IntelliMetric®

The gold-standard in automated essay scoring

How IntelliMetric® Works

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IntelliMetric Background and Overview

> *"The program in your mind contains a compact description of the world. The objects in the world are elements of that compact description, but they correspond to reality . . . because the program is a compact description reflecting training on vast amounts of data." (Baum 2004, 170)*
>
> *"Semantics comes from compression . . . If one compresses enough data into a small representation, the representation captures real semantics, real meaning about the world." (Baum 2004, 102)*

Evaluating examinee skills based on a written assessment is certainly not a new phenomenon. Accounts of written assessments date back several hundred years BC within the Chinese Civil Service System. While we may no longer use ink brushes as the Chinese once did, today's writing assessments bear more similarity to ancient Chinese civil service testing than we care to admit. Still, written assessments have undergone some changes over the centuries.

Arguably, one of the most significant innovations in written assessment is the advent of automated essay scoring, or the use of computers to assist in the evaluation of written responses to assessment questions. The automated essay scoring movement dates back to the early 1960s, when Dr. Ellis Paige demonstrated that a computer could be used to score student written responses to essay questions. Automated essay scoring has come a long way since its infancy in the 1960s, but Dr. Paige still deserves recognition and credit for the earliest practicable automated essay scoring system. His vision and innovation gave birth to today's automated essay scoring systems.

Rolling the clock forward a few decades, Vantage Learning's IntelliMetric automated essay scoring system has taken the reins by defining the state of the art in automated essay scoring. IntelliMetric is based on research and development stemming back to the 1980s and has been used successfully to score open-ended essays since 1998. IntelliMetric was the first commercially successful tool able to administer open-ended questions and provide immediate feedback to students in a matter of seconds.

IntelliMetric has been used for a variety of purposes in low- and high-stakes assessment environments. But arguably the most important application has been in the area of writing instruction. Teachers, schools, state educational agencies, certification programs, and the federal government have been placing more emphasis on improving writing performance through better quality writing instruction. Numerous studies have shown that focusing on writing improvement also brings about gains in other subjects. In short, it is critical to ensure that students and professionals are able to write clearly, effectively, and appropriately, and in order to do so, they must be allowed numerous attempts at writing assignments and provided frequent, detailed feedback.

IntelliMetric. IntelliMetric is an intelligent scoring system that emulates the process carried out by human scorers. IntelliMetric is theoretically grounded in a cognitive model often referred to as a "brain-based" or "mind-based" model of information processing and understanding. IntelliMetric draws upon the traditions of cognitive processing, artificial intelligence (AI), natural language understanding, and computational linguistics in the process of evaluating written text. Among the key tools employed in this process are natural language processing, statistics, and machine learning.

The system must be “trained” with a set of previously scored responses with known scores as determined by experts. These papers are used as a basis for the system to “learn” the rubric and infer the pooled judgments of the human scorers. The IntelliMetric system internalizes the characteristics of the responses associated with each score point and applies this intelligence to score essays with unknown scores.

IntelliMetric has begun to have major effects on both classroom instruction and large-scale assessment. With virtually instantaneous electronic scoring, IntelliMetric dramatically reduces the cost and time required to evaluate student and professional writing. Moreover, IntelliMetric improves the instructional process by offering more frequent and immediate feedback to writers.

IntelliMetric shares much in common with the holistic scoring systems commonly employed to score large-scale writing assessments. Typically, a group of individuals asked to score essay papers are provided with examples of each score point determined by experts. After internalizing the characteristics associated with each score point and demonstrating calibration with the expert-assigned scores, the group is asked to score the remaining papers whose scores are unknown. Much like human scorers who are generally trained on each specific question or prompt, IntelliMetric creates a unique solution for each prompt. This process leads to high levels of agreement between the scores assigned by IntelliMetric and those assigned by human scorers.

In essence, IntelliMetric internalizes the pooled wisdom of many expert scorers. IntelliMetric benefits from the “expert judgments” reflected within the set of papers used to train the engine, not any single scorer’s judgment. Since IntelliMetric scoring is a synthesis of many expert opinions, scoring is more reliable and applied more consistently, even though these scores may not agree with any single opinion as reflected in a score for a particular paper.

IntelliMetric can be used for standardized assessments where a single essay submission is required as well as for various instructional applications where a student can provide multiple submissions of an essay response. IntelliMetric provides feedback on overall performance as well as diagnostic feedback on several domains of writing: focus, organization, grammar, etc. MY Tutor® and MY Editor® are complements to the IntelliMetric scoring engine. MY Tutor delivers real-time, prescriptive feedback based upon the genre, score scale, score point, and specific traits of a given writing prompt or assignment whereas MY Editor offers various editing and revision tools, such as a multi-lingual grammar checker, a dictionary, and a thesaurus.

Gaining Acceptance. People often fear and misunderstand new technologies, particularly those that automate some element of human activity. Throughout history, people have feared and resisted technologies that insert themselves into activities previously reserved for humans.

Since the Luddite resistance to the automation of looms in England centuries ago, there have been a number of examples of this fear of technology. Automated essay scoring is certainly no exception.

The evaluation of student written work has been the purview of humans since the birth of the written word. So it comes as no surprise that the introduction of computers into this mix would raise a few eyebrows. But, as with most new technologies, a better understanding of the technology can help. Understanding what IntelliMetric is and what it is not can help erase these fears.

IntelliMetric is in good company. While the promise of artificial intelligence has not been fully met, many applications based on the same principles as IntelliMetric have been successful. For example, since the 1960s the academic community has explored the use of computers to help with medical diagnoses. Computers programmed based on the experience of experts have been consulted to make effective diagnoses for novel cases in the field of medicine.

IntelliMetric: Common Misconceptions

As with any innovation, the novelty of IntelliMetric has led to many misconceptions. Before turning to an explanation of how IntelliMetric works, let us take a few moments to dispel some common misconceptions.

1. ***IntelliMetric cannot "think" in the traditional sense of this word.*** Unfortunately (or fortunately depending on your perspective) the human brain is far more sophisticated than IntelliMetric can ever hope to be. IntelliMetric cannot independently score essays without significant input from experts. It is merely a tool (albeit a sophisticated one) for applying the thinking of experts to novel situations. The information gained from known-score essays is applied to unknown essays. In short, while IntelliMetric seeks to model a human brain to score essays, it pales in comparison to the human brain.

2. ***IntelliMetric cannot "undo" problems caused by poor human scoring***. Inaccurate human scoring will lead IntelliMetric astray; similarly, IntelliMetric needs to receive enough papers (100-300) during training to learn how to score correctly. Finally, there must be a sufficient number of papers at each score point on the scale being used to teach the engine (preferably a minimum of 20 at each of the score points). While IntelliMetric can mitigate the effects of occasional aberrations in scoring and can do so better than statistically based models, it cannot "make up for" significant errors in the human scoring of training papers.

3. ***IntelliMetric is far from infallible.*** It can and does make mistakes. Still, it makes fewer errors than human scorers. Interestingly, while critics of automated scoring are quick to point this out, human scoring may be subjected to far less scrutiny. Unfortunately, any process is fallible whether undertaken by humans or computers.

4. ***IntelliMetric is not magic.*** It is not a mysterious unknown force. It is the product of established scientific principles that are both explainable and repeatable. While looking for the gears and detailed mechanisms powering IntelliMetric is unlikely to be fruitful, there is a clear set of processes that are well-grounded in theory driving IntelliMetric.

5. ***IntelliMetric does not focus on surface features.*** On the contrary, IntelliMetric examines a complex pattern of more than 400 features that include both relatively straightforward aspects of text such as punctuation and sophisticated features such as the expression of concepts. More importantly, as emphasized later in this paper, any single feature is not important; it is the overall emergent pattern that gives rise to meaning.

Why is IntelliMetric More Accurate Than Human Scorers? IntelliMetric is more successful at scoring responses to essay questions than are most human scorers. While IntelliMetric still cannot "hold a candle" to the human brain, it does compensate for its limitations in four key ways.

1. ***IntelliMetric focuses on a narrow domain of understanding*.** The human brain must be prepared to solve a vast array of problems in many contexts and domains. This requires the ability to size-up unique situations and transfer understandings from one domain of knowledge to another. Unlike the human brain, IntelliMetric can focus on a domain of understanding defined by a single essay prompt or topic.

2. ***IntelliMetric consistently applies the internalized rubric***. Once IntelliMetric learns the rubric and standards for scoring, it never waivers from that rubric. Human scorers are notorious for having difficulty "sticking with" the rubric. A cup of coffee or a rest break can lead to a drift in criteria and standards; it is very difficult for a human scorer to score the first and last paper in a set exactly the same way. On the other hand, IntelliMetric can maintain the exact same standards throughout the process.

3. ***IntelliMetric scores consistently over time***. IntelliMetric will produce the same scores for a given response from time to time. If IntelliMetric assigns a score of "1" today, it will continue to do so ad infinitum. The same cannot be said for human scorers.

4. ***IntelliMetric is less subject to bias*****.** IntelliMetric is not affected by the emotional content of a given essay response or a particular line of argument that may be offensive or unappealing to a human. It is blind to a particularly inflammatory argument or topic. Again, the same cannot be said for human scorers.

What Does IntelliMetric Look at to Score Essays?

One of the most frequently asked questions is: What does IntelliMetric look at to score essays? To some extent this is a misguided question. This is akin to asking what do you look at when you make a decision to open a door—certainly the features of the door that are examined are important, but the process for deciding whether or not it is a door is far more important. There is no one formula for identifying a door; not all of the features we associate with "door" need to be present for an individual to recognize a door as a door, nor do these features need to be present in the exact same quantity each time to recognize a door effectively. It is the unique combination of learned features and the remarkable ability of the human brain to see the organizational pattern of those features that lead you to conclude "door" or "not a door."

In a similar vein, what is most important about IntelliMetric is the process it uses to evaluate essay responses.

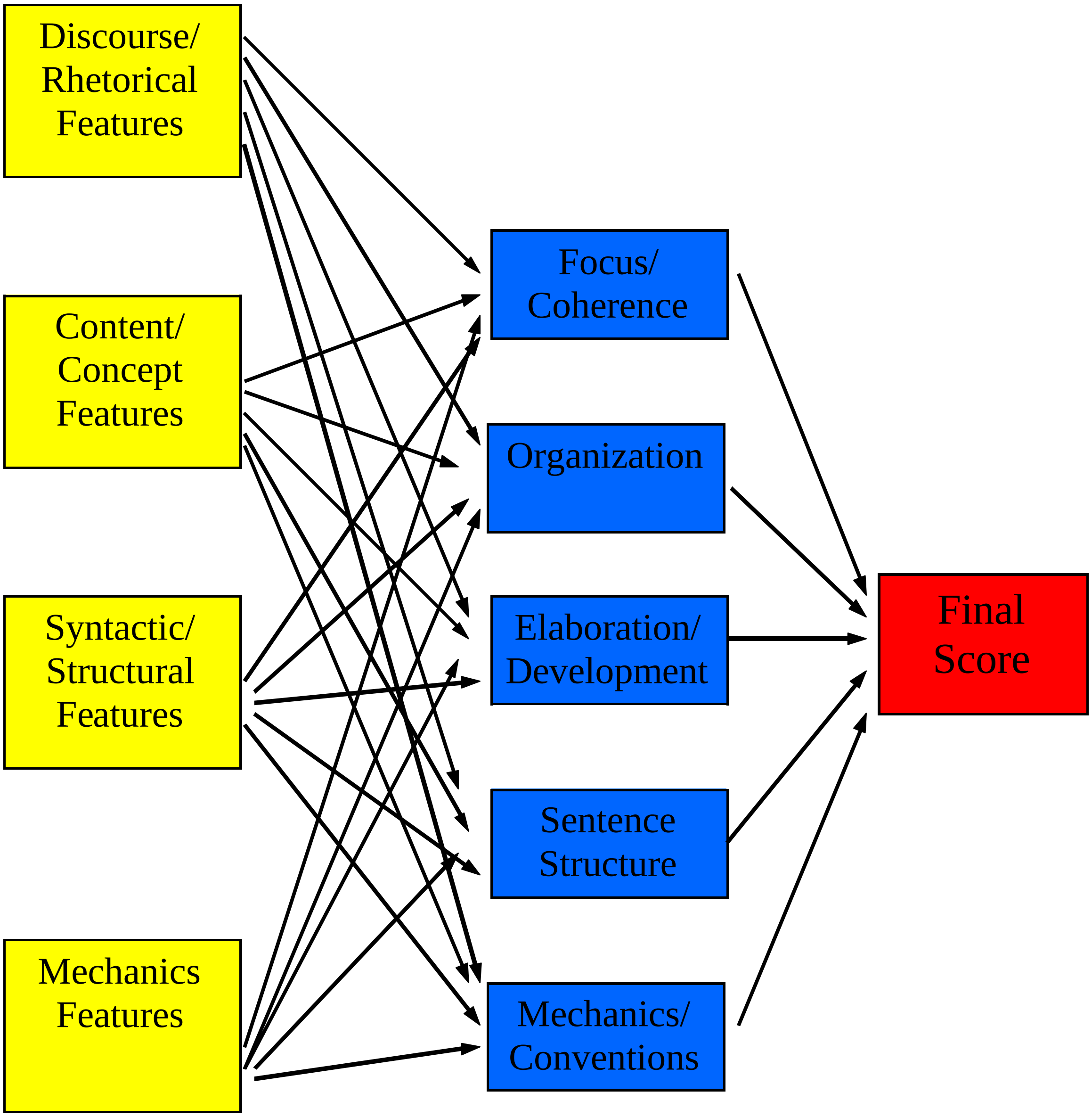
More than 400 features of text are examined by IntelliMetric, but it is the systemic interaction, or the way in which these features relate to each other, that produces meaning. A composite picture of the writing is formed from these 400 or so individual elements. Moreover, it is the comparison of this interacting set of features to past learning (from the training phase and the prior knowledge base) that produces meaning.

Text Features Examined. IntelliMetric analyzes more than 400 semantic, syntactic, and discourse level features to form a composite sense of meaning as illustrated in Figure 1. Based on these and other features, IntelliMetric identifies the underlying semantic structure for a given piece of writing. Fundamentally, IntelliMetric synthesizes broader meanings from many more molecular features. More than 400 features of the text and multiple mathematical models are applied to derive the critical semantic structure of text.

Features. IntelliMetric analyzes more than 400 semantic, syntactic, and discourse level features. These features fall into five major categories:

- **Focus and Unity.** Features related to cohesiveness and consistency in purpose and main idea.
- **Development and Elaboration.** Features related to the breadth of content and the support for advanced concepts.
- **Organization and Structure.** Features related to the logic of discourse, including transitional fluidity and relationships among parts of the response.
- **Sentence Structure.** Features related to sentence complexity and variety. **Mechanics and Conventions.** Features related to conformance to mechanics and conventions of Standard American English.

Figure 1
IntelliMetric Feature Model



How Does IntelliMetric Use this Information to Score Essays?

There is a long-standing academic curiosity about how the human brain creates meaning and how to model this process. While a review of this literature is well beyond this paper, we make a brief attempt to characterize this nearly two-century tradition in the following paragraph.

Many mark the formal beginning of this area of inquiry with William James' (1890) fundamental work in association. Inquiry into understanding continued through the early part of the twentieth century with the behavioral movement and slipped into a more cognitive understanding of meaning with the early work of Joos (1950) in language understanding and Osgood, Suci, and Tannenbaum's (1957) landmark work "The Measurement of Meaning." Understanding how we understand has been the holy grail of cognitive science. Minsky (1986) captures the perspective embodied by IntelliMetric in his "Society of Mind" view of the brain; here, understanding is seen as the result of thousands of millions of interacting subprograms each doing simple computations.

The cognitive scientific approach to understanding continued to grow throughout the latter part of the twentieth century. Most recently Baum's (2004) work has extended this search and produced an integrated view of meaning best reflected in the quotes presented at the beginning of this report.

Key Principles. In developing IntelliMetric, we sought to integrate current thinking about the human brain and how the brain processes text to develop meaning. IntelliMetric is based on this brain-based model of understanding.

There are five primary principles that guide IntelliMetric:

1. ***IntelliMetric is modeled on the human brain*****.** A neurosynthetic™ approach is used to reproduce the mental processes used by human experts to score and evaluate written text.

2. ***IntelliMetric is a learning engine*****.** IntelliMetric acquires the information it needs by learning how to evaluate writing based on examples that have already been scored by experts.

3. ***IntelliMetric is systemic*****.** IntelliMetric is based on a complex system of information working together to yield a result that is much more than its component parts. Judgments are based on the overall pattern of information and the preponderance of evidence.

4. ***IntelliMetric is inductive*****.** IntelliMetric makes judgments inductively rather than deductively. Judgments are made based on inferences built from "the bottom up" rather than "hard and fast" rules.

5. ***IntelliMetric uses multiple judgments based on multiple mathematical models*****.** IntelliMetric is based on several different types of judgments using many types of information that are organized using sophisticated mathematical tools.

Principle 1: IntelliMetric is Modeled on the Human Brain.

IntelliMetric is designed to emulate the way in which the human brain acquires, stores, accesses, and uses information. We refer to this approach as neurosynthetic; i.e., relating to the brain (neuro) and artificially created (synthetic).

The brain is composed of a complex network of neurological pathways. The way in which the brain organizes these neurological pathways and the strength of the connections within these pathways is widely believed to drive thinking and action.

The science and art of creating machines that can think and behave like humans is often referred to as artificial intelligence. While there are many definitions of artificial intelligence (AI), one interpretation of AI is the ability of machines to think. More specifically, AI, as it is used here, is the ability of a machine to carry out a task or action that requires intelligence and that produces results similar to what might be expected of a human.

IntelliMetric relies on a family of techniques falling under the heading of AI. The specific aspect of intelligence we are interested in here is the intelligence applied by human experts to score and evaluate written text provided by examinees when writing essay question responses. The information contained in the text of an essay is “harvested” and then organized into a meaningful model by IntelliMetric.

Computer Scoring. We often use the term “computer scoring” when referring to automated essay scoring approaches such as IntelliMetric. But the concept of a computer scoring an essay is really a misnomer; the computer does not score an essay per se—it merely reflects what it has been taught by experts and applies acquired information to make a decision in a novel situation.

Principle 2: IntelliMetric is a Learning Engine

While how we learn is still somewhat of a mystery, we know more about this process than ever before. It is widely believed that we learn to assign meaning—from basic concepts to social patterns of behavior—through our exposure to phenomena and events over time (Schank 1999; Baum 2004). In developing IntelliMetric, we borrowed liberally from what we know about the human learning process. Although there are many differences of opinion on precisely what constitutes learning, for the purposes of this paper, we view learning as a process of acquiring and organizing information to apply to new situations. Eric Baum captures this point in stating “…if a compact solution solves a large class of learning problems, it can be expected to be good at solving learning problems in that class which it has not yet encountered” (Baum 2004, 122).

Learning is central to brain function and plays a large role in the thinking process. Therefore, IntelliMetric was developed to be a “learning engine.” IntelliMetric learns how to score responses to each question or prompt by “reading” examples that have been previously scored. Its wisdom is gained primarily from exposure to many examples of essay responses that have been scored by expert scorers. (Although much like the human brain, this wisdom is complemented by a prior knowledge base of “stored experience.”) The more than 400 content and structure characteristics of the response described previously are associated with the score point assigned.

This learning process is an iterative process. Through an iterative algorithm, IntelliMetric learns how to score accurately. IntelliMetric goes through a repetitive process of applying the information gleaned from each essay example, "testing" its accuracy at each stage in an effort to improve its scoring accuracy. It gets better and better as it learns more and more from seeing each example essay. It's almost as if you can hear IntelliMetric saying at some point in the learning process after seeing several examples: "Oh, I get it now, *this* is what a score of 3 looks like!" and "Oh, I see how this essay is different than an essay with a score of 4."

IntelliMetric has no pre-defined set of rules that it uses to score a response; the rubric for scoring emerges from the learning process described above. There is no mechanism for the inclusion of a set of rules in advance; this would be inconsistent with underlying principles of inferential learning.

Learning Over Time. Unlike many techniques that have been applied to essay scoring, IntelliMetric can learn over time. Much like a baby learns from its mistakes, IntelliMetric is capable of increasing its accuracy over time by seeing its mistakes. This error correction function makes IntelliMetric unique among essay scoring techniques. IntelliMetric relies on a continuous learning model; it gets smarter.

While IntelliMetric has this unique continuous learning ability, this process is often blocked to ensure consistency in scoring over time; IntelliMetric is only updated as it is determined that IntelliMetric would significantly increase its accuracy based on what it has learned.

Modeling the Traditional Expert Scoring Process. IntelliMetric mirrors the scoring process typically used by human scorers. The system learns the underlying rubric and internalizes the characteristics that are important for evaluating responses to the question. Human scorers learn to accurately score student writing through repeated exposure to examples of student writing at each score level. Much like the training of human scorers, IntelliMetric needs to "understand" the characteristics of each score point. Through repeated exposure to examples of each score point—a score of one, two, three, etc.—IntelliMetric "learns" what writing characteristics are important in making an evaluation and how those characteristics are reflected at each score point.

If this process sounds familiar, it should. It is essentially the same process the human brain engages in. The brain acquires information based on experience, organizes this information, and applies this knowledge in making decisions. So too IntelliMetric acquires information about how to evaluate essays based on exposure to repeated examples at each of the score points. It then organizes this information into meaningful patterns reflecting the underlying rubric to make a decision about what score to assign to new essays with an unknown score.

Natural Language Processing. One of the tools used to understand the meaning of the text is called natural language processing (NLP). NLP seeks to understand the meaning of text by parsing the text in known ways according to known rules conforming to the rules of Standard American English. This is an advanced form of what many of us did in school under the guise of diagramming a sentence. Vantage's patented NLP engine (used for the past 25 years in various text processing applications ranging from grammar checking to text search and retrieval) is used within IntelliMetric to analyze a response.

CogniSearch™. CogniSearch™ is a technology designed to understand natural language; CogniSearch was developed specifically for use with IntelliMetric and is targeted directly at the accurate understanding of language to support essay scoring. CogniSearch technology uses natural language techniques to analyze student writing. For example, the engine examines sentences in relation to each other to assess coherence, concept threading, and focus. Similarly, CogniSearch parses the text to understand parts of speech and how they relate to each other syntactically. This allows IntelliMetric to evaluate the text in relation to expectations for standard written English.

Background Knowledge of the English Language. Most automated text analysis tools and research seek to evaluate or score text based on a limited, “closed” corpus of information—typically a few hundred examples of student work written to a specific topic. However, much like any one of us brings a wealth of experience of communication (writing, reading, speaking, and listening) to read a given piece of text, an effective automated text evaluation tool must have a thorough “background” understanding of the English language.

IntelliMetric possesses a vocabulary containing more than 500,000 unique words. This vocabulary is organized into a 16 million word concept net that retains an understanding of the relationships between and among words. Further, the information on parts of speech and frequency of use are stored as additional information for understanding a piece of writing that IntelliMetric may encounter. As an additional enhancement, the concept net includes a thorough understanding of these relationships within and across 37 languages.

The concept net provides a significant “leg up” in understanding text over other automated essay scoring approaches that rely on simple matrices of words or solely on rules-based text parsing. For example, IntelliMetric understands that “the computer technician is repairing your computer” is related to “the repair person is fixing the CPU.”

Principle 3: IntelliMetric is Systemic

IntelliMetric contains many individual pieces of information working in unison to produce a scoring solution that is much more than is represented by any of those individual pieces of information. The score is an emergent property of the individual features studied. For example, it is nearly impossible to characterize an automobile in terms of its component parts; they no more “add up” to a car than do the individual pieces of IntelliMetric “add up” to an essay scorer.

Systems theory also tells us that there is more than one way to arrive at the correct answer. This is important to understanding IntelliMetric. At the risk of oversimplification, different combinations of features taking on different values can all lead to similar scoring decisions.

This is in sharp contrast to other attempts at automated essay scoring that rely on purely statistical models. For example, at a gross level, one can achieve a high score with a significant development of well-organized content that lacks in the areas of mechanics and grammar or achieve that same score with somewhat less development and somewhat less sophisticated organization by excelling in sentence structure.

Non-linear. Other automated essay scoring systems are based on what statisticians call the General Linear Model. Linear, in this context, means that when looking at two variables, as one quantity increases the other increases a proportional amount in a straight line. This approach would have us believe that as the values of the text features increase, the score increases in a lock-step fashion in a straight line. This approach is overly simplistic and ignores the complexity of understanding human text and represents a significant departure from a systems approach that recognizes understanding as both nonlinear and multidimensional.

Principle 4: IntelliMetric is Inductive

Inference. You may remember back to grade school that there are two basic types of reasoning: inductive and deductive. Deductive thinking applies a general principle to a specific situation (general to specific); inductive reasoning derives a principle from several example situations (specific to general). Inductive reasoning is based on using several specific instances to form a generalization, whereas deductive reasoning starts with a generalization that is applied to specific instances. They are two different sides of the reasoning coin.

IntelliMetric is largely an inductive process; it is inferential rather than rule-governed. IntelliMetric makes inferences about how an essay should be evaluated based on its acquired knowledge from specific examples previously evaluated by experts. Again, IntelliMetric models the human scoring process by using information gained from “reading” the text to make an inference about the score to be assigned. IntelliMetric makes an inference based on several pieces of information in the form of the features of text in the major feature categories previously described. By examining these features of the text, IntelliMetric can make an inference as to what score should be assigned.

Preponderance of Evidence. In making inferences, IntelliMetric need not have the complete and absolute answer; it can make use of many sources of information and make decisions based on the preponderance of evidence. At the core of IntelliMetric is an embarrassment of riches—many, many sources of information from which to draw upon to make a judgment about the quality of an essay. Rather than relying on a single source of information, IntelliMetric looks to this variety of sources. The preponderance of evidence is the basis for the decision; all factors need not point to the same evaluation.

Pattern Matching. We would simply be overwhelmed with too much information, and it would be far too slow, if we statically reviewed every piece. We would all like to believe that we carefully process each piece of information available to use and, after developing a complete understanding of that information, we take action. On the contrary, it is now widely believed that much of how we think and interpret the world around us is based on pattern matching—a simultaneous interpretation of key pieces of information against a background of historical information to form a reasonable picture.

One area where this process of pattern matching has been studied extensively is the process of human vision. It appears that we create a picture of what we “see” by filling in the information based on only partial information.

A students’ score is a function of a combination of writing features previously identified as important characteristics of student writing. Similarly, IntelliMetric explores the pattern of writing characteristics to provide an evaluation. While any given response is unique, the overall pattern can be matched to the pattern seen for examples at each score point from prior scoring. Much like human judgments, the evaluation of a response emerges from the overall pattern of features seen in the response.

Greenspan and Shanker (2004) provide an enlightening discussion of the central role of pattern matching in communication. Analyzing infant and child communication, they provide support for the criticality of pattern matching within communication. In short, the developing child learns to interpret a complex array of cues including facial expressions, tone of voice, gestures, postures, and later, linguistic cues as patterns that lead to the satisfaction of physical and emotional needs.

What is most interesting is the role that ignoring information plays in making communication effective. It is not so much the ability to focus on the relevant aspects of a communication, but rather the ability to ignore non-salient information. In fact, the success of interpreting a communication—whether a letter, an essay, or a conversation—lies in the ability to not only identify the salient information but ignore information that does not contribute significantly to the overall meaning.

This is among the key features that distinguish IntelliMetric from other primarily statistically based models. Unlike purely statistical models that rely on a static set of text features and values consistently applied from response to response, the underlying architecture of IntelliMetric is predicated on arriving at judgments that are founded on the preponderance of evidence and ignoring information that is not consistent with the pattern observed.

Principle 5: IntelliMetric Uses Multiple Judgments Based on Multiple Mathematical Models

Hybrid of Techniques. Most attempts at automated essay scoring rely primarily on a single mathematical methodology. Techniques used include linear regression, Bayesian Analysis, and Latent Semantic Analysis. We recognize the value of these approaches and have incorporated these underlying concepts in the development and implementation of IntelliMetric. But unlike other automated essay scorers, IntelliMetric creates several independent judgments or separate scores.

A Panel of Experts. The independent judges are treated like a "panel of experts." In the human essay scoring arena, it is better to have several judgments of the score rather than a single judgment. This is no less true in automated essay scoring. IntelliMetric calculates likely solutions (potential scores) from the different mathematical models and sources of information ("electronic experts"). IntelliMetric then combines this information using proprietary algorithms to obtain the optimal solution, or more simply, the solution that is most likely to produce an accurate score. This approach produces the most stable and accurate score possible.

In short, rather than relying on a narrow single method and limited information, IntelliMetric draws from several approaches to produce the most accurate results. Since any single judge is less reliable than several judges, relying on a broader array of information and looking to the optimal solution improves the accuracy and stability of IntelliMetric scoring decisions.

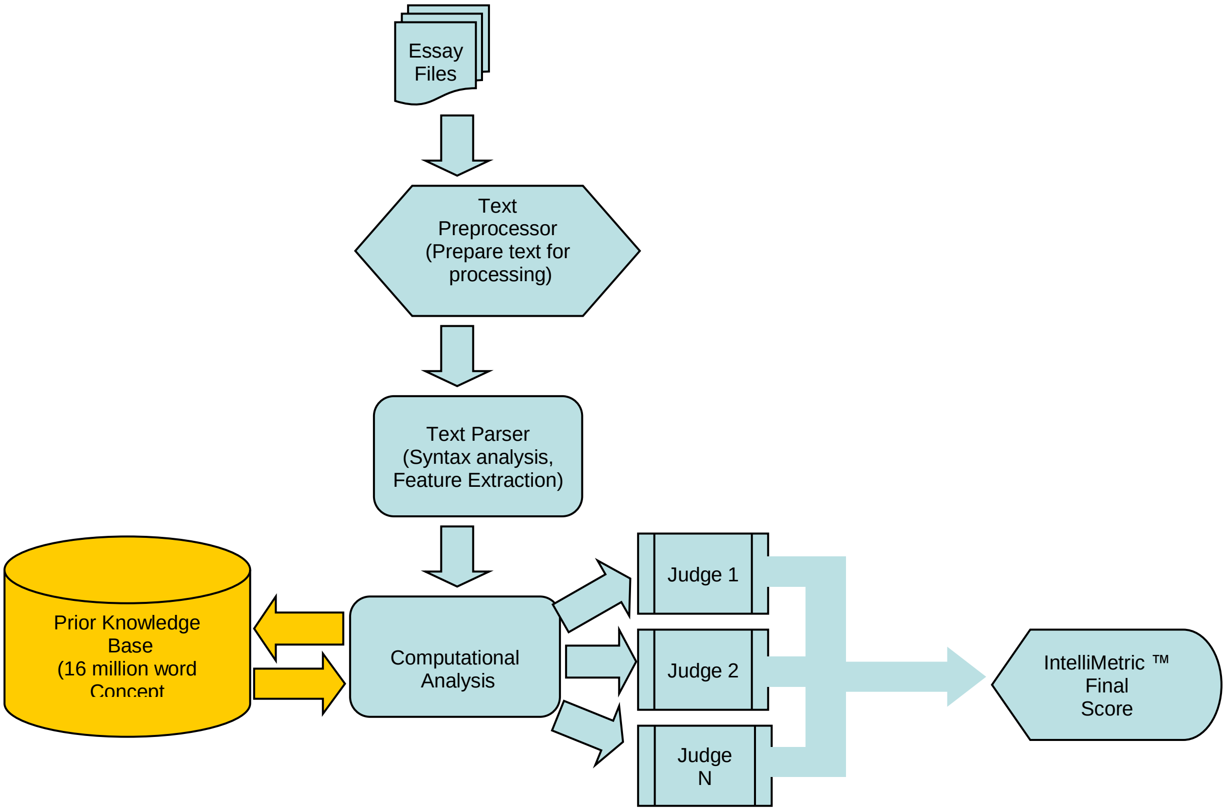
IntelliMetric Process

To this point we have examined the theoretical and conceptual basis for IntelliMetric. This section describes the specific process IntelliMetric uses to score essays.

Overview of the Process. IntelliMetric uses a multi-stage process to evaluate responses. First, IntelliMetric is exposed to a subset of responses with known scores from which it derives knowledge of the scoring scale and the characteristics associated with each score point. Second, the model reflecting the derived knowledge is tested against a smaller set of responses with known scores to validate the developed model. Third, after making sure that the model is scoring as expected, the model is applied to score novel responses with unknown scores. Using Vantage Learning's proprietary Legitimatch™ technology, responses that appear off topic, are too short to score reliably, do not conform to the expectations for Standard American English, or are otherwise unusual are identified as part of the process.

IntelliMetric evaluates an essay in significantly less than one second; however, to provide a better understanding of how IntelliMetric works, this process is broken into steps presented in Figure 2 and accompanied by a description of the individual steps.

Figure 2
IntelliMetric Architecture


Essay Files
Text Preprocessor (Prepare text for processing)
Text Parser (Syntax analysis, Feature Extraction)
Prior Knowledge Base (16 million word Concept
Computational Analysis
Judge 1
Judge 2
Judge N
IntelliMetric ™ Final Score

Step 1: Create Essay Files. IntelliMetric requires that essays be provided in electronic form (ASCII text). Essay responses can either be transcribed versions of handwritten essays or essays entered electronically. IntelliMetric can accept information as an individual response or as a "batch" of many responses. Increasingly, information is submitted using the Internet as part of a broader educational application, such as MY Access®.

Step 2: Preprocessing. After the information has been received in electronic form, IntelliMetric prepares the information for further analysis. This preprocessing stage makes sure than all materials are in a form that is readable and understandable by IntelliMetric. The preprocessor removes extraneous characters and corrects formatting.

Step 3: Analyze Text. Once converted to a usable form, the text is then parsed using Vantage's patented natural language processing engine to understand the syntactic and grammatical structure of the language in which the essay is written. Each sentence is identified with regard to parts of speech, vocabulary, sentence structure, and concept expression. Several patented techniques are used to make sense of the text including morphological analysis, spelling recognition, collocation grammar, and word boundary detection. A 500,000 unique word vocabulary and 16 million word concept net are consulted to form an understanding of the text.

Step 4: Calculate Information. After all the information has been extracted from the text, it is translated into numerical form to support computation of the mathematical models. This process relies on a variety of statistical techniques and computational linguistics to create the more than 400 features described earlier.

Step 5: Evaluate Text Based on Virtual Judges (Mathematical Models). The information obtained from Step 4 is used to determine mathematical models that make judgments about the score to be assigned to an essay response. Rather than relying on a single "judge" or mathematical model, IntelliMetric employs multiple mathematical judges ("virtual judges") based on a variety of techniques.

While the number of judges used by IntelliMetric varies depending on several factors, they all share certain things in common. At the highest level, each judge seeks to associate the features extracted from the text with the scores assigned in the training set in order to make accurate scoring judgments about essays with unknown scores. They differ with respect to the specific information used to score and, more importantly, the underlying mathematical model used to make judgments. Several statistical, AI, and machine learning methodologies are used to create judges.

In the development stage for a new prompt or topic, this step actually creates the mathematical models or "judges" to be used. After the models have been created, this step would simply apply the mathematical understanding to a novel essay response.

Step 6: Resolve Multiple Judges' Scores. Step 5 yields several possible judgments. Using a proprietary mathematical model, IntelliMetric integrates the information obtained from the judges to yield a single accurate, reliable, and stable score. This is much like human scoring situations where multiple scorers evaluate an essay response and some model must be applied to integrate those diverse opinions.

How Do We Know IntelliMetric Works?

Over the past 20 years, more than 200 studies using IntelliMetric were conducted. We have compared the scores assigned by IntelliMetric to the scores assigned by human experts for the same set of essays. We looked at how often two experts agreed on what score to assign an essay and compared that to how often IntelliMetric agreed with the experts. We have compared IntelliMetric to the experts in studies looking at K-12 students, college admissions candidates, higher education students, and graduate school admissions candidates, to name a few.

In most cases, IntelliMetric was more likely to agree with either expert than two experts were to agree with each other. For example, when we looked at student responses to an eighth grade writing test, IntelliMetric scores agreed with the experts about 98% of the time; the two experts agreed with each other 96% of the time. These findings vary somewhat from study to study, but all in all, we typically have found that IntelliMetric agrees with experts about 95% to 100% of the time—as often as, or more often than, experts agree with each other.

Another way we verified that IntelliMetric works was to compare the scores assigned by IntelliMetric to the average score across many experts. We assumed that the average score of about 8 to 10 experts was a pretty good estimate of the "real" score for an essay. We looked at how often IntelliMetric agreed with the average expert score and found that the scores assigned by IntelliMetric agreed with the average scores significantly more often than any individual expert's score agreed with the average score. In fact, not one of the individual experts did as well as IntelliMetric in comparison to this average score.

The third major way we have looked at IntelliMetric is in comparison to other ways of measuring writing and language skills. In other words, we asked, "Does IntelliMetric tend to agree with the evaluations of student skills offered by other measures such as multiple choice tests, independent teacher judgments, etc.?" We found that IntelliMetric agreed with teachers' judgments of student writing, student SAT scores, multiple choice writing tests, and several other instruments as much as, or more often than, the scores assigned by experts agreed with these measures.

Based on these studies, we know that IntelliMetric shows stable results across samples; agrees with expert scoring, often exceeding the performance of expert scorers; accurately scores open-ended responses across a variety of grade levels, subject areas, and contexts; and shows a strong relationship with other measures of the same writing construct.

IntelliMetric seems to perform best under the following conditions:

- **Larger number of training papers.** 300+ (although models have been constructed with as few as 50 training papers).
- **Sufficient papers defining the tails of the distribution.** For example, on a 1 to 6 point scale it is helpful to have at least 15 papers defining the "1" point and the "6" point (although, models have been constructed with few or no papers at the extremes).
- **Larger number of expert scorers used as a basis for training.** Two or more scorers for the training set seem to yield better results than one scorer.
- **Six-point or greater scales.** The variability offered by 6 as opposed to 3- or 4-point scales appears to improve IntelliMetric performance.

- **Quality expert scoring used as a basis for training.** While IntelliMetric is very good at eliminating “noise” in the data, ultimately the engine depends on receiving accurate training information.

Under these conditions, IntelliMetric will typically outperform human scorers.

Conclusion

IntelliMetric is an advanced artificial intelligence application for the evaluation and scoring of open-ended responses to open-ended essay questions. Applying a variety of advanced technologies, IntelliMetric scores student responses to open-ended questions as accurately as expert human scorers. Through a complex array of techniques, IntelliMetric can evaluate essay responses, providing virtually instant feedback, dramatically reducing costs, freeing up valuable instructional time, and improving student writing.

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