data analysis tools R, Python, and ..."
Doc 2	"Programming languages: Java, Python, SCALA, C++ ..."

**Ask** My Collection **Which candidates have worked at FooBar?**

Two candidates, Riley (Doc 1) and Parker (Doc 2), list prior experience in Software Engineering and Program Manager roles at FooBar.

Doc 1	"Contributed to systems and tools at FooBar."
Doc 2	"FooBar. Program Manager 2017-2018. Collaborated with ..."

**Summarize** Leadership skills

Doc 1	This document is a resume for Riley Jones, ... , who has demonstrated leadership through roles at ...
Doc 2	This document is a resume for Parker Bond, ... , with some leadership skills through their position at ...

# Collection-centric information foraging via **actions**

Table of results, one row per document

**Ask** Each Document **Does this candidate have experience with ...**

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# Actions | Ask Each Document

## Document QA

Ask Each Document Does this candidate have experience with ...

Doc 1 Yes, this candidate has experience ...

Doc 2 No, this candidate does not have experience ...

Search programming experience

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Short, generated answers

Search Leadership skills

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# Actions | Search

**Ask** Each Document Does this candidate have experience with ...

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## Semantic and lexical search

**Search** programming experience

Doc 1	"experience with data analysis tools R, Python, and ..."
Doc 2	"Programming languages: Java, Python, SCALA, C++ ..."

**Summarize** Leadership skills → **Extracted**

Doc 1	This document is a resume for Riley Jones, ... , who has demonstrated leadership through roles at ...
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# Actions | Summarize

**Ask** Each Document Does this candidate have experience with ...

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**Summarize** Leadership skills

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Generated, with guidance

User-guided summarization

# Actions | Ask My Collection

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**Summarize** Leadership skills

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Generated, for synthesis

Extracted

Cross-document QA

# Computational notebook enables **lightweight exploration**

## Notebook View

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**Summarize** Leadership skills

Doc 1	This document is a resume for Riley Jones, ... , who has demonstrated leadership through roles at ...
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**Ask** My Collection **Which candidates have strong academic ...?**

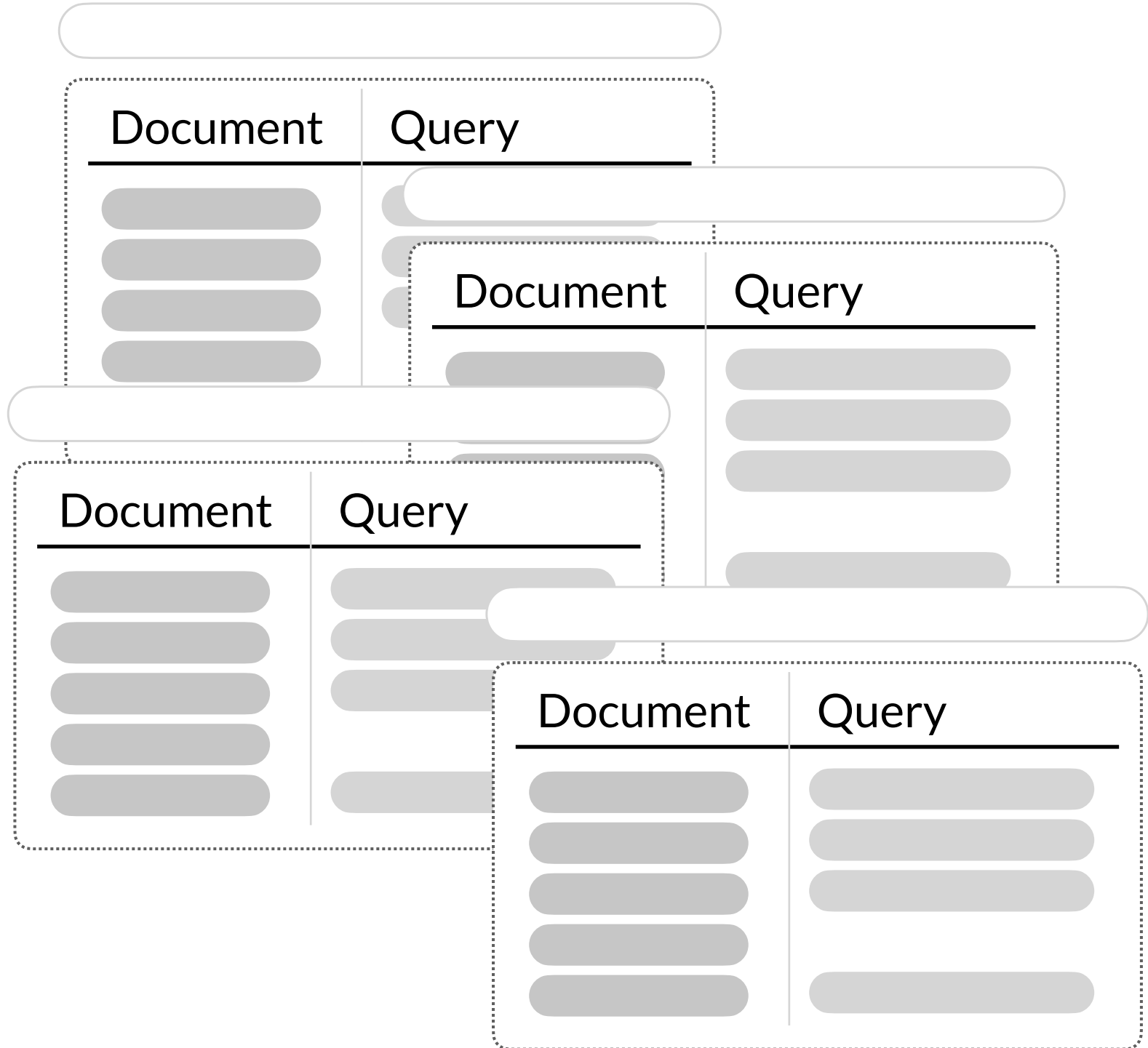
Suggest follow-up actions

Here are some suggested next steps:

- Ask** Has this candidate managed a team of engineers before?
- Search** database technology experience

# Aggregated result table provides information overview

## Table View




The screenshot shows a 'Table View' interface with a search bar and a list of results. The search bar contains the text 'fees' and 'termination clauses'. The results are displayed in a table format with columns for 'Filename' and 'Query'. The 'Filename' column contains the text 'Pristine\_ProClean'. The 'Query' column contains the text 'Client shall pay Contractor \$3,100 on the first day of each month for all services to be performed during the rest of that month, all fees and expenses included.' and 'III. Termination The Provider may terminate the Contract by giving to the Customer not less than 30 days' written notice of termination, expiring at the end of any calendar month.' and 'The Customer may terminate the Contract by giving to the Provider not less than 30 days' written notice of termination expiring at the end of any calendar month.' and 'Return of Property. Upon termination, all property provided by the Client, including but not limited to cleaning supplies,'.

Filename	Query
Pristine_ProClean	Client shall pay Contractor \$3,100 on the first day of each month for all services to be performed during the rest of that month, all fees and expenses included.
	III. Termination The Provider may terminate the Contract by giving to the Customer not less than 30 days' written notice of termination, expiring at the end of any calendar month.
	The Customer may terminate the Contract by giving to the Provider not less than 30 days' written notice of termination expiring at the end of any calendar month.
	Return of Property. Upon termination, all property provided by the Client, including but not limited to cleaning supplies,

# Deep linking to evidence supports verification

## Document View

 Ask Each Document Does this candidate have experience with ...

Doc 1	Yes, this candidate has experience with data modeling and statist...
Doc 2	No, this candidate does not have experience ...
Doc 3	
Doc 4	
Doc 5	

### EDUCATION

Expected 12/23 **NEW YORK UNIVERSITY** New York, NY  
The Courant Institute of Mathematical Sciences  
**M.S. in Mathematics in Finance**  
• *Expected Coursework:* stochastic calculus, time series analysis, scientific computing, risk and portfolio management, dynamic asset pricing, algorithmic trading, equity derivatives

08/16 - 06/20 **NANYANG TECHNOLOGICAL UNIVERSITY** Singapore  
**B.ENG. in Electrical and Electronic Engineering**  
• *Coursework:* linear algebra, probability & statistics, numerical methods, differential equations, data structure & algorithms, intelligent system design, business finance, accounting fundamentals  
• *Graduated with Honors (Highest Distinction)*

02/18 - 07/18 **ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE (EPFL)** Lausanne, Switzerland  
Semester Exchange  
• *Award:* Exchange Student Scholarship

### EXPERIENCE

09/20 - 07/22 **JPMORGAN CHASE & CO.** Singapore  
**Analyst, Software Engineer** (Asset and Wealth Management)  
• Created data-centric investment technology that facilitates portfolio management and trading decisions for private bank's internal investors and financial advisors  
• Contributed to development of new global strategic data framework that consolidates and processes data from all accounting systems, using big data, cloud, and automation technologies  
• Expanded portfolio analytics space with new features (e.g., trending trades analysis, large cash position indicator, overdraft alert, client service communication, morning briefs, trade idea feeds)  
• Developed an automated monitoring system for data pipelines, specializing in financial risk analysis. Now the central platform for international service-level agreement management.

06/19 - 08/19 **Summer Analyst, Software Engineer** (Corporate and Investment Banking)  
• Collaborated with London commodities team to develop new Python-based software for base metal post-trade customer information maintenance in firm's cross-asset platform, Athena  
• Accelerated legacy system decommissions, saving time and effort as well as reducing expenses

01/19 - 05/19 **ERNST & YOUNG SOLUTIONS LLP** Singapore  
**IT Advisory Intern**  
• Facilitated business design, implementation, and data migration of Sales & Distribution module in largest global SAP S/4HANA ERP project at EY Singapore in 2019 for client, DyStar Group  
• Conducted international localization workshops for franchises in 8 countries; communicated business demands with key stakeholders and produced requirement traceability matrices

### PROJECT

08/19 - 04/20 **NANYANG TECHNOLOGICAL UNIVERSITY** Singapore  
**Onboard 3D SLAM for AGV Localization** - With Delta Electronics, Inc. (C++, Linux)  
• Designed Simultaneous Localization and Mapping (SLAM) system for automated guided vehicles (AGVs), addressing dangers of human-robot collisions and human interference during robot positioning process in dynamic environments such as modern warehouses  
• Proposed human classifier in complex 3D point clouds utilizing anthropometric geometry and support vector machine model; implemented system with ROS in C++ in Linux environment

*Programming Languages:* Java, Python, SCALA, C++, SQL, Unix Shell  
*Languages:* English (fluent); Mandarin (native); Japanese and French (elementary)  
*Affiliations/Certifications:* Certified Financial Risk Manager (FRM); Passed CFA Exam Level II (November 2021)  
*Activities:* NTU Chinese Orchestra, Two-String Fiddle Performer (Singapore, Taipei); Singapore Marathon (2017, 2019)



## Document View

## Notebook View

## Table View

**Aegis Hygiene Group – Cleaning Services**

**Proposal for Services**  
 This Cleaning Service Agreement (hereinafter referred to as the "Agreement") shall stand effective on 10-10-2023 (hereinafter referred to as the "Effective Date"), by and between Aegis Hygiene Group (hereinafter referred to as the "Provider") with their principal place of business at 894 Miller Ave, San Mateo, CA and Acme, Inc. (hereinafter referred to as the "Client", and together with the Service Provider, the "Parties") situated in 72 Big Street, San Francisco, CA (hereinafter referred to as the "Client's Premise").

THEREFORE, the covenants and other mutual promises and agreements contained herein, the receipt and sufficiency of which are to be acknowledged hereby, the Parties agree to the terms and conditions as mentioned below.

**1. Scope of Work**  
 The following outlines the comprehensive scope of work for the provision of cleaning services by the Provider to the Client:

- a) **General Cleaning Services:** The Provider shall perform regular cleaning tasks to maintain the cleanliness and hygiene of the designated premises. This includes, but is not limited to, dusting, sweeping, mopping, vacuuming, and waste disposal in all designated areas.
- b) **Surface Cleaning:** The Provider shall clean and sanitize all surfaces, including countertops, desks, tables, windowsills, and other commonly used surfaces, ensuring a germ-free environment.
- c) **Restroom Sanitation:** The Provider shall thoroughly clean and sanitize restrooms, including toilets, sinks, mirrors, and fixtures. Restocking of essential supplies, such as soap, hand towels, and toilet paper, shall also be included.
- d) **Floor Care:** The Provider shall clean, vacuum, mop, and polish all types of flooring as appropriate, paying special attention to high-traffic areas and removing stains and spills.
- e) **Kitchen/Area Cleaning:** In areas with kitchen facilities, the Provider shall clean and sanitize countertops, appliances, sinks, and any communal eating areas, ensuring a clean and safe environment.
- f) **Dusting and Cobweb Removal:** Regular dusting of surfaces and removal of cobwebs from ceilings, corners, and high points shall be performed to maintain a

Drill down for details

What do you want to accomplish? Set Goal

Clear cells

Search what services are covered under this contract?

Filename	what services are covered under this contract?
Aegis_Hygiene_Group	<p>schedules, or additional services shall be detailed in a separate agreement or work order.</p> <p>This includes, but is not limited to, dusting, sweeping, mopping, vacuuming, and waste disposal in all designated areas.</p>
CrystalClear_Services	<p>The Contractor agrees to provide the following services: Carpet and upholstery cleaning Tile and grout cleaning Baseboard and molding cleaning</p> <p>Scope of Work: The Contractor shall provide comprehensive cleaning services as outlined in the following section which details the specific tasks, areas, and frequency of cleaning to be undertaken.</p> <p>This payment is inclusive of any charges related to equipment rental, liability insurance, and any other fees or materials necessary to complete the work.</p>

Forage across documents

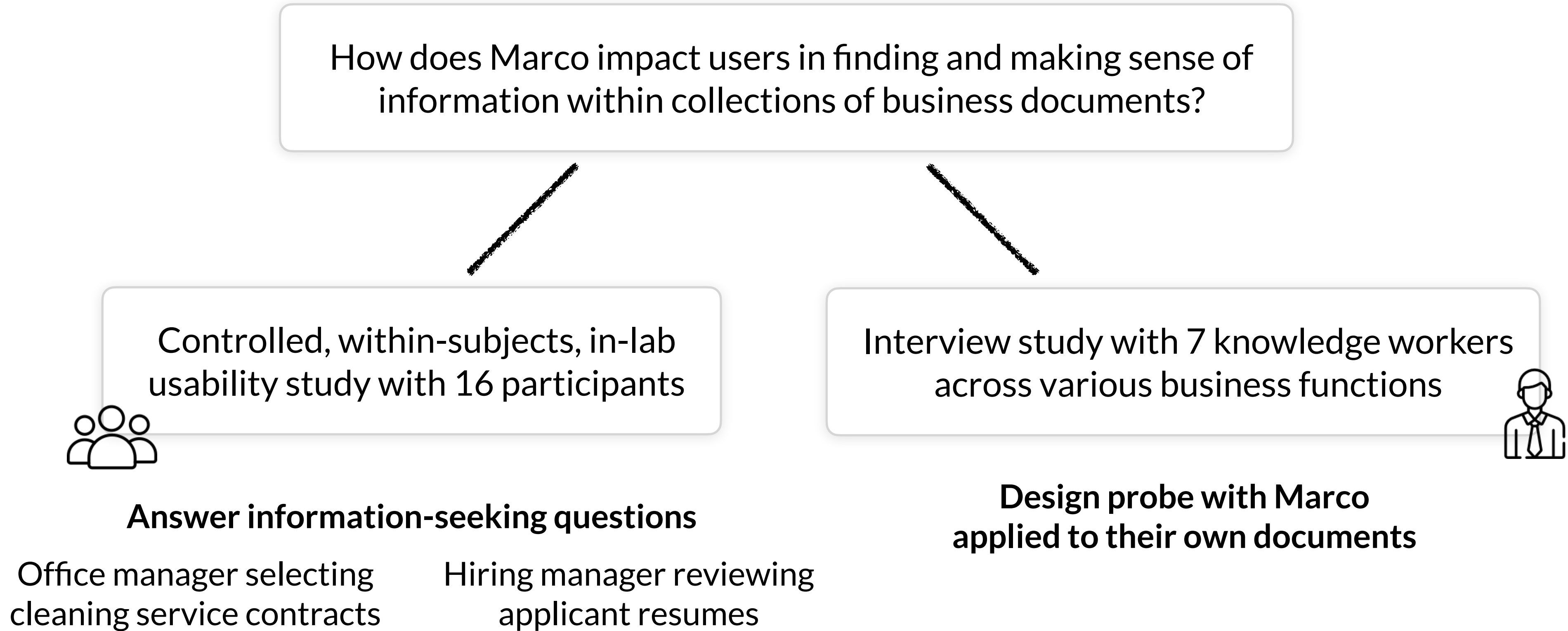
Search Enter search terms separated by a comma.

Filename	fees	termination clauses	what services are covered under this contract?
Pristine_ProClean	<p>Client shall pay Contractor \$3,100 on the first day of each month for all services to be performed during the rest of that month, all fees and expenses included.</p>	<p>III. Termination The Provider may terminate the Contract by giving to the Customer not less than 30 days' written notice of termination, expiring at the end of any calendar month.</p> <p>The Customer may terminate the Contract by giving to the Provider not less than 30 days' written notice of termination expiring at the end of any calendar month.</p>	<p>Services to be performed by Contractor include dusting and polishing of furniture and decorations; cleaning of bare floors, kitchen appliances, bathtub and/or shower stall, toilet, sinks, and water fixtures; vacuuming and steam cleaning of soiled carpets and rugs; cleaning of windows and mirrored surfaces; and removal of trash from interior trash containers to outdoor Dumpster or other disposal container located on Client's premises.</p> <p>The services covered under this contract include cleaning services such as vacuuming, washing, dusting, wiping, and scrubbing of various</p>
	<p>Return of Property. Upon termination, all property provided by the Client, including but not limited to cleaning supplies,</p>		

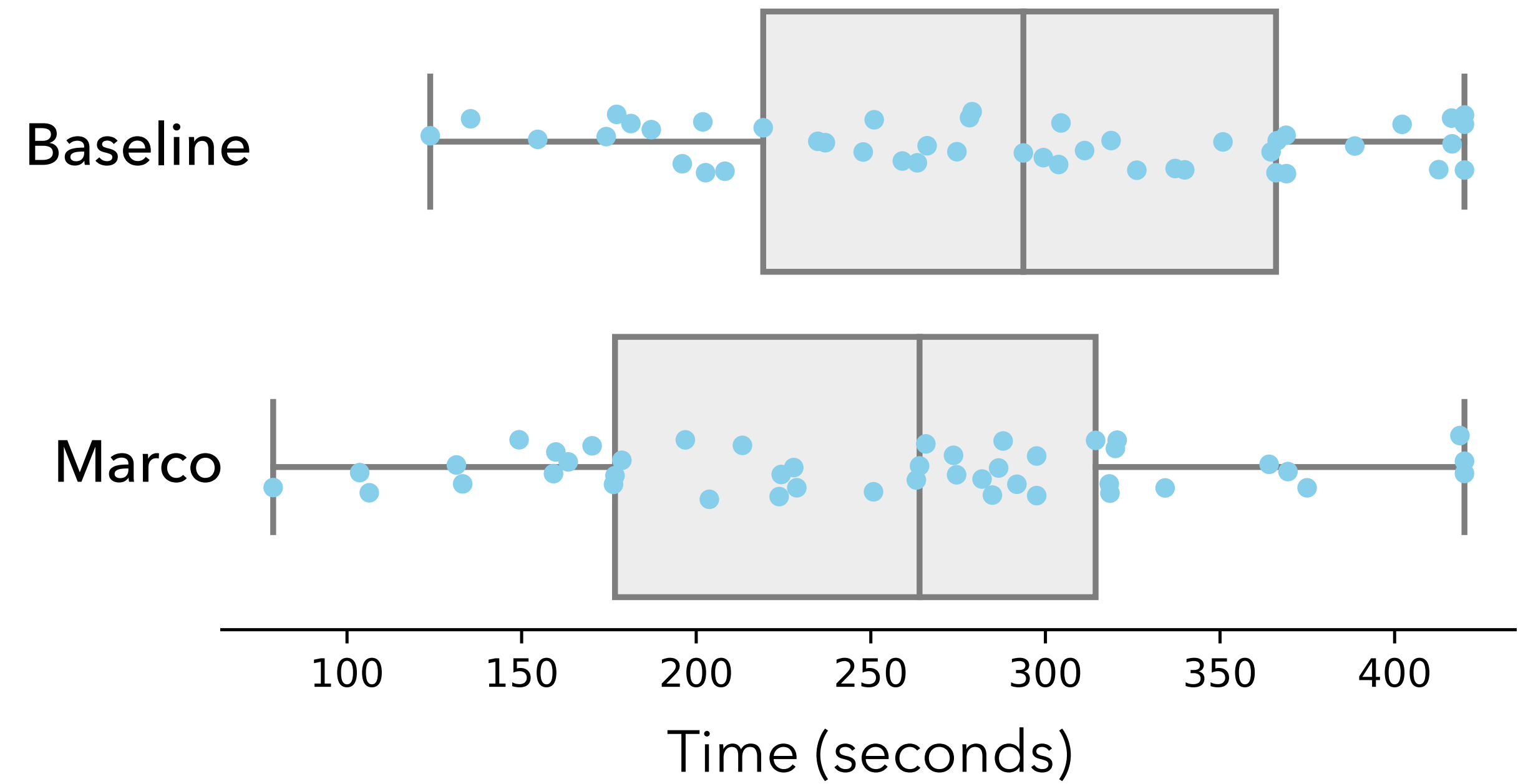
Analyze across collection



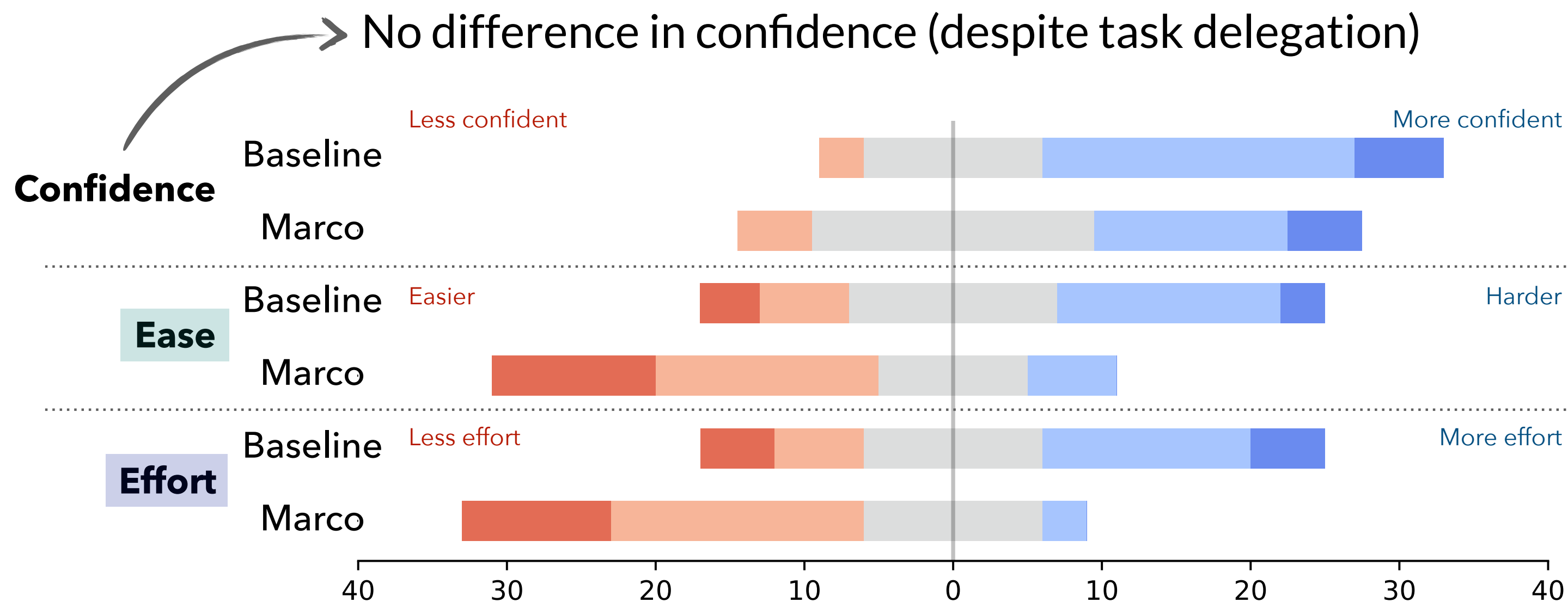
# User evaluation



Participants answered information seeking questions ~16% **more quickly** using Marco than the manual baseline.



Participants reported locating necessary information was easier and required less effort using Marco.



## Actions reflected and complemented participants' existing workflows.

*"I love the fact that it's all documents, each document, a custom set of documents that you want ... where you could choose. That's really important because that's how people are working."*

Participants liked in-context highlights and evidence, which provided an explanation for how the AI arrived at its conclusion and allowed verification.

*“This is perfectly transparent because it points us to exactly the language in the document and highlights it. The transparency is more so required whenever you're asking it to provide an analysis that may have some subjectivity to it.”*

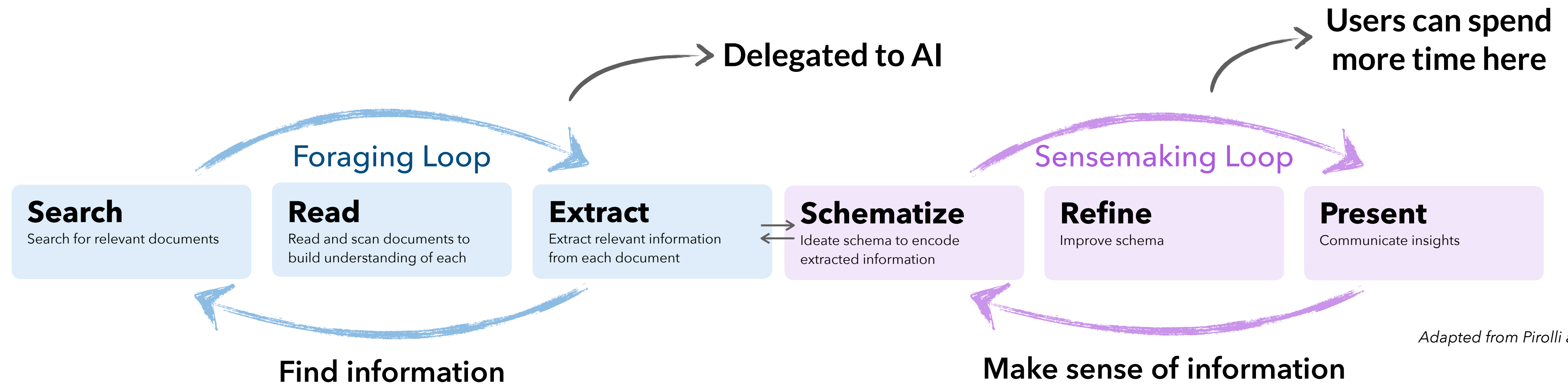
Imperfect AI was viewed as useful,  
especially since the alternative is manual.

*“Even if it's like not 100%, like even just  
catching stuff we might miss is valuable”*



## **AI viewed as coworker rather than replacement.**

Designing collaborative human-LLM systems (for knowledge work) involves effectively **communicating user goals, delegating tasks, and evaluating AI outputs.**



By delegating foraging to AI, users can retain control, leverage task expertise, and focus on higher-level sensemaking.





**Verification is critical** (in high-stakes contexts)

Supporting effective **evaluation of AI outputs at scale** is a new challenge.



# Supporting Business Document Workflows via Collection-Centric Information Foraging with Large Language Models

## Questions?

Raymond Fok @rayrayfok rayfok@cs.washington.edu  
University of Washington

Nedim Lipka, Tong Sun, Alexa Siu  
Adobe Research



Paper

The screenshot displays a document viewer interface with three distinct views:
 

- Document View:** Shows a full document page titled "Aegis Hygiene Group - Cleaning Services" with a search bar and navigation controls.
- Notebook View:** Shows a search interface with a search bar and a list of search results, including a snippet from a document.
- Table View:** Shows a table of search results with columns for filename, content, and other metadata.

Below the views are three callout boxes:
 

- Drill down for details:** Corresponds to the Document View.
- Forage across documents:** Corresponds to the Notebook View.
- Collate across collection:** Corresponds to the Table View.

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