Implementing a Work Analysis Recommender System

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Definitions & Background

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Defining the Enterprise

Goals

1. Describe occupations, jobs, or roles in a way that augments work analysis procedures and guides human resources initiatives
2. Estimate relevance of descriptors for a given occupation, job, or role
3. Complete #1 and #2 in a manner that is quick, useful, and low expense

Guiding Question

How can we use Artificial Intelligence (AI) concepts to produce credible job analysis information?

- Recommender systems are one approach

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Utility: Does Your Work Involve the Following Tasks?

Today's Emphasized Capabilities

- Identifying competencies and tasks for subsequent review by subject matter experts
- Tagging relevant predefined competencies or tasks to a position description or job announcement
- Linking competencies to tasks (or vice versa)
- Crosswalking competency models
- Identifying occupational classifications, and related occupations, based on text narratives

Related Procedural Capabilities

- Estimating (numerically) the job relevance of predefined work descriptors for positions/roles
- Summarizing text into core points or themes (e.g., identifying new skills; analyzing comments)
- Identifying passages of job materials related to a technical competency when developing items
- Estimating (numeric) scores from written constructed responses

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What do we mean by "AI" in this case?

Generalized Application in Human Resources/People Analytics

- Organizing and summarizing existing information
  - Natural language processing
  - Unsupervised dimensional/structural analysis

- Estimating similarity between quantitative data elements
  - Related to, but distinct from, supervised learning

- This project entails extensions of classical multivariate statistics…*we are not talking about autonomous reinforcement learning or generative AI in this case*

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Background on AI/ML in Job Analysis Method 1

- Prediction system
  - Enables automatic estimation of quantitative knowledge, skill, or ability (KSAO) ratings given narrative text input describing a job
  - Requires a starting database containing high-quality occupational text and ratings on KSAOs of interest
  - The Occupational Information Network (O*NET) provides a suitable database; this focuses results/output on O*NET KSAOs
  - Key references: Putka et al. (2022); Mracek et al. (2021); Schmerling (2020)

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Background on AI/ML in Job Analysis Method 2

- Recommendation system
  - Enables automatic identification of relevant output content given input content of interest
  - Input examples: job descriptions / competencies / KSAOs / task statements
  - Output examples: competencies / KSAOs / task statements / related occupations
  - Quite flexible: accommodates differing taxonomies of output content

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Building a Work Analysis Recommendation System

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What is a Recommender System?

- Given a starting universe of content, intent is to produce the most relevant or applicable portions of that universe when presented with a new user input (or instance of content)

- Content-based systems profile sets of input on common attributes
  o Set 1: Content from which the system designer wants to draw suggestions
  o Set 2: Instance(s) of content for which recommendations from Set 1 are desired

- Familiar uses: video streaming; online shopping

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Common Work Analysis Procedures

1. **Review of relevant documentation (often in narrative form)**
2. **Development or identification of draft descriptor lists**
3. Facilitation of job expert workshops/interviews
4. Distribution and analysis of questionnaires
5. **Establishment of links between work and person descriptors**

Recommender systems could be relevant for steps 1, 2, & 5

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Development Steps

1. Develop a language model to represent text numerically (alternatively, leverage pretrained language models)

2. Identify new text describing the job, role, or work element we would like to understand (e.g., position descriptions, job announcements)

3. Identify a desired set of competencies, tasks, or occupations on which to profile the input job descriptive text

4. Create profiles of the text from steps #2 and #3 in terms of the language model derived in #1; commonalities based on the language model are key

5. Combine the profiles from #4 and use a profile similarity algorithm to ascertain degrees of match

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Step 1: Focus on Custom Embeddings

1. Import text input

2. Preprocess the input

3. Create a unigram term co-occurrence matrix (TCM)

4. Calculate embeddings via a latent Dirichlet allocation on the TCM

Many analytic choices – and additional work could supplement with pretrained models

Input: Developing Embeddings

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    Tasks (n = 1448)
    Competencies (n = 326)

O*NET
    Occupation Descriptions (n = 967)
    KSAO Descriptions (n = 162)
    General Work Activities (n= 41)
    Intermediate Work Activities (n = 332)
    Detailed Work Activities (n = 2067)
    Tasks + Emerging Tasks (n ~ 19500)

Step 1: Representing Text as Custom Embeddings

tool _ hand _ machine	service _ provide _ activity	develop _ plan _ test	efficiency _ environmental _ energy	fitness _ event _ promote
hand	service	develop	efficiency	fitness
tool	provide	design	increase	encourage
power	monitor	maintain	improve	subordinate
machine	ensure	prepare	maximize	instruct
part	include	plan	minimize	volunteer
equipment	program	program	effectiveness	donation
--	work	--	organizational	participation

Step 2: Identify the Text of Job Analysis Interest

- Job group illustrations
  - 60 JOAs randomly selected from those live in mid-June on USAJOBS.gov
    - 20 Information Technology (2210 series)
    - 20 Accounting/Finance (0510 series)
    - 20 Human Resources (0201 series)
  - Extracted major duties sections
    - Prior to random selection, removed JOAs if: <30 words; public notice of future JOA
  - Analyzed each job family as a concatenated string across JOAs
    - 3 separate focal analyses: IT, Finance, & HR

- Task—Competency linkage illustrations

Step 3: Identify Attributes to Recommend

- Tasks
  - O*NET detailed work activities (n = 2,067)
  - MOSAIC tasks (n = 1448)

- Competencies
  - MOSAIC technical and leadership competencies (n = 252)
  - MOSAIC/FWCI general competencies (n = 32)

- Occupations
  - Federal occupational series (n = 375)
  - O*NET occupations (n = 967)

Step 4: Generate Quantitative Profiles

"Set Two" Text (from Step 2)	Var$_1$ tool _ hand _ machine	Var$_2$ service _ provide _ activity	Var$_3$ develop _ plan _ test	Var$_4$ efficiency _ environmental _ energy	…Var$_k$
Job descriptive text	#	#	#	#	#

"Set One" Text (from Step 3)	Var$_1$ tool _ hand _ machine	Var$_2$ service _ provide _ activity	Var$_3$ develop _ plan _ test	Var$_4$ efficiency _ environmental _ energy	…Var$_k$
Descriptor 1	#	#	#	#	#
Descriptor 2	#	#	#	#	#
Descriptor 3	#	#	#	#	#
Descriptor k	#	#	#	#	#

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Step 5: Ascertain Profile Similarity

Text	Var$_1$ tool _ hand _ Machine	Var$_2$ service _ provide _ activity	Var$_3$ develop _ plan _ test	Var$_4$ efficiency _ environmental _ energy	…Var$_k$
Job descriptive text	#	#	#	#	#
Descriptor 2 (1st rank)	#	#	#	#	#
Descriptor 1 (2nd rank)	#	#	#	#	#
Descriptor 3 (3rd rank)	#	#	#	#	#
Descriptor k (kth rank)	#	#	#	#	#

In this step, a similarity coefficient determines which attributes appear most relevant to the job descriptive text.

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Questions of Interest

1. Does the recommender system suggest tailored and applicable:
   o Technical competencies?
   o General competencies?
   o Tasks/work activities?
   o Related occupations?

2. Do the recommended competencies & tasks differentiate between occupations?

3. Do these methods hold promise for establishing task—competency links?

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Illustrative Results
Custom Embedding Approach

Note: Results are presented without the curation that would be a next step in an applied project.

Top MOSAIC Technical Competencies

2210: IT	0510: Accounting/Finance	0201: HR
Information Systems/Network Security	Accounting Operations	Managing Human Resources
Technology Awareness	Principles of Accounting	HR Information Systems
Information Technology Program Management	Economics and Accounting	Recruitment/Placement
Information Systems Security Certification	Financial Systems	Classification
Managing Human Resources	Accounting	Personnel and Human Resources
Configuration Management	Financial Management (*)	Employee Development
Information Resources Strategy and Planning	Principles of Finance	Developing Others
Project Management	Cost Accounting	Human Capital Management
Systems Life Cycle	Financial Management (‡)	Information Technology Program Management
Financial Management (*)	Control of Funds	Employee Benefits

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Top FWCI General Competencies

2210: IT	0510: Accounting/Finance	0201: HR
Organizational Awareness	Organizational Awareness	Customer Service
Technology Application	Information Management	Organizational Awareness
Planning and Evaluating	Project Management	Planning and Evaluating
Information Management	Oral Communication	Project Management
Customer Service	Customer Service	Information Management
Project Management	Planning and Evaluating	Digital Collaboration
Technical Competence	Technical Competence	Technical Competence
Self-Management	Technology Application	Decision Making
Digital Collaboration	Creative Thinking	Teaching Others
Learning	Self-Management	Self-Management

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Top MOSAIC Tasks: Information Technology

2210: IT
Develops or implements information systems security plans and procedures.
Develops, modifies, or provides input on plans, goals, or objectives (for example, strategic plans, work breakdown structures,   integration plans) for projects, programs, systems, or operations.
Develops, modifies, or provides input on plans, goals, or objectives for projects, programs, systems, or operations (for example, strategic plans, work breakdown structures, integration plans, performance measures).
Develops implementation plans or procedures for systems security.
Oversees the implementation of systems security plans and procedures.
Provides technical support.
Plans or coordinates work activities, projects or programs.
Evaluates users' proficiency levels in using information technology hardware or software.
Markets work plans to higher management to gain their support.
Develops information systems implementation plans or strategies.

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Top MOSAIC Tasks: Accounting/Finance

0510: Accounting/Finance
Identifies accounting errors and reconciles accounts or other financial records.
Performs various account servicing duties (for example, monitors accounts, adjusts delinquent loan accounts, administers trust   funds).
Ensures compliance with accounting and auditing requirements.
Determines compliance with accounting and auditing requirements.
Performs financial audits.
Conducts financial audits.
Identifies inconsistencies in suspects', witnesses', or other persons' accounts.
Analyzes or interprets financial information.
Conduct periodic assessment of internal control program management under the Federal Manager's Financial Integrity Act.
Prepares complex financial statements or reports.

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Top MOSAIC Tasks: Human Resources

0201: Human Resources
Explains or provides guidance on laws, regulations, policies, standards, or procedures to management, personnel, or clients.
Develops position descriptions and performance standards.
Develops position descriptions or performance standards.
Provides career development opportunities for staff.
Provides employee coaching and counseling for career development.
Provides technical advice or assistance to others.
Explains or provides guidance on laws, regulations, policies, standards, or procedures.
Provides guidance or assistance on policies or procedures.
Prepare position descriptions and performance elements and standards.
Provides guidance and direction to other employees.

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Top O*NET Detailed Work Activities: IT

2210: IT
Develop business or financial information systems.
Manage information technology projects or system activities.
Develop computer or information systems.
Develop organizational goals or objectives.
Analyze security of systems, network, or data.
Provide technical support for software maintenance or use.
Maintain data in information systems or databases.
Recommend changes to improve computer or information systems.
Implement security measures for computer or information systems.
Identify information technology project resource requirements.

Top O*NET Detailed Work Activities: Accounting

0510: Accounting/Finance
Maintain financial or account records.
Maintain records of customer accounts.
Analyze budgetary or accounting data.
Discuss account status or activity with customers or patrons.
Develop business or financial information systems.
Disburse funds from clients' accounts to creditors.
Develop procedures for data management.
Analyze financial information.
Design energy production or management equipment or systems.
Monitor financial information.

Top O*NET Detailed Work Activities: Human Resources

0201: Human Resources
Develop plans for programs or services.
Provide technical guidance to other personnel.
Develop procedures for data management.
Report information to managers or other personnel.
Recommend personnel decisions or human resources activities.
Conduct employee training programs.
Coordinate personnel recruitment activities.
Direct natural resources management or conservation programs.
Develop program goals or plans.
Communicate with management or other staff to resolve problems.

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Related Occupations: Information Technology

Federal Occupational Series	O*NET Occupational Classification (SOC)
GS-2210 Information Technology Management Series	15-1142.00 Network and Computer Systems Administrators
GS-1601 General Facilities and Equipment Series	15-1199.02 Computer Systems Engineers/Architects
GS-0391 Telecommunications Series	15-1143.00 Computer Network Architects
GS-0301 Miscellaneous Administration and Program Series	15-1152.00 Computer Network Support Specialists
GS-0343 Management and Program Analysis Series	15-1143.01 Telecommunications Engineering Specialists
GS-2001 General Supply Series	11-9199.07 Security Managers
GS-1101 General Business and Industry Series	15-1199.09 Information Technology Project Managers
GS-0080 Security Administration Series	11-3021.00 Computer and Information Systems Managers
GS-1670 Equipment Specialist Series	15-1133.00 Software Developers, Systems Software
GS-0854 Computer Engineering Series	13-1199.02 Security Management Specialists

Related Occupations: Accounting/Finance

Federal Occupational Series	O*NET Occupational Classification (SOC)
GS-0501 Financial Administration and Program Series	11-3031.01 Treasurers and Controllers
GS-0510 Accounting Series	13-2011.01 Accountants
GS-0511 Auditing Series	13-2011.02 Auditors
GS-0525 Accounting Technician Series	43-3031.00 Bookkeeping, Accounting, and Auditing Clerks
GS-0503 Financial Clerical and Assistance Series	13-2052.00 Personal Financial Advisors
GS-0561 Budget Clerical and Assistance Series	13-2061.00 Financial Examiners
GS-0540 Voucher Examining Series	13-2031.00 Budget Analysts
GS-0505 Financial Management Series	13-2099.01 Financial Quantitative Analysts
GS-1160 Financial Analysis Series	43-3011.00 Bill and Account Collectors
GS-1831 Securities Compliance Examining Series	13-2071.01 Loan Counselors

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Related Occupations: Human Resources

Federal Occupational Series	O*NET Occupational Classification (SOC)
GS-0203 Human Resources Assistance Series	13-1071.00 Human Resources Specialists
GS-0201 Human Resources Management Series	11-3121.00 Human Resources Managers
GS-0301 Miscellaneous Administration and Program Series	19-3032.00 Industrial-Organizational Psychologists
GS-1849 Wage and Hour Compliance Series	11-3111.00 Compensation and Benefits Managers
GS-1101 General Business and Industry Series	13-1141.00 Compensation, Benefits, and Job Analysis Specialists
GS-1710 Education and Vocational Training Series	43-1011.00 First-Line Supervisors of Office and Administrative Support Workers
GS-0140 Workforce Research and Analysis Series	11-1011.00 Chief Executives
GS-0313 Work Unit Supervising Series	11-9199.02 Compliance Managers
GS-0343 Management and Program Analysis Series	43-4161.00 Human Resources Assistants, Except Payroll and Timekeeping
GS-0142 Workforce Development Series	11-9032.00 Education Administrators, Elementary and Secondary School

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Between-Job Differentiation

- Mean correlation among competency recommendations
  - General competencies: r = .80
  - Technical competencies: r = .45

- Mean correlation among work activity recommendations
  - MOSAIC tasks: r = .59
  - O*NET DWAs: r = .58

Task—Competency Linkages: Example 1

- Task: Discusses results, problems, plans, suggestions, terms or conditions with others.

  - General competencies
    - Planning & Evaluating, Flexibility, Problem Solving, Mathematical Reasoning, Creative Thinking

  - Technical competencies
    - Technical Problem Solving, Geotechnical Engineering, Mine Safety & Health, Strategic Thinking, Public Planning

Task—Competency Linkages: Example 2

- Task: Promotes products or services.

  o General competencies
    - Customer Service, Digital Collaboration, Memory, Attention to Detail, Leadership

  o Technical competencies
    - Sales & Marketing, Operations Support, Entrepreneurship, Product Evaluation, Food Service

Task—Competency Linkages: Example 3

- Task: Certifies that plants or animals are free of disease or infestation.

  - General competencies
    - Memory, Attention to Detail, Leadership, Information Management, Resilience

  - Technical competencies
    - Biology, Pathology, Animal Husbandry, Botany, Horticulture

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Extensions

Expanding the Enterprise

1. Predicting relevance of work descriptors for a given occupation, job, or role (*prediction system* using embeddings as **X**)
2. Incorporating state-of-the-art transformer-based embeddings
3. Building a production system

Outside of Traditional Work Analysis
1. Job knowledge/certification test item development helper
2. Career path information

Expanding the Enterprise: Prediction Example

Method: Ridge regression | 600 embedding vectors as predictors
          Cross-validated R's | n = 967 occupations

Criteria	#	Mean R	SD R
Abilities	52	0.76	0.10
GWAs	41	0.68	0.10
Interests	6	0.83	0.07
Job Zone	1	0.86	--
Knowledges	33	0.75	0.08
Skills	35	0.80	0.06
Work Context	57	0.70	0.08

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Closing Thoughts

Focus is on evidence-based practice and decision support, as opposed to emphasis on use of analytics as an end state in itself

Purpose is to work toward solving problems people care about in the workplace

The decision to be made, or problem to be solved, begets analytic strategy choices

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