Forecast Competency Migration by a Methodology of Competency Analytics

Gang Zhao[1], Debbie Carlton[2]

[1]Intelartes, Brussels, Belgium
[2]Dynamic Knowledge, London, UK
Email: Gang.Zhao@intelartes.com

Abstract

Competency migration is an evolution from one competence profile to another. A basic task in forecasting competency migration is comparing competency data. It is both methodological and technological challenge to make competency data comparable syntactically and semantically, since they vary in purpose, origin, assumption and format. The paper describes a knowledge-based data processing approach to competency forecasting. It combines knowledge and data engineering methodologies and takes advantage of knowledge technologies, with the aim at objective, comprehensive, consistent, traceable and scalable analysis. The competency data are collected from Gas, Power, Waste and Water industries and analyzed for skill foresights into 2030 in a research programme at Energy & Utility Skills Group, UK.

Keywords

Competency, Competency Framework, Gap Analysis, Knowledge Base, Competence Semantics, Competency Analytics, Career Migration, Workforce Planning

1. Introduction

This study is part of the research *Skills Foresight*: *Making the Transition* at the Energy & Utility Skills Group (http://www.euskills.co.uk), intending to anticipate skill challenges in the Gas, Power, Waste and Water sectors in UK on the horizon of 2030. Based on the foresight research of key drivers and trends in these sectors [1], it studies the evolution of competency requirements from current jobs into future ones to support decisions in workforce planning and upskilling in organizational or sectorial contexts. Similar studies are occupation forecasts [2]-[5] and need analysis of competency [6]. The former presents a projection of labour markets in terms of predefined occupations on a given time horizon. The latter looks beyond job categories into the details of their skill dimensions. It collects or speculates about the *competency data* of given *subjects* such as an individual, team, organization, project, training or role at work (see [6] for a systematic methodology of defining the future competency data of a role at work).

The *competency migration* is about how subjects change from one set of their competency data to another. Forecasting competency migration defines and analyses competency data of different timestamps. The *competency data* in this context are typically created from multiple sources, in divergent perspectives and for different

purposes. Their representation also varies from free text, questionnaire, vocabulary-controlled, keyword-based to checklists of predefined parameters from psychometrics [7] or information model [8] or competence frameworks [9]. Competency comparison is prone to subjectivity and arbitrariness, if the issue of data comparability is dealt with informally or implicitly. It is, therefore, both a technical and methodical challenge to transform competency data into terms comparable semantically as well as syntactically. Our study of methodology is focused on how to transform and compare competency data. We take a knowledge-based approach [10] to competency analysis. This approach seeks to interpret, transform and compare competency data with respect to the UK National Occupational Standards (NOS) [11]. NOS are selected as terms of reference for comparability, because of its functional approach to competence specification, in-depth and comprehensive coverage, wide consensus of employment experts and methodical compilation [12].

This approach of competency analytics is described in Section *An approach of knowledge-based competency analytics* and illustrated with empirical findings in Sections *Competency knowledge*, *Competency data* and *Competency analysis*.

2. An Approach of Knowledge-Based Competency Analytics

2.1. Concepts

Competence is a concept used in various contexts and applications, hence different viewpoints or emphasis in conceptualization and presentation. As Elleström [13] puts it, "there is such confusion and debate about the concept of competence that it is impossible to identify or impute a coherent theory or to arrive at a definition capable of accommodating and reconciling all the different ways the term is used". In our current context, however, *competence* refers to a capability to perform a professional duty with required ability, knowledge and behaviour. *Duty* is the purpose or context of professional activity, knowledge and behaviour. *Ability* is a capacity to conduct an activity or undertake a task for a professional duty. *Knowledge* is cognitive awareness of know-what, know-why and know-how. *Behaviour* is the personal traits, such as attitudes and manners, in the professional context. No conceptual distinction of *potential* and *actual* [14] is made between *competence* and *competency*. The latter is treated as a collective noun of the former.

A *competency description* is a free text description of competences. It is unstructured competency data found in job advertisement and descriptions. A *competency specification* is also textual description, but it is structured along specific conceptual dimensions such as skills, knowledge and behaviour. It is often put in restricted linguistic style with controlled syntax and vocabulary. Competency frameworks are examples of such semi-structured competency specification. A *competency profile* is a list of symbols representing competences and their inter-relationship for automatic data processing.

Competency analytics computes the set relationship between competency profiles. Given competency profiles, A and B, the *competency adequacy* of A for B is their intersection, i, where i = A∩B; the *competency lack* in A for B is the difference of B and A, g, where g = B\A; the *competency redundancy* of A for B is the difference of A and B, d, where d = A\B. The redundancy is a cost of a career move or indicator of "over-qualification": abilities, skills and knowledge will be disused, possibly depreciate in time. The competency comparison is scored between 0 and 1, where 0 is negative and 1 is positive.

A *role* refers to a set of duties to perform at work. They are the subject of competency description, specification and profile in the current study. *Future roles* are roles predicted to come up in the future. *Feeder roles*, which exist in today's professional activities, are closer akin to future roles and thus are more immediate point to evolve or migrate from.

2.2. Principles

We have identified seven principles which competency analytics ideally adheres to. They are **factuality** in information collection, **objectivity** in analysis and conclusion, **comprehensiveness** in details and coverage, **consensus** in data interpretation and assumption, **scalability** in the scope of analysis, **traceability** towards intermediate and final results, **consistency** regardless of who, what, when and where the analysis is made. Factuality, objectivity, comprehensiveness and consensus are requirements on competency data and knowledge in the analysis. Consistency, scalability and traceability are guidelines for developing and evaluating the data and knowledge processing, such as data transformation and comparison in the analysis.

In consideration of these requirements, we have adopted three strategies in our approach to forecasting competency migration: data formalization, use of a knowledge base and automation in analysis and presentation. An unstructured-to-structured transformation of competency data is implemented to restructure data conceptually and formally without reducing their factuality and comprehensiveness. It is standard-based in the light of competency frameworks to maximize its objectivity, comprehensiveness, consensus and traceability. The automatic comparison of resultant competence profiles guarantees the consistency, traceability and scalability of analysis. Its reference to competence frameworks maintains comprehensive and consensus-based business logic.

2.3. Processes

Our approach of competency analytics implements three processes: knowledge engineering, data engineering, knowledge-based data processing (**Figure 1**).
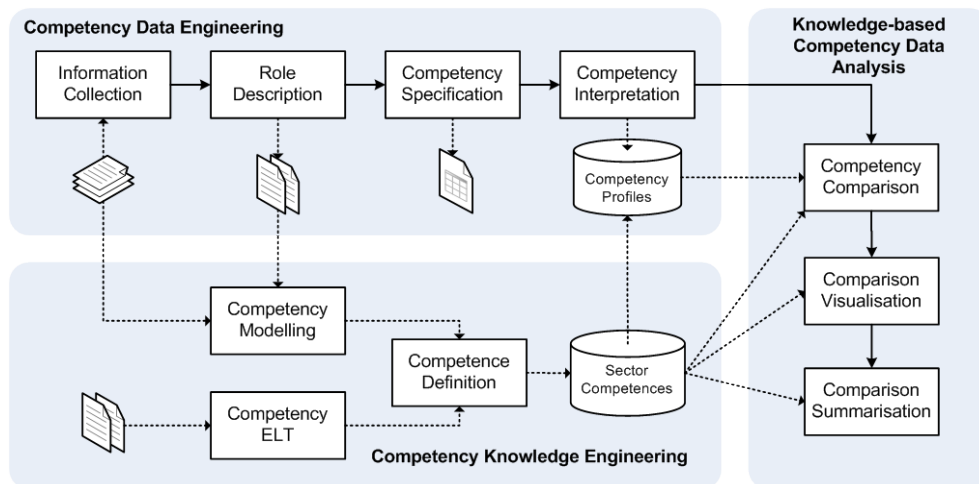
Figure 1. Processes of knowledge-based data engineering and processing.

Competency knowledge engineering develops a Sector Competence Knowledge Base (SCKB) from NOS. Similar to other competency frameworks, NOS is intended for human readership. It is not a formal model, readily available for automatic competency processing. This is a major technological challenge to the adoption of competency frameworks in machine-assisted competency management. We make use of knowledge base and semantics technology [15] to make its contents deployable for automatic processing. The machine knowledge base of competences adds intelligence to competency processing, as well as improves the consistency, objectivity, traceability, comprehensiveness and scalability of competency analytics. In addition to the standard competence framework with NOS, a competency model is built for the specific purpose and integrated in SCKB, which serves to highlight specific competences found in the context of the current study.

Competency data engineering is a two-step unstructured-to-structured data transformation to make data comparable for traceable, consistent and scalable analysis. The first step is to paraphrase competency descriptions into competency specifications in view of our definition of competence and assumptions in NOS. The second step is to interpret competency specifications into competency profiles manually or automatically according to the NOS competence framework and purpose-built competence model.

Knowledge-based competency data analysis compares competency profiles with reference to SCKB to quantify and visualize the competency adequacy, lack and redundancy in a move of competency migration.

3. Competency Data

Four future roles are defined for the sectors of Gas, Power, Waste and Water respectively. Three feeder roles for each future role are identified from job boards and validated through extensive interviews and stakeholder workshops [16]. Sixteen *role descriptions* are edited from collected job information and paraphrased into *competence specifications*, written in simple declarative statements of action, state and attribute, structured under 5 headings:

- Duty Responsibility or function of the role
- Ability Capability to conduct activities to fulfill the duty or role
- Knowledge Know-what, know-why and know-how required to fulfill the duty or role
- Behaviour Manners and attitudes needed for the duty or role
- Qualification Certification or education required for the duty or role

Sixteen competency profiles (**Figure 2**) are interpreted from resultant competence specifications according to NOS.

1	Install domestic gas cookers, tumble dryers and leisure appliances		DownStreamGas_EUSDSG3.1
2		Design gas systems for installing domestic gas cookers, tumble dryers and leisure appliances	DownStreamGas_EUSDSG3.1_D1
3		Plan and prepare work activities for installing domestic gas cookers, tumble dryers and leisure appliances	DownStreamGas_EUSDSG3.1_D2
4		De-commission domestic gas cookers, tumble dryers, and leisure appliances to industry standards	DownStreamGas_EUSDSG3.1_D3
5		Install, Exchange, and Remove domestic gas cookers, tumble dryers and leisure appliances to industry stan	DownStreamGas_EUSDSG3.1_D4
6		Pre-commission and Commission domestic gas cookers, tumble dryers and leisure appliances to industry s	DownStreamGas_EUSDSG3.1_D5
7		Use and communicate data and information to carry out de- commissioning, installation and commissionir	DownStreamGas_EUSDSG3.1_D6
8		Resolve problems which could affect the de-commissioning, installation and commissioning process	DownStreamGas_EUSDSG3.1_D7
9	Maintain gas warm air central heating systems and appliances		DownStreamGas_EUSDSG3.11
10		Plan and prepare work activities for maintaining warm air central heating	DownStreamGas_EUSDSG3.11_D1
11		De-commission warm air central heating to industry standards	DownStreamGas_EUSDSG3.11_D2
12		Maintain warm air central heating to industry standards	DownStreamGas_EUSDSG3.11_D3
13		Pre-commission and Commission water heating and wet central heating appliances to industry standards	DownStreamGas_EUSDSG3.11_D4
14		Use and communicate data and information to carry out de- commissioning, maintenance and commissior	DownStreamGas_EUSDSG3.11_D5
15		Resolve problems which could affect the de-commissioning, maintenance and commissioning process	DownStreamGas_EUSDSG3.11_D6
16	Install gas meters and regulators (2.5 to 16.0m cubed/ hour)		DownStreamGas_EUSDSG3.12
17		Design gas systems for installing and exchanging gas meters and regulators (2.5 to 16.0m3/hr) on gas syste	DownStreamGas_EUSDSG3.12_D1

Figure 2. Excerpt of competency profile data sheet.

Competency interpretation thus refers to a competency descriptive framework instead of a reductionist model of competency categorization or taxonomy. This non-reductionist approach is taken in order to maintain the factuality, objectivity and comprehensiveness of competency profiles. **Table 1** shows the numbers of competences of their competence profiles of the future and associated feeder roles.

Table 1. Roles and numbers of associated competences.

Role	Abbr.	Sector	Type	Duty	Ability	Knowledge	Behaviour
Gas Network Planner	*GNP*	Gas	Future	139	910	1497	65
Energy Demand Manager	EDM	Gas	Feeder	19	207	356	41
Network Maintenance Planning and Performance Manager	NMPPM	Gas	Feeder	68	583	1023	90
Network Planner	NP	Gas	Feeder	34	319	695	44
Commercial Director of Resource Operations	*CDRO*	Waste	Future	153	1158	1077	84
Carbon Manager	CM	Waste	Feeder	51	430	629	39
Head of Sustainability	HS	Waste	Feeder	48	551	643	56
Senior Resource Efficiency & Waste Consultant	SREWC	Waste	Feeder	60	484	1311	49
Power Balance Technician	*PBT*	Power	Future	59	272	165	26
Electrical Control Room Engineer	ECRE	Power	Feeder	29	148	427	16
Power System Analysis Engineer	PSAE	Power	Feeder	19	64	60	12
Transmission Control Engineer	TCE	Power	Feeder	72	489	360	32
Water Treatment Engineer	*WTE*	Water	Future	90	840	867	47
Network Engineer	NE	Water	Feeder	134	1553	1170	63
Process Engineer	PE	Water	Feeder	93	833	971	41
Water Treatment Engineer	WTE	Water	Feeder	103	1050	1873	40
			Average	**73**	**618**	**820**	**47**

The statistics reveals that competency interpretation and comparison are beyond what human cognition can handle consistently at this level of knowledge details without technical aids. This has not yet taken into account of the complexity due to synonymous, logical or co-occurring relationship among the competences. It is thus a methodological challenge to maintain consistency, traceability and scalability over such comprehensive knowledge coverage and assumption and potentially large data sets.

4. Competency Knowledge

The competency knowledge engineering builds SCKB as terms of reference for *competency interpretation* and *comparison*. The purpose is to project the competency data of a role on the canvas of NOS for comparison. The process extracts competences from NOS documents, transforms them into competence entries and loads into SCKB. It consists of 33 sector specific competence themes such as utility management, network design and construction, utility metering, gas utilization, waste management, water treatment, and five common themes, for example, customer service, supply chain management, environmental and social governance (**Table 2**).

Table 2. Competence entries by theme in SCKB.

Dimension	Utility	Gas	Power	Waste	Water	Common	Average
Duty	222	33	288	310	221	41	186
Ability	1300	3122	1333	2093	1837	1181	1811
Knowledge	1630	4338	1342	2051	2322	1604	2215
Behaviour	47	47	55	112	50	83	66
Total	3199	7540	3018	4566	4430	2909	4277

It also includes a set of special competences of 75 activities, 135 knowledge (know-what and know-how), 39 behaviours, 13 qualifications and 29 experience in posts. They are modelled from the 16 role specifications, purpose-built to emphasize and complement specific aspects of the NOS sector coverage (**Table 3**).

Table 3. Excerption of purpose specific competences.

Activity	Knowledge	Behaviour	Qualification	Experience
Advise	3 D modeling	Action-oriented	APM practitioner	Asset intervention manager
Analyse cost and effect	6 Sigma	Analytical	BEng	Biologist
Analyse data	Bidding, tendering and contracting	Articulate	BSc	Chemical engineer
Analyse prices	biochemistry	Commerce-oriented	Chartered quantity surveyor	Chemist
Analyse quality	Biomethane injection	Communicative	CIWM	Civil engineer
…	…	…	…	…

Competence semantics [15] are extracted from competence entries with semantics and language technologies for competency comparison in semantic terms. It is beyond the scope of the paper and will be discussed in a technical publication to come.

5. Competency Analysis

The competency analysis in the current study takes two views: data comparison and analytical comparison. The *Competency Comparison* in the data view compares competence profiles automatically with reference to competences and their semantics in SCKB in order to identify, quantify and visualize the competency adequacy, lack and redundancy of feeder roles for future roles (**Figure 3**).
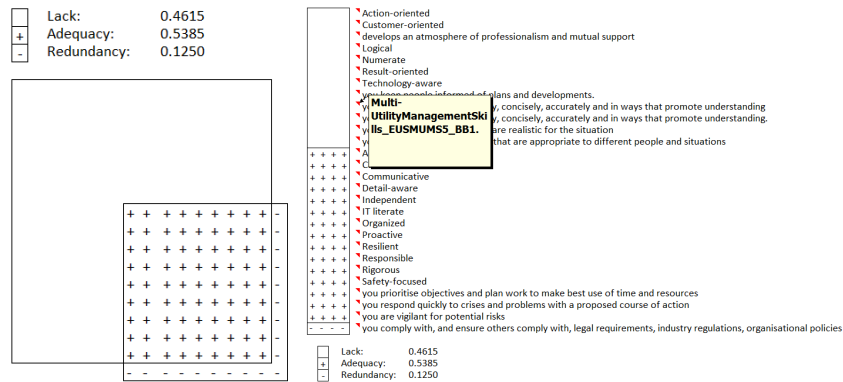
Lack: 0.4615
Adequacy: 0.5385
Redundancy: 0.1250

Action-oriented
Customer-oriented
develops an atmosphere of professionalism and mutual support
Logical
Numerate
Result-oriented
Technology-aware
you keep people informed of plans and developments.
Multi-UtilityManagementSkills_EUSMUMS5_BB1.
..., concisely, accurately and in ways that promote understanding
..., concisely, accurately and in ways that promote understanding.
... are realistic for the situation
... that are appropriate to different people and situations
Communicative
Detail-aware
Independent
IT literate
Organized
Proactive
Resilient
Responsible
Rigorous
Safety-focused
you prioritise objectives and plan work to make best use of time and resources
you respond quickly to crises and problems with a proposed course of action
you are vigilant for potential risks
you comply with, and ensure others comply with, legal requirements, industry regulations, organisational policies

Lack: 0.4615
Adequacy: 0.5385
Redundancy: 0.1250

Figure 3. Views of behaviour comparison of PBT with ECRE.

Figure 4 visualizes the competency of three feeder roles compared with that of the future role, water treatment engineer on 4 competency dimensions. The current study does not consider the life cycle of competences [6], though it can be introduced to weigh the score of competency adequacy, lack and redundancy.
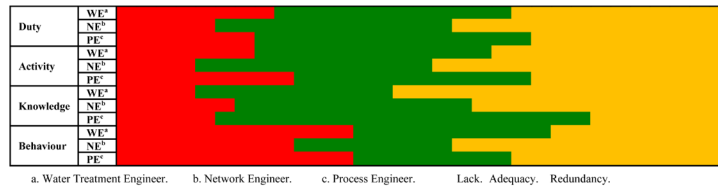
Figure 4. Dimensional view of competency of feeder roles compared with the future role of water treatment engineer.

The *Analysis Summarization* seeks to create an analytic analysis, summarized from data views of competency, on parameters or dimensions of different abstraction or perspectives. **Table 4** presents a strategic view of competency comparison, an executive summary from the perspective of 11 functional skills. The star indicates the existence of the competence in the role. The score from 0 up to 10 indicates the extent of overall competency adequacy of the role by the dimension. It serves to reveal highlight key aspects, given specific motivations of analysis. Though it is selective and generalized, the summarization analysis is based on a comprehensive and objective data analysis of multiple dimensions and large sets of parameters of data description. The analytic views are thus grounded on comprehensiveness, factuality and consistency in description.

Table 4. Analytic overview of functional skills comparison.

Functional Skill	GNP	EDM	NMPPM	NP	CDRO	CM	HS	SREWC	PBT	ECRE	PSAE	TCE	WTE	NE	PE	WTE
Manage data, information and knowledge	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Organize work	*		*	*	*	*	*	*	*	*			*	*		*
Manage work relations	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*
Manage risks and hazards	*		*		*				*			*	*	*	*	*
Control quality	*		*		*		*			*	*	*			*	*
Systems and utilities	*									*	*	*	*		*	*
Instrument (use & manage ICT etc.)	*				*	*		*	*		*	*	*	*	*	*
Ensure compliance	*	*	*	*	*	*	*			*	*	*	*	*		*
Emergency (incl. contingency)					*							*	*			
Manage training & knowledge transfer					*											
Develop sustainable business practice					*		*	*								
	10	4	6	5	10	5	5	6	10	6	4	8	10	8	6	9

a. Water Treatment Engineer.   b. Network Engineer.   c. Process Engineer.   Lack. Adequacy. Redundancy.

6. Conclusions

The paper presents a methodology of competency analytics for a knowledge-based data processing approach to forecasting competency migration. It promotes an objective, comprehensive, consistent, traceable and scalable analysis of competency data. It supports both the data and strategic views of competency migration for planning workforce, career moves and upskilling pathways [16]. The use of SCKB introduces methods and technologies of knowledge engineering and management to take advantage of extensive development of competency frameworks as well as adding machine intelligence in processing human resource data. This knowledge based approach promises an effective way to adopt, implement and institutionalize the competency standards and policies. The approach with the methodology constitutes a central component to competency assurance in human resource management and development.

The manual competence interpretation is highly skilled work requiring good knowledge of human resource management and expert understanding of NOS and competency data in the sector. The work is demanding intellectually and error-prone due to monotony in routine, superficial similarity in the data, the large population of data and scope of knowledge involved. We have explored the automatic interpretation by the case-based reasoning approach [17] to resolve this issue of scalability. The competence profile is inferred from the competency specification analogically by a case library of roles and their competency profiles. A detailed description will be the topic of a technical paper on competency analytics.

Acknowledgements

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