

Table Extraction via Eye Gaze Tracking

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Agenda

- ❑ Project Motivation and Objective
- ❑ Methodology
- ❑ Datasets
- ❑ Data Exploration and Insights
- ❑ Implementation
 - ❑ Baseline Solution
 - ❑ Advanced Solution
- ❑ Conclusion
- ❑ Future Work

An aerial photograph of a city grid, viewed from a high angle. The streets are arranged in a regular pattern, with yellow lines forming a grid and green lines forming a secondary grid. The background is a dark, textured surface, possibly a map or a satellite image. The text "Project Motivation and Objective" is overlaid in white, bold, sans-serif font, centered horizontally and slightly above the vertical center.

Project Motivation and Objective

Project Motivation

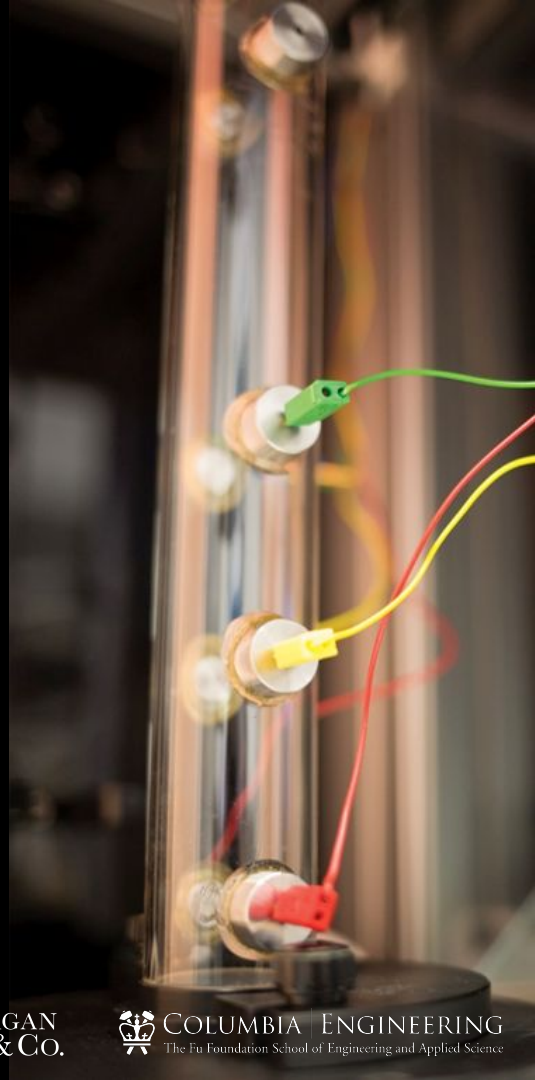
Why is table extraction important?

- Drastically increasing use of tabular data
- Needs for efficient workflow and smooth knowledge sharing throughout the business

Consider a use case scenario?

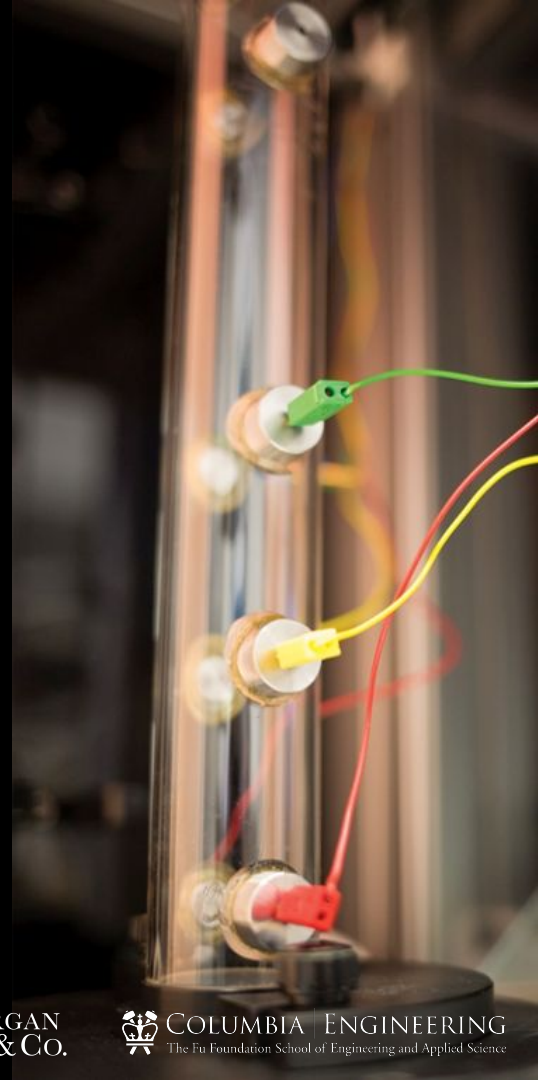
Why bring in eye gaze tracking?

- For documents with multiple tables, current table extraction solutions cannot distinguish which table is of user's interest
- Eye tracker knows where your attention is on



Objective

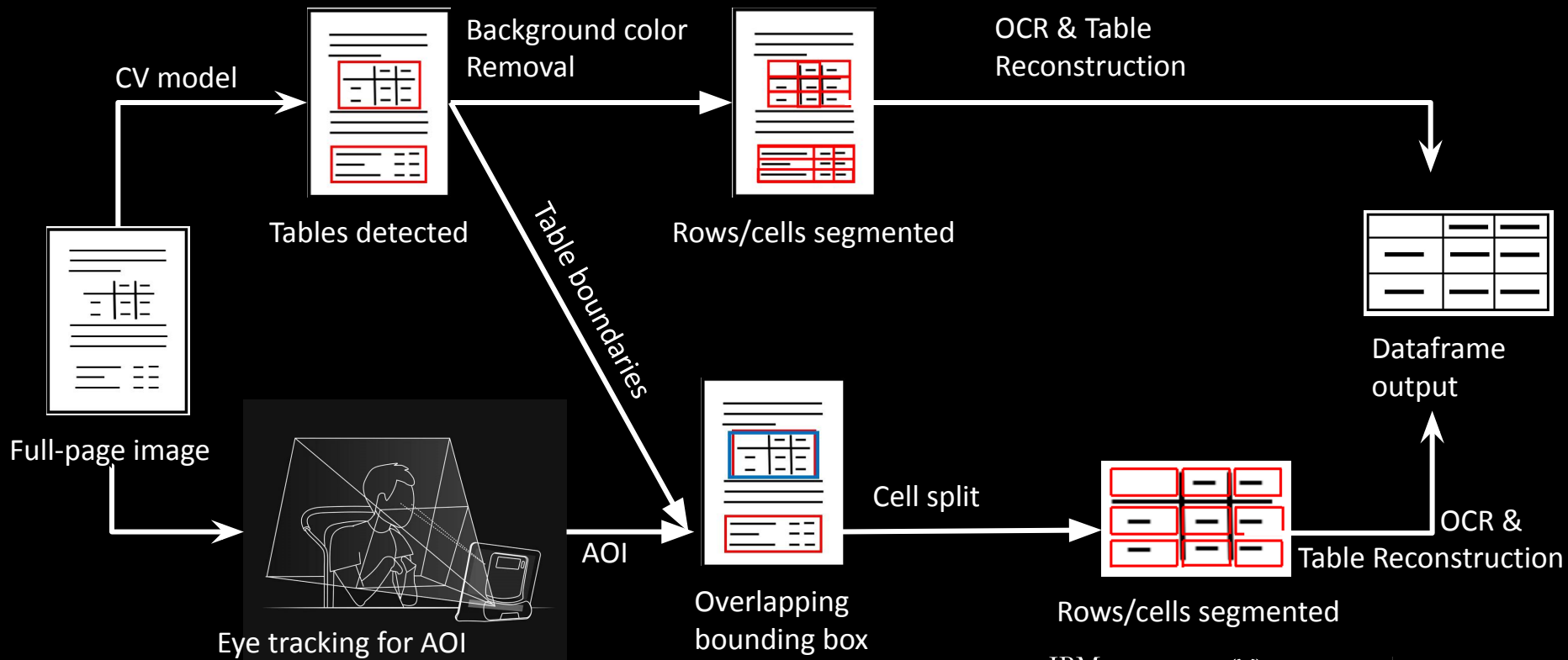
- Leveraging eye gaze technology and Computer Vision (CV) to design a system that automatically detects tables from an image
- Extracting texts from tables with the Optical Character Recognition (OCR) engine Tesseract



An aerial photograph of a city grid, likely New York City, viewed from a high angle. The image is overlaid with a grid of yellow and green lines. The yellow lines form a dense grid, while the green lines form a sparser grid. The word "Methodology" is written in white text on the left side of the image.

Methodology

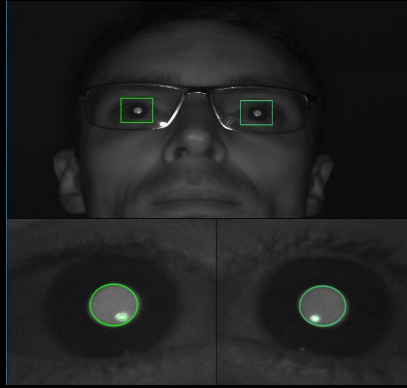
Flow Chart of pygazeTE



An aerial photograph of a city grid, likely New York City, showing a dense network of streets. The image is overlaid with a grid of yellow and green lines, suggesting a data visualization or a map overlay. The word "Datasets" is written in white text on the left side of the image.

Datasets

Eye Gaze Data



- Designed a **webcam-based eye tracking experiment** in Python using Gazepoint's eye tracker GP3 and the open-source toolbox PyGaze
- Instructions would lead the participant to calibrate the device, then a number of images would be displayed on the screen for 10 seconds each.
- Eye movements are recorded and used to identify eye movements and areas of interest (AOIs).

Public Data: FinTabNet

- **Source:** IBM's open source dataset
- **Format:** PDF (documents), JSON (annotations)
- **Size:** 16 GB
- **Data coverage:** about 90k pages of earnings reports from S&P 500 companies with cell annotations
- **Description:** We used the **2,000** documents images using `pdf2img` for modeling.
- **Challenges:** borderless, tight rows

dates through 2048. We leased 9% of our total aircraft fleet under operating leases as of May 31, 2017 and 10% as of May 31, 2016. A portion of our supplemental aircraft are leased by us under agreements that provide for cancellation upon 30 days' notice. Our leased facilities include national, regional and metropolitan sorting facilities, retail facilities and administrative buildings.

Rent expense under operating leases for the years ended May 31 was as follows (in millions):

	2017	2016	2015
Operating leases	\$1,144	\$1,044	\$944
Other	25	25	25
Total	\$1,169	\$1,069	\$969

(1) Component results are based on equipment usage.

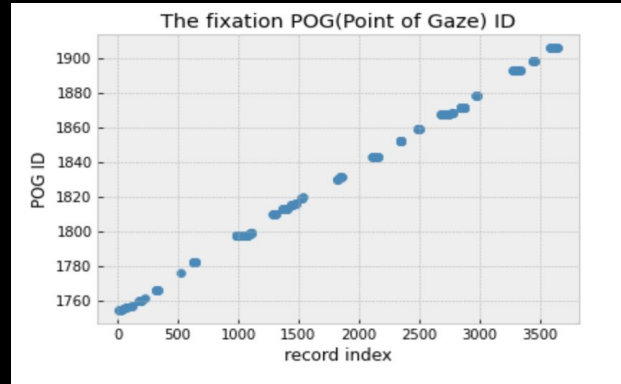
A summary of future minimum lease payments under noncancelable operating leases with an initial or remaining term in excess of one year at May 31, 2017 is as follows (in millions):

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007	3008	3009	3010	3011	3012	3013	3014	3015	3016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An aerial photograph of a city grid, viewed from a high angle. The streets are represented by a network of lines. A prominent set of yellow lines runs diagonally from the bottom-left towards the top-right. Another set of green lines runs diagonally from the top-left towards the bottom-right. These two sets of lines intersect to form a grid pattern. The background is a dark, textured surface, possibly a map or a satellite image, with various small, colorful shapes scattered throughout, including some yellow and green circular patterns.

Data Exploration and Insights

Data Exploration and Insights

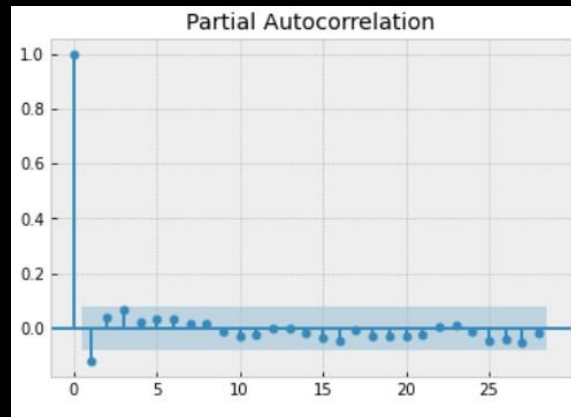


- **Critical impact of calibration accuracy**
- **Consistency of missing value:** Some data were missed during regular blinking. *The frequency of blinking = total time / counts of blinking.* On average, we found blinks happen every 2.5 seconds and each lasted about 0.3 seconds.

Data Exploration and Insights

Classification at April 27, 2018

(in million)	Valuation				Balance Sheet Classification	
	Cost	Unrealized Gains	Unrealized Losses	Fair Value	Investments	Other Assets
Available-for-sale securities						
Level 1:						
U.S. government securities	\$ 732	\$ —	\$ (26)	\$ 706	\$ 706	\$ —
Marketable equity securities	83	88	—	162	—	162
Total Level 1	815	88	(26)	867	706	162
Level 2:						
Corporate debt securities	1,422	162	(16)	1,568	—	—
U.S. government and agency securities	764	782	(76)	1,470	—	—
Mortgage-backed securities	1,127	127	(127)	1,127	613	—
Non-U.S. government and agency securities	—	—	—	73	73	—
Other asset-backed securities	349	—	(2)	356	356	—
Debt funds	299	—	(354)	585	585	—
Total Level 2	6,923	22	(290)	6,655	6,633	—
Level 3:						
Auction rate securities	47	—	(3)	44	—	44
Total Level 3	47	—	(3)	44	—	44
Investments measured at net asset value⁽¹⁾						
Debt funds	199	—	(2)	197	197	—

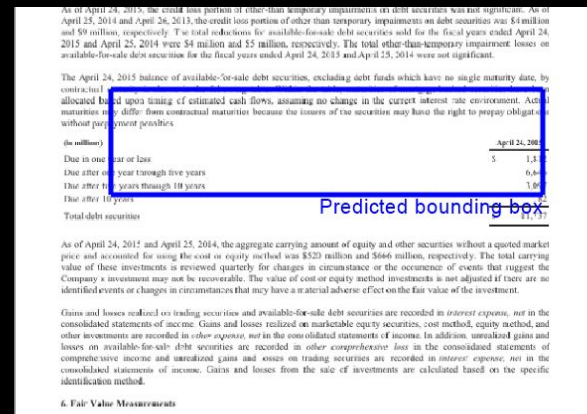
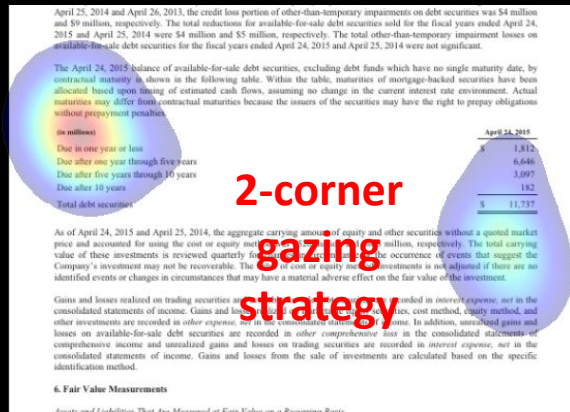
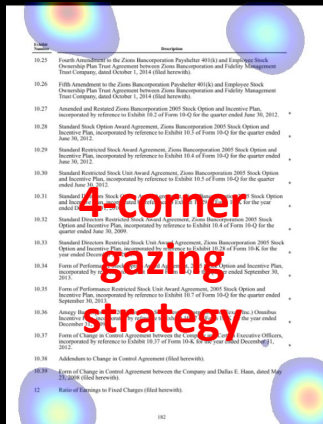


- **Difference of reading patterns:** reading habits differ from person to person.
- **Time Series analysis:** eye movements can be potentially predicted with ARIMA(0,1,1) model

Implementation

A high-magnification, angled photograph of a silicon microchip. The chip's surface is covered with a complex pattern of circuitry, including various sized rectangular blocks, lines, and circular features. A grid of thin, glowing green lines is superimposed over the chip, creating a perspective of depth. The lighting is dramatic, with a warm orange glow on the left side and a cooler greenish-blue glow on the right, highlighting the intricate details of the semiconductor technology.

Baseline solution: Eye gaze only



Fixation density maps

Predicted bounding box

Idea: Crop a bounding box by capturing corners of a table via DBSCAN clustering

Gaze strategy attempts:

1. Four-corner: all corners of the table, 2 seconds each
2. Two-corner: only the *upper left* and the *bottom right* corners, 5 seconds each

pygazeTE: Eye gaze + CV + OCR

Schedule 6 presents a comparison of the major components of noninterest expense for the past three years.

table 0.91 (507, 134)

	2014	Percent change	2013	Percent change	2012
Salaries and employee benefits	\$ 896.4	4.9%	\$ 912.9	3.1%	\$ 883.7
Occupancy, net	115.3	8.2	112.3	(6.5)	122.9
Furniture, equipment and software	115.3	8.2	106.4	(2.3)	109.9
Other real estate expense	(1.2)	(78.6)	3.5	(91.4)	30.9
Goodwill-related expense	28.0	(16.7)	33.6	(5.5)	36.1
Provisions for unfunded liability commitments	(8.6)	(6.7)	(1.1)	(488.6)	4.4
Professional and legal services	66.0	(2.9)	68.0	26.5	53.7
Advertising	28.1	7.3	23.4	(8.9)	25.7
FDIC premiums	12.2	(15.3)	36.8	(12.4)	42.4
Amortization of core deposit and other intangibles	10.9	(24.3)	14.4	(13.3)	17.0
Other compensation cost	44.4	(61.1)	120.7	9.2	110.7
Total	\$ 1,483.7	(2.9)	\$ 1,514.4	5.4	\$ 1,376.8

(507, 336)

Salaries and employee benefits increased by 4.9% in 2014 compared to 2013, driven by a higher amount of salaries and bonuses. The increase in base salaries resulted, in part, from increased headcount related to the Company's major system projects and build-out of its enterprise risk management and stress testing functions, partially offset by reductions elsewhere. Staff involved in these projects tend to be in more highly compensated roles than positions in which reductions occurred. As June 30, 2014, the Company's headcount had increased to 10,536 full-time equivalent ("FTE") employees from 10,452 as of December 31, 2013. During the third quarter of 2014, the Company incurred severance costs of approximately \$5 million and reduced FTE employees to 10,462 as of December 31, 2014.

Salaries and employee benefits increased by 3.1% during 2013. Most of the increase can be attributed to higher base salaries and bonuses, which were partially offset by decreased share-based compensation and lower retirement expense.

Salaries and employee benefits are shown in greater detail in Schedule 7.

table 0.90 (542, 567)

	2014	Percent change	2013	Percent change	2012
Other income in millions	\$ 814.2	5.3%	\$ 773.4	5.7%	\$ 745.7
Salaries and bonuses	55.9	10.2	49.6	6.6	46.4
Employee benefits	15.4	(10.3)	17.0	(4.4)	17.8
Provision for unfunded liability commitments	(8.6)	(6.7)	(1.1)	(488.6)	4.4
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(542, 712)

Full-time equivalent ("FTE") employees at December 31:

2014	10,536
2013	10,452
2012	10,368

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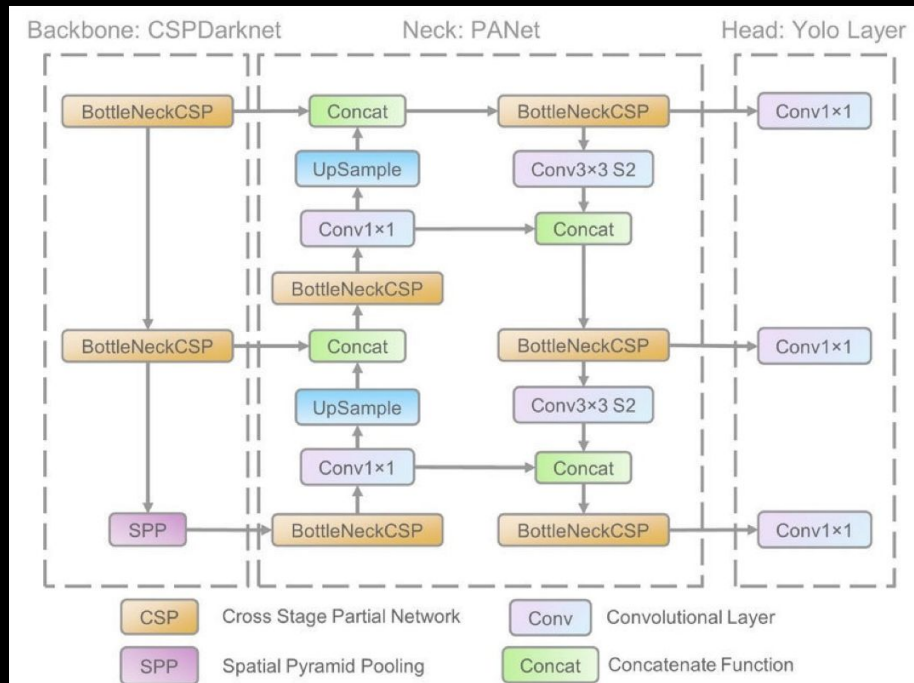
Density of fixations: 59.84%

Idea: Use more precise CV and OCR models to first identify table boundaries and texts, and then use eye fixations to determine the table of interest.

- **YOLO-v5:** table boundaries prediction
- **Tesseract:** text recognition
- **Pygaze:** AOI prediction

Gaze strategy: Center-focused

Table Detection by Transfer Learning (CV Model)



- **Backbone:** CSP Darknet
- **Neck:** PANet
- **Head:** Yolo layer
- Data are first input to CSP Darknet for feature extraction.
- Then fed to PANet for feature fusion.
- Finally, Yolo Layer outputs detection results (class, score, location, size).

Source:

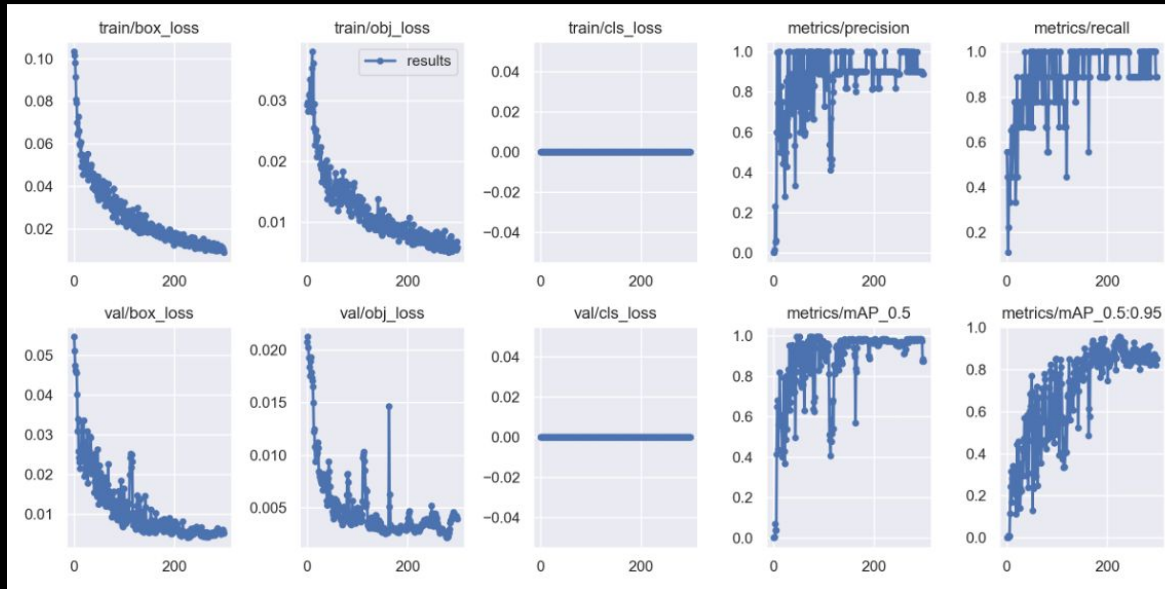
https://www.researchgate.net/figure/The-network-architecture-of-Yolov5-It-consists-of-three-parts-1-Backbone-CSPDarknet_fig1_349299852

CV Model

1. Train

Trained using **Yolov5x.pt** pretrained weights for 300 epochs, on 80 annotated images and tested on 20 images with the mAP of 0.824.

- As the object category in this experiment is only table, the classification loss is 0.



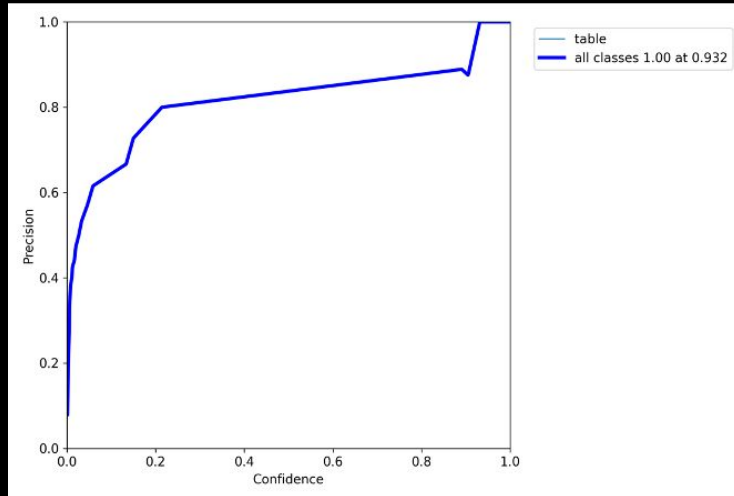
CV Model

2. Evaluate

Total Loss = Classification Loss + Localization Loss + Confidence Loss

- Classification Loss : 0.0
- Localization Loss : 0.005
- Confidence loss : 0.004

The P-Curve shows that the model has a high confidence on detecting a table with high precision in the test set.

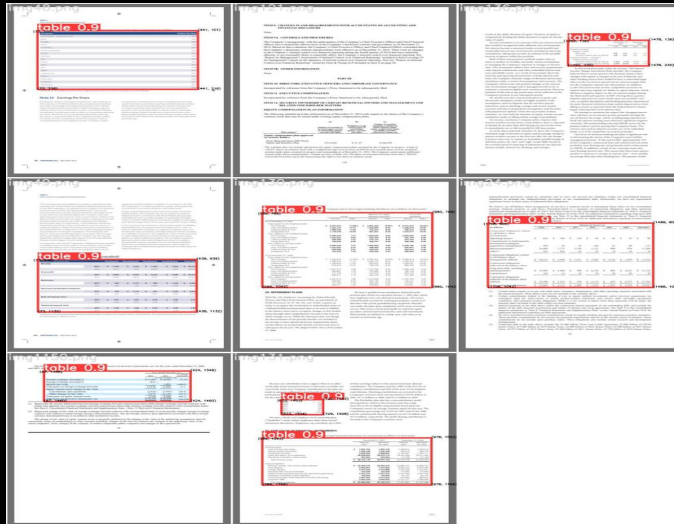


CV Model

3. Output

Given document images as input, the model will :

- detect all tables with confidence scores
- crop each table with its coordinates



	Fiscal Year		
	2014	2015	2014
(in millions, except per share data)			
Net sales	\$ 28,833	\$ 20,261	\$ 17,005
Costs and expenses:			
Cost of products sold	9,142	6,309	4,333
Research and development expense	2,224	1,640	1,477
Selling, general, and administrative expense	9,409	8,904	5,847
Special charges (gains), net	70	(18)	40
Restructuring charges, net	290	237	78
Certain litigation charges, net	26	42	770
Acquisition-related items	243	550	117
Amortization of intangible assets	1,931	733	349
Other expense, net	107	118	181
Operating profit	5,291	3,766	3,813
Interest income	(431)	(386)	(271)
Interest expense	1,386	666	379
Interest expense, net	955	280	108
Income from operations before income taxes	4,336	3,486	3,705
Provision for income taxes	798	811	640
Net income	\$ 3,538	\$ 2,675	\$ 3,065
Basic earnings per share	\$ 2.51	\$ 2.44	\$ 3.06
Diluted earnings per share	\$ 2.48	\$ 2.41	\$ 3.02
Basic weighted average shares outstanding	1,409.6	1,095.5	1,002.1
Diluted weighted average shares outstanding	1,425.9	1,109.0	1,013.6
Cash dividends declared per ordinary share	\$ 1.52	\$ 1.22	\$ 1.12

p 0.507949 0.336025 0.799682 0.458385

OCR Model: Tesseract

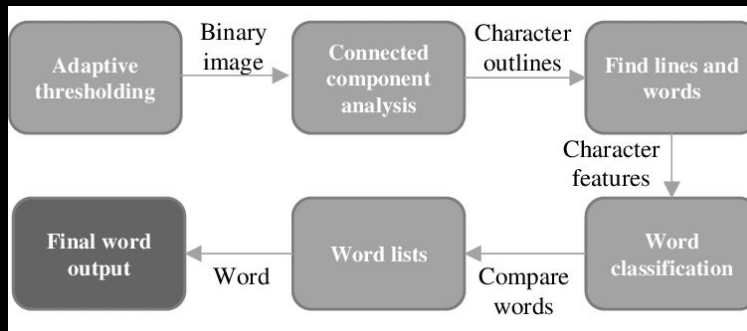
1. Train

Trained using Tesseract with annotated images of 2000 tables, based on English-language pretrained model

- method: single-line page segmentation([psm=7](#))
- datasize: 12.8k
- input: cropped single-cell images of each table
- output: retrained language model *fintabnet_full.traineddata*



Tesseract OCR



OCR Model

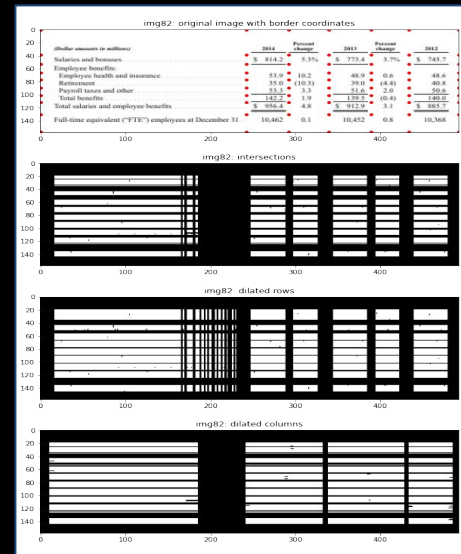
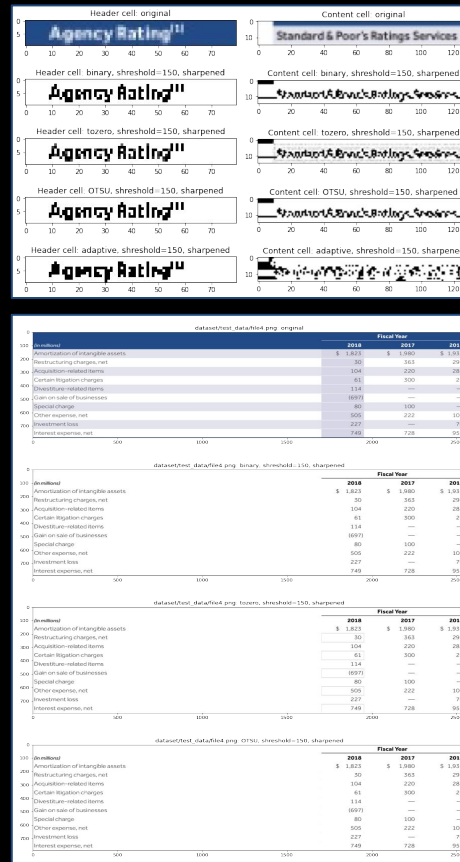
2. Preprocessing

Problems for prediction:

- headers with darker background colors are hard to recognize
- recognizing the whole table is harder than recognizing each cell

Solution:

- background removal
- reconstruct table structure, then separate each cell
- implemented using OpenCV



reconstructing table structure, drawing borders and separating cells

comparisons among background removal methods, for single cell and the entire table

OCR Model: Tesseract

3. Predict

Our OCR predictor supports two modes:

(1) **Table mode:** recognize the entire table, output all text with built-in table structure ([psm](#)=6 or 12)

- faster, preserves row-column table structures

(2) **Cell mode:** recognize text per cell, then reconstruct table structure ([psm](#)=7)

- more accurate, preserves row structures

Raw			
In millions	Fiscal Year		
	2018	2017	2016
Amortization of intangible assets	\$ 1,823	\$ 1,980	\$ 1,931
Restructuring charges, net	30	363	290
Acquisition-related items	104	220	283
Certain litigation charges	61	300	26
Divestiture-related items	114	—	—
Gain on sale of businesses	(697)	—	—
Special charge	80	100	—
Other expense, net	505	222	107
Investment loss	227	—	70
Interest expense, net	749	728	955

Processed			
In millions	Fiscal Year		
	2018	2017	2016
Amortization of intangible assets	\$ 1,823	\$ 1,980	\$ 1,931
Restructuring charges, net	30	363	290
Acquisition-related items	104	220	283
Certain litigation charges	61	300	26
Divestiture-related items	114	—	—
Gain on sale of businesses	(697)	—	—
Special charge	80	100	—
Other expense, net	505	222	107
Investment loss	227	—	70
Interest expense, net	749	728	955

Fiscal Year

(in millions) 2018 2017 2016

Amortization of intangible assets \$1,823 \$1,980 \$1,931

Restructuring charges, net 30 363 290

Acquisition-related items 104 220 283

Certain litigation charges 61 300 26

Divestiture-related items 114 — —

Gain on sale of businesses (697) — —

Special charge 80 100 —

Other expense, net 505 222 107

Investment loss 227 — 70

Interest expense, net 749 728 955

OCR Model: Tesseract

4. Evaluate

- Evaluated using 1.2k single-line images of table cells (10% of the entire dataset)
- Metrics:
 - Character Error Rate (CER)
 - Word Error Rate (WER)
 - Accuracy

$$CER = (S+D+I)/N$$

$$WER = (S_w + D_w + I_w) / N_w$$

where:

S = Number of Substitutions

D = Number of Deletions

I = Number of Insertions

N = Number of characters in reference text
(aka ground truth)

$$Accuracy = (1-WER) * 100\%$$

Mode	Structured text (psm 6)	Unstructured text (psm 12)	Single-line (psm 7)
Train Acc.	-	-	98.4%
Test Acc.	97.0%	97.7%	98.9%

Time Comparison

- Average time spent based on 4 images per trial (includes response wait time) :

		Eye gaze	Eye gaze +CV+OCR
Mean time		4.5 min	3.5 min
Time decomposition	Model prediction	/	13 sec
	Initiation	70 sec	70 sec
	Calibration	70 sec	30 sec
	Experiment	130 sec	90 sec
	Preprocessing	0.67 sec	0.06 sec
	AOI prediction	0.06 sec	0.01 sec

Note: Initiation time doesn't vary with # images; each calibration attempt takes about 30s; experiment time fluctuates with fixation data validity; other time components are linear varying with # images

An aerial photograph of a city street grid. The streets are mostly dark, but a series of yellow lines highlights a specific set of streets running diagonally from the top-left towards the bottom-right. Another set of green lines highlights a different set of streets, also running diagonally but in a slightly different orientation. The overall image has a dark, almost black, background with the highlighted streets providing a strong contrast.

Conclusion

Conclusion

- Implemented transfer learning to develop a YOLOv5 object detection model and a Tesseract OCR model to identify tables in a document and recognize texts
- Designed an end-to-end table extraction pipeline to automatically extract the table in AOI based on eye fixations, and returns it in tabular format.
- Built a Python package `pygazeTE`, wrapping up all functions used in the project for preprocessing, visualizing, and predicting. More information can be found in the repo: <https://github.com/ybliu9/pygazeTE>

An aerial photograph of a city grid, likely New York City, viewed from a high angle. The image is overlaid with a grid of yellow and green lines, which appear to be digital overlays on the physical streets. The yellow lines form a primary grid, while the green lines form a secondary, slightly offset grid. The text "Future Work" is overlaid in white on the left side of the image.

Future Work

Future Work

- **Eye gaze data quality improvements:** The accuracy of eye gaze data was unstable caused by calibration inaccuracy and trivial posture changes. Improving eye gaze validation would lead to more consistent results.
- **Generalization to more diverse tables:** Our current solution was not tested on unstructured tables or tables with multi-level headers.
- **Deep learning methods for table structure:** We used OpenCV's image processing techniques to recognize table structures, but DL solutions would allow training and tuning to provide more flexible and accurate results.

Thanks for listening!