Solving the Identity Search & Matching Problem in Criminal Justice Applications

An overview of the identity search & matching problem space, and an introduction to Identity Systems technology

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Introduction

A primary requirement of CHRS and CJIS systems is to query and locate criminal records or justice information using identity attributes such as Name, Date of Birth, Address, SSN and other supporting data.

Anyone who has ever searched a telephone book for a name like Ricky Smith knows that the endless variations and errors in this class of data make for an almost impossible task. (Possible matches include Rick Smythe, Richard Smithe, Smith Richard A., Ricardo A Smith, R. A. Smithe, etc). Computer systems that use names to locate critical information records face the same challenges. The difficulty in overcoming the error and variation in names is compounded by the volume of information records being searched, and the need to perform searches in real-time. In addition, it is typical in such systems that apart from the accidental error and variation - the identity data is subject to *deliberate* abnormal or extreme variation.

On their own, traditional phonetic search techniques like Soundex and NYSIIS don't address all aspects of the problem space, do not provide matches in ranked order, cannot address words that are in the wrong order (i.e. Lee Kwok Ki and Kwok Ki Lee), and do not handle data from multiple countries/character sets/languages efficiently.

Indexing and search techniques that rely on clean and complete data will struggle with the often incomplete and unpredictable data that must be recorded and searched in such systems.

Reliable, fast identity searches, and accurate matching, as well as the ability to reliably screen data batch or online, are fundamental requirements of CHRS and CJIS systems

The identity search problem is complex – and requires sophisticated tools and techniques to address and solve the problem.

The Identity Search Problem

Names (and other identity data) suffer from unavoidable error and variation.

The variations that occur include spelling, typing and phonetic error; synonyms & nicknames; Anglicization, ethnic, and foreign versions of names; initials, truncation and abbreviation; prefix and suffix variations; compound names; account names; missing words, extra words and word sequence variations, as well as format, character and convention variations.

Variation examples

Person Names:

Nicknames: William, Bill, Billy, Will

Name Variation: Chris, Kris, Christie, Krissy, Christy, Christine, Tina

Abbreviation/Spelling: Mohammed, Mohd, Mohamad, Mhd, Muhammad

Foreign Versions: Peter, Pete, Pietro, Piere, Pierre

Spelling Variation: Johnson, Johnsen, Johnsson, Johnston, Johnstone, Jonson

Suffix Variation: Smith II, Smith 11, Smith Jr, Smith jnr

Anglicization: De La Grande, Delagrande, D L Grande

Out of Order: Henry Tun Lye Aun; Mr Aun Tun Lye (Henry)

Initials/Order: Frank Lee Adam; A. Frank Lee; Lee Frank

Titles: Dr. Henry Lee, Henry Lee, M.D., Mr. Henry Lee

Company Names:

Town Park Plaza Hotel, Park Plaza, Hotel Plaza, Town Park

John Deer Engg Labs, John Deare Laboratories, Engineering Research Labs c/o John Deere Inc

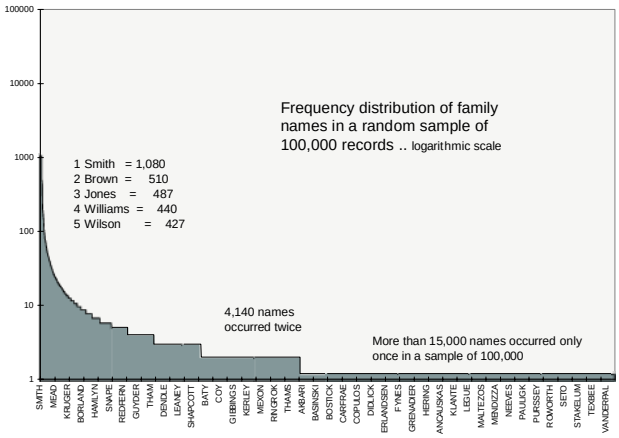
IBM, International Business Machines, Intl. Bus. Mach., I.B.M., IBM Inc.

Addresses:

Jackson Rd. East Hartford
117-2a Jackson Rd East, Hartfrd
2a East Jackson, Hartford
117a Jackson Rd, E. Hartford
Grd. Fl. 192 Aberdeen St Southhead
192/1 Aberdeen Sreet Sth. Hd.
Ground Floor 192 Aberdeen St South Head

Common and Uncommon Words – the Performance Problem

The words we use to label things are chosen from a very different vocabulary than meaningful language. There are no dictionaries, spell checkers or rules for the names of people, places, things or even addresses. The vocabulary in use for people's first names includes in excess of 2,500,000 words in the USA alone, yet as much as 80% of the population may have names from as few as 500 words.



Accurate and high-performance name searching must perform for the uncommon names as well as for very common words. This is an extremely difficult challenge when a database of 100,000,000 people may contain 100,000 John Smiths, or Juan Rodriguezs or 1 Main Streets.

International Data

Most large identity databases contain data from multiple languages, countries and cultures which often have different structures, follow different parsing rules, and have different variation characteristics. Also, if transliteration, Romanization, character set conversions and other such transformations are employed, a new class of error and variation is introduced.

Names are Truly Many-to-Many

It is obvious that two people or companies, or products, can have exactly the same name. It is also obvious that, even ignoring error and variation, people places and things have more than one name:

People have maiden names and married names;

People have aliases and professional names;

Companies have registered names, trading names and division names;

Places have several addresses, on two separate streets, old addresses, billing addresses, postal addresses etc.

People and places can have names in more than one language.

The relationship between a name and that which it names is quite naturally a true "many-to-many relationship."

Indexing these "many to many" relations requires careful design in the majority of today's search applications. Search techniques that depend on two fields, one for "name" and one for "maiden name", or "alias" are not good. When we are searching for a person's name, or address we do not know which "role" it plays. We do not know if it is a birth name, married name or maiden name, we do not know if it is a current or prior address. In order to address this problem effectively, it is necessary to have several keys or index entries pointing to the same identity.

Popular but Less Successful Techniques

Cleaning, Standardizing or Enhancing Names and Addresses

While the concept of cleaning, enhancing or otherwise standardizing names and addresses to make search and matching easier is very enticing, there is a logical conflict between the idea of "cleaning" and the "unpredictability" of identity data. Incorrect assumptions made by formatting and cleaning routines can corrupt good data, and records rejected by the cleaning process can mean lost opportunities to match.

Cleaning and enhancement of identity data may be a valid process for preparing names and addresses for some marketing functions, however such pre-processing does not solve all of the data matching problems, particularly when the data is unreliable or the need to find a match if one exists is critical.

Text Searching

The idea that text retrieval packages can successfully be used for name search applications is only believed by users who are unaware of the "good" data that they miss. Even when "Full Text" indexes have phonetic algorithms, or "expert" rule bases for Name searches the indexing mechanism will result in an inefficient process. Imagine the cost of finding all the index values for the records containing John and then joining them with those that contain Smith to discover the subset John Smith. In actuality, many text search packages fail to recognize that Bill Smith and William Smith could be the same person, let alone some obscure abbreviation such as Wlm Smith.

Typical free text indexing techniques do not allow high performance or high quality retrieval of data containing names. Text searches are not for the serious searcher dealing with identity data.

In those applications where there is a need to index, search and classify both identity and non-identity data in free text or unstructured data – a combined solution is necessary. The non-identity data can be handled by text retrieval and categorization engines – but the identity data must be handled by a sophisticated identity search & match product that recognizes, finds or discovers the "name phrases" in the text and indexes them with the same specialized techniques that are necessary for quality and performance in any other name search system.

Wild-Card Searches

Wild-card searches do overcome SOME error and variation in the name. That is why users believe in them. If the users knew what data they were missing they would not believe in them. Programmers believe in them because they learned to program them in their computer science classes at university. In reality they only work if the searcher correctly guesses the right characters to include or exclude, and the database had no error in the characters actually used. They cannot find all the relevant records, do not address nicknames and abbreviations, nor the fact that different records have different errors.

Wild-card searches normally return too many irrelevant candidates and will always miss many of the relevant candidates. Wild-card searches are not for the serious searcher.

Match-Codes

A Match-code is an entity key built from a combination of the entity's attributes. The Match-code for: John Smith dob: 22 Feb 1979 2/234 33RD St., New York, NY12345, might be: SMITHJ79NY. Match-codes require that the entity is first strictly formatted into its pieces; that all pieces used are in the "stable" order; and that there are no errors in the pieces used.

Once each source record has a Match-code, "like" Match-codes can be used to bring together similar records for more intense matching. Some match-coding aims to build a unique key for entities such that search and match can be done in one step.

Match-codes can also be used in real-time searching. Depending on their granularity, they can make getting to a matching record very quick. The search width can also be expanded by truncating attributes (e.g. search for Family Name + Initial + Birth Year) without including the State Code).

The problem with Match-codes is that to be really effective they require error-free data, which is why they depend so heavily on cleaning and formatting routines to prepare the data. A missed match could be caused by something as simple as a transposition during data entry (213 Main Street vs. 123 Main Street).

Typically Match-Codes do find "correct records," but they frequently miss other good candidates. If there is no ability to overcome error and variation in the name parts, all records with such error and variation will be missed. Missing word, extra word and word order variations are often missed unless the searcher permutes the search criteria or the batch process is run in multiple passes.

Match-Codes fail if any one piece of the data used to build the code is not identical. Match-Codes are not for the serious search or matching application and definitely not for the critical search applications or large volume systems.

N-Gram Indexing

An n-gram is a set of "n" consecutive characters extracted from a word or code. Typical values for "n" are 2 or 3. These extracted n-grams are subsequently indexed for all names or addresses in the database. At search time, the idea is that words or codes that are similar between the search and file data will have a high proportion of n-grams in common. N-grams are particularly well suited to string and text searching; however, unless supported by extensive rule bases for phonetic and synonym variation, as well as for noise words, they do not readily overcome the typical error and variation found in identity data, nor do they easily scale to very large data volumes.

Yesterday's Soundex's, NYSIIS, and other simple Phonetic Algorithms

In the early 1900's the Russell Soundex, was developed to provide a stable manual filing code for the USA Census documents. The development of this algorithm for encoding the last name of a person was based upon phonetics and certain classes of typical spelling and filing errors. It was a simple set of rules to convert a last name word into a four, five or six digit number that had a high probability of being the same for two words that were variations of each other.

Since then, many Algorithms with a similar objective have been developed and modified. In 1969 the New York State Identification Intelligence System project evaluated the then popular algorithms. This included evaluation of last names on New York State criminal records to see how effective algorithms were at overcoming the error and variation. To this they used records that were previously paired using fingerprints. They evaluated such algorithms as: Soundex and many of its variants; LA County Sheriff; Consonant coding; Phonic standard and extended; Michigan Lien; and several Extract list based systems. The end result of their project was to define a popular algorithm known as NYSIIS which they proved was better optimized for their data at that point in time.

At Identity Systems we have conducted many such exercises on data from many customers and countries and have found that, even in one country, **no single algorithm is optimum for all naming data**.

Fundamentally the choice of the optimum word stabilization algorithm depends upon the source

of the data and the frequency distribution of certain classes of error in the data. For example carefully written and captured Criminal Records have a very different error distribution than urgent verbal requests for information over a radio. While such stabilization algorithms can be a critical piece of a name search engine, the algorithms of the past are not suitable for use as database keys with today's data or volumes. Typically they either cause too many records to be found, or they miss too many relevant records.

Where stabilization algorithms are used, the choice of the right algorithm can be critical and must be based upon the true distribution of the error and variation in both the population of file data, and the population of the search data. The objective of word stabilization algorithms should be limited to retain as much of the original words form as is commensurate with the objective of "not missing valuable records."

However, the problem of phonetics and spelling is only one part of the general name search problem – and as such a complete name search solution cannot be solely dependent on just a phonetic algorithm**. The design of suitable database keys to maximize quality is a separate and much more complex exercise**.

Identity Systems Approach

The ideal identity search solution:

- Overcomes the error and variation in the data
- Maintains performance even in extreme volume situations
- Finds all valid candidates without generating false matches.

This implies:

- Intelligent and scalable algorithms, which, through the use of rich keys and search strategies, return all of the candidates an expert user would consider as being the same as the search criteria.
- These algorithms must be able to cope with data from the real world. This includes data that is not formatted or cleaned or which contains missing, extra, truncated, out of order, non standard, or noise characters/words, initials, abbreviations, nicknames, numbers, codes, and concatenations.
- The algorithms need a customizable rule base to incorporate the knowledge of the expert user, and a default population rule base in the case where the user is not that experienced.
- The algorithms require phonetic and orthographic correction functionality, to address spelling and typing errors.
- Intelligent matching routines must be available and tuned to mimic the expert user making a choice as to which candidates are the correct matches. Such matching routines need to take into account all of the error and variation in the identities' attributes, as well as weighting the attributes as the user would.
- The Algorithms must work well regardless of the country of origin and language of the data and must insulate the application developer from the differences between country and language.

Identity Systems software is designed and built on these premises and is being used by many law enforcement, justice and intelligence organizations around the world.

The Identity Systems products provide efficient on-line search and scaleable batch matching on data of any quality. Identity Systems software is used by organizations for:

- Primary address searching (for utilities, insurance companies, police agencies, government departments...)
- Address searching as a secondary locator (e.g. finding matches when the name is wrong)
- Supplementing or confirming identity matches
- Grouping of data by address for house-holding
- Matching to post office and other address reference files
- Fraud investigation (e.g. looking at a large number of insurance claims using the same address)

Partial List of Identity Systems Law Enforcement, Public Safety and Justice Customers

USA Users include:

Federal Bureau of Investigation (NCIC 2000)
Los Angeles County Consolidated Criminal History System
State of Connecticut - CJIS
State of Connecticut - Child and Family Services Dept
Colorado Bureau of Investigation
Florida Dept of Law Enforcement
Massachusetts Criminal History Systems Board
State of Washington Courts
North Carolina Courts Administration
Maryland, Dept. of Public Safety
Wayne County (MI) Third Circuit Court
Shelby County TN
Cuyahoga County (OH)
State of California (various systems)
New York State Office of Child and Family Services

International Users include:

Canada Customs & Revenue Agency
Citizenship & Immigration Canada
Australian Bureau of Criminal Intelligence
Australian Federal Police
Attorney General of Victoria
Office of the Narcotics Control Board - Thailand
Australian Police Network (NEPI)
Australian Customs Service
Australian Dept of Immigration
New Zealand Immigration Service
New Zealand Police
Hong Kong Customs
UK Home Office - Offenders Index
UK Customs & Excise, European Patent Office
Czechoslovakia Security - Information Services

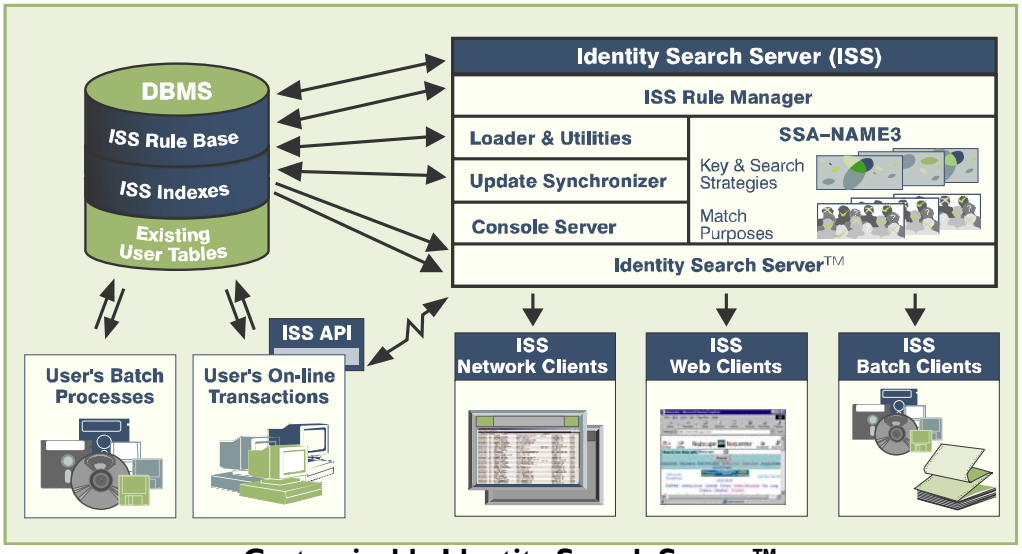
Identity Systems Products

There are three products:

- **Identity Search Server (ISS):** Online / Batch
- **SSA-NAME3:** Core SDK/API (included in other products)
- **Data Clustering Engine (DCE):** Batch

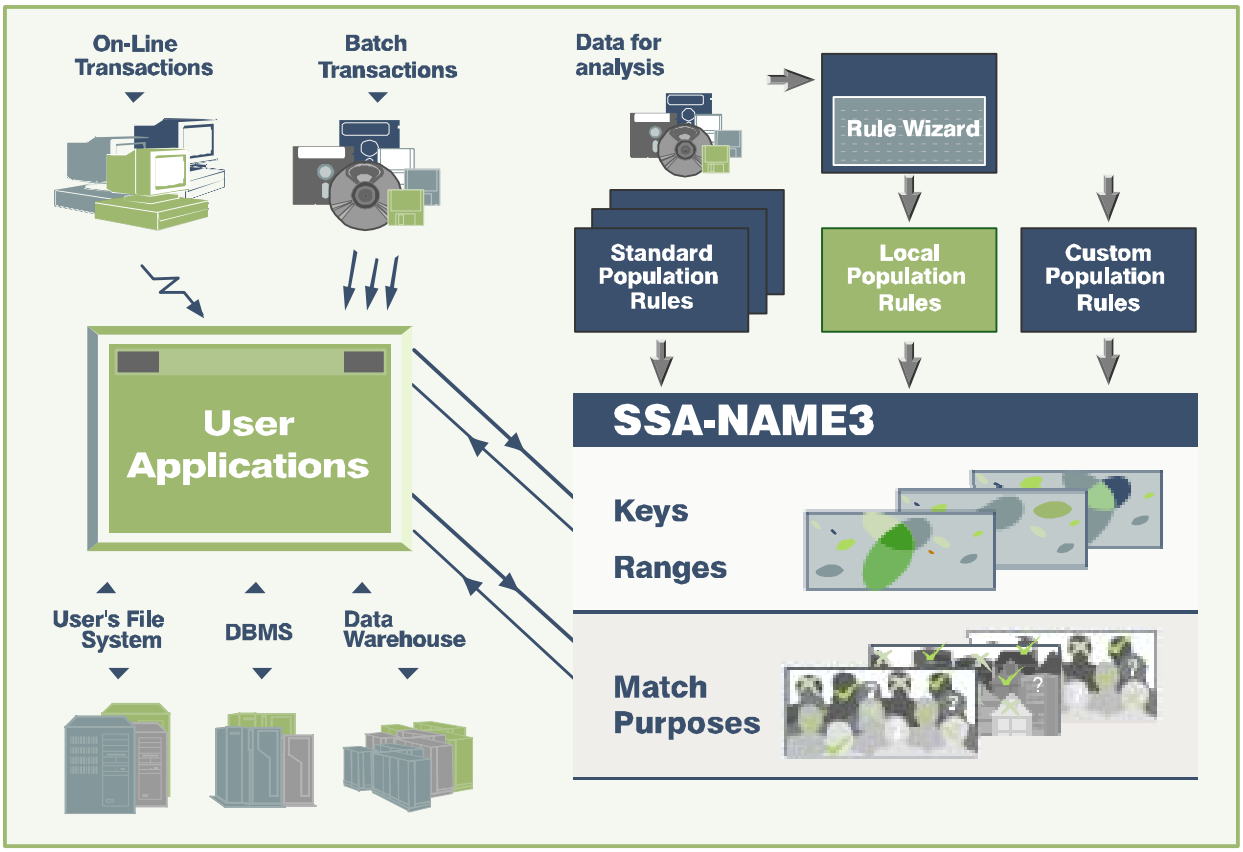
All these products can search, match, and rank identity **data of any quality or format** and do not require any "cleaning" or "scrubbing" of the source data nor is the source modified in any way by Identity Systems products. **All countries/languages** are supported, both singularly and in combination. All products can be used to centrally index and simultaneously search, match, and group identity data from disparate sources such as from Current Sales, Legacy, and External databases. An overview of each product follows.

The Identity Search Server (ISS) is the product that provides **on-line and batch searching, matching and duplicate discovery** for all types of identification data stored in relational databases (**DB2/UDB, Oracle, and SQL/Server)** on OS/390, NT, AIX, HP/UX, Linux, & Solaris platforms. High-performance indexes are automatically maintained **without changes to existing application programs**. Custom search clients can be developed using an easy-to-use API. ISS uses an **n-tier** architecture, making it the ideal solution for organizations implementing the latest technologies, including web-based applications. With ISS, the capability to **centrally** index identity information from **disparate** source tables, databases, and computers is particularly advantageous since the central index can then be used to search, match, rank, group, and maintain all the data **simultaneously** and in **real time**.

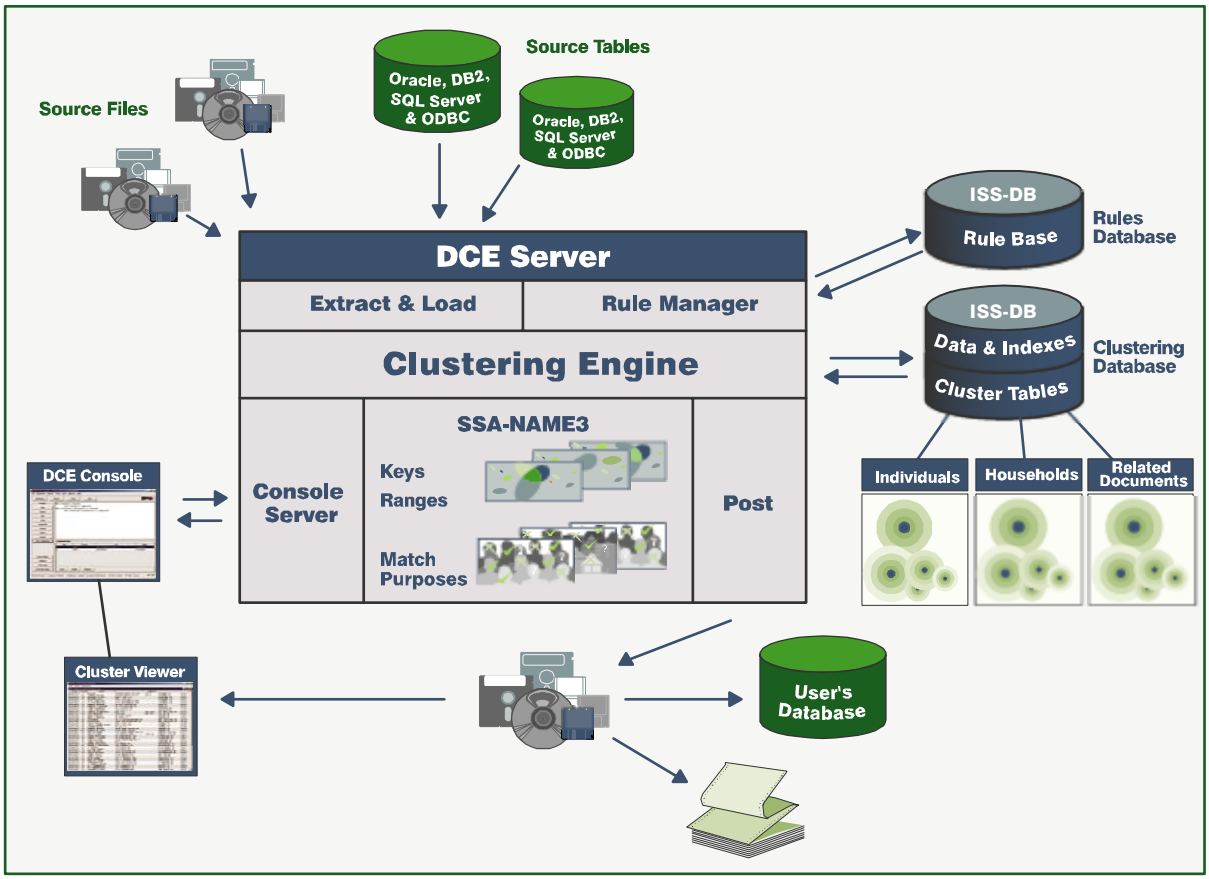


Customizable Identity Search Server™

SSA-NAME3 is Identity Systems **core technology** and included in all the other Identity Systems products. It is a system development kit that enables organizations to build business application programs to **search, match, rank, and analyze** records about people, companies, products, addresses and various other identity data. It can be executed on most any platform and operate on data stored in any database. The software contains algorithms for computing 'fuzzy' search keys and strategies, as well as algorithms for complex matching of identity data.



The Data Clustering Engine (DCE) is a **stand-alone, batch** data **grouping and investigation engine** for all forms of identification data and can execute on AIX, HP/UX, Linux, Windows NT, Solaris, & Compaq Tru-64 Unix platforms. The DCE performs a thorough analysis of the relationships between people, companies, addresses, products and other entities. This powerful software is used by numerous leading corporations and institutions for **de-duplication, file matching, householding, fraud investigation**, and various other analyses. It **does not require programming** and is highly scalable for the processing of large and extreme data volumes.



Identity Systems

Identity Systems is the pioneer in enabling organizations to build and maintain high-quality identity data search and matching software solutions. Identity Systems have been in this area of specialization for more than 20 years. Identity Systems now has over 600 clients worldwide who rely on its robust enterprise-wide software. Identity Systems became a wholly owned subsidiary of Nokia in 2006.

Company History

Identity Systems was originally established in Australia in 1987 as Search Software America (SSA) with the purpose of formally developing and marketing its founders experience in building identity search and matching systems. This experience had shown that, while the significance of identity matching in different systems varies considerably, there has always been the same basic set of concerns:

- **Performance problems arise because the most frequently occurring names are also usually those upon which searches are most often performed.**
- **Traditional phonetic algorithms create poor response time and prevent the user from locating a match among many candidates. Traditional match-codes fail to find matches when data is invalid or incorrectly parsed.**
- **True phonetics is only a subset of the errors in names, addresses and other identity data.**

Some of our projects emphasized the need to quickly achieve a match, if there was one. Others placed their emphasis on proving that there was no match at all. One project presented the unusual opportunity to empirically develop and modify an algorithm designed to solve phonetic, orthographic, and Anglicization problems in more than 2,000,000 hand-written credit records. During the project development activity, some 300,000 computerized matches were compared to manual matches done by expert searchers. Whenever the searcher found data not found by the system, the algorithm was refined.

Another project involved the re-processing of 25 million records of international data from virtually every country in the world, where it was known that at least 99% of the records were in fact pairs about the same person. The project also demanded a performance breakthrough since the design objective was to develop an identity search system to handle over 30,000 inserts per day and to support a 50,000,000 record on-line database. Based on the fact that the project's purpose was to identify the records that were not pairs and the population was smaller than the error rate in the data, the successful solution required considerable research.

The experience gained from such projects and Identity Systems work with customers around the world for the last 20 years, has been incorporated into ongoing development and maintenance of Identity Systems product suite. Although the identity search and matching problem may never be completely solved, Identity Systems enables organizations to reach unparalleled levels of quality and performance.

Contact Us

For more information about Identity Systems and our products, please visit our website, or request information from one of the contacts below. For other locations and distributors, visit www.identitysystems.com/contact.htm.

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