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Modeling *Meaningful Use* as Utility in Emergency Medical Services

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***Abstract*—This paper describes a case study focused on identifying and modeling opportunities to support emergency medical services (EMS) with next-generation interactive technologies. The method used is a novel integration of different approaches including scenario-based design, task analysis, and utility-based interaction modeling. The goal of the project is to develop a structured model of EMS activity and to identify where and how this activity can be supported with current and emerging information technologies. Of particular importance is identifying tasks with the highest potential for *meaningful use* of these technologies. The SUMMIT method and tool set is being used to model meaningful use as a function of the overall utility (benefits, costs, and risks) potentially derived from technology support. The paper provides a description and rationale for the approach and gives lessons learned from the early phases of the project. The SUMMIT approach may be generally useful for organizations that need to understand how new interactive technologies might provide meaningful support for healthcare operations. These models may also be an effective resource for promoting continuous learning and reflection on EMS skills.**

Keywords*—*healthcare informatics, usability, meaningful use, emergency medical services

I. INTRODUCTION

The metric *meaningful use* is increasingly applied to measure the real impact of new healthcare technologies to the organizations where they are implemented. Of particular importance is the 2009 American Recovery and Reinvestment Act [1], which stipulates that organizations applying for incentives for adoption of electronic healthcare records (EHR) must show that this technology is being used in a meaningful way. The U.S. Government has provided definitions and suggested measures to assess meaningful use [2], but more work is needed to help healthcare organizations justify and measure the effectiveness of their information technology investments.

This paper describes an approach to evaluating and designing meaningful use scenarios for interactive healthcare technologies. The approach, called SUMMIT, is a novel integration of both established and emerging methods in human-computer interaction including scenario-based design and evaluation, task analysis, and utility-based interaction modeling. SUMMIT is a structured approach to understanding human activity in context and to identifying and assessing ways that this activity can be supported with information technology. Products of the SUMMIT approach include specifications of core organizational activities, a technology and information architecture to support these activities, and measures of the relative utility (benefits, costs, and risks) of supporting different activities.

The paper first describes the goals and context of the case study, which is being undertaken within an emergency medical services organization. It then details how the SUMMIT approach is being used to understand EMS healthcare operations, and provides examples drawn from an evolving SUMMIT model being developed at a study site, Centre LifeLink EMS in Centre County, Pennsylvania, in the United States. Finally, some general suggestions and lessons learned are provided to help researchers and healthcare organizations understand whether the SUMMIT model provides an appropriate framework for capturing, modeling, and measuring meaningful use.

II. EMERGENCY MEDICAL SERVICES (EMS)

Emergency medical services are the forward-facing extreme of the patient healthcare continuum. Among the most pressing challenges to effective emergency medical services (EMS) are information gathering, information capture and integration, and information use. Paramedics and emergency medical technicians (EMTs) use a variety of information management methods and tools to support on-scene decision making. Information gathering practices are however, still largely based on verbal communication with patients, family members, and bystanders; and information capture and integration is still largely done with pen and paper. Because of this, we view EMS as an information-intensive domain that is so-far under-served by available information technologies.

Emergency medical services generally perform three types of service: responding to 9-1-1 emergencies; routine transports between a patient's residence and a healthcare facility, or between healthcare facilities; and ambulance standbys at both planned (e.g. a state fair) and unplanned (e.g. a fire) events. Here the focus is on 9-1-1 emergencies and the intensive information capture, creation, communication, use, and management activities that attend these events. Ambulance 9-1-1 responses (calls) are generally categorized in one of two ways: as medical, such as a diabetic emergency or myocardial infarction (a heart attack), or as trauma, such as a broken leg at a sporting event or a motor vehicle accident. In either case, a very large quantity of information is captured in a relatively small amount of time. This includes dispatch information, the location and nature of the call; patient information, both demographics and healthcare-relevant; treatment information, what was done to address the patient's condition; and transport information, including times and mileage. Many different people may be involved in the management of this information including the local emergency response communications center; the patient, their family, friends, and bystanders; other emergency response personnel including police and firefighters; and EMS, which can include one or more EMTs and paramedics.

An ambulance crew generally consists of two personnel, either two EMTs or an EMT and a paramedic, and more than one ambulance can respond to an event depending on the circumstances. Information produced and exchanged between all parties involved in an incident can have a significant impact on patient care throughout the healthcare system. A simplified view of the EMS information flow is shown in figure 1 below.

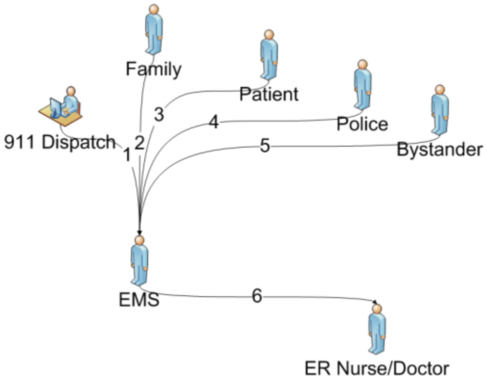


Figure 1 - Essential Information Flow in EMS

The figure demonstrates how the EMS team acts as both a collector and conduit for information about an incident, the events leading to the incident, and the progression of the patient's injury or illness. Managing this information is a challenge in the often-chaotic and time-pressured environment of an emergency in the field. This context and the importance of the information to the patient's continuum of care suggests that EMS should be equipped with the most up-to-date information technologies, that is not always or even often the case.

A 2007 report from the National Academy of Sciences [1] identified a number of pressing challenges to achieving more effective pre-hospital emergency care. These include especially that EMS is a relatively under-resourced layer in the continuity of care that begins in the field and extends through emergency departments to more specialized care facilities. The report also highlights the importance of information and communications systems integration as a key enabler of more seamless and cost-effective information sharing across different levels and functions in the health care system.

Current and emerging technologies considered especially relevant to EMS include increasingly capable mobile devices, voice control interfaces, location-aware services, and cloud computing. The potential for integration of these technologies is especially promising. Still needed though is a reference design model of an integrated EMS architecture focused on delivering critical and time-sensitive information to pre-hospital care providers. Components of the architecture should include a service layer supporting common EMS capabilities, and a presentation layer making use of emerging mobile technologies and alternative interfacing styles. Perhaps most important is to develop ways that the potential for such technologies can be understood and measured in the context of actual EMS operations.

In the sections that follow we describe an approach to modeling the ecology of the EMS information environment. The approach attempts to account both for the unique context of EMS information management, and for the need to show how increased investment in information technology can be justified by models of meaningful use.

III. SUMMIT

SUMMIT is a method and supporting software tool used for analyzing, designing, and evaluating information systems. It evolved as an approach to modeling large-scale, integrated systems of interactive technologies. SUMMIT consists of both a methodology and a supporting software tool designed to capture, model, and communicate elements of these large-scale systems. SUMMIT has been used for both design and evaluation of 'real world' systems, and in undergraduate human-computer interaction (HCI) courses as a means for students to model class projects. The SUMMIT conceptual model appears in Figure 2 and is described in more detail below.

One approach to developing information systems is to focus on identification of concrete and specific scenarios where information technology can have a real impact on organizational objectives. In the SUMMIT approach, this involves collecting, elaborating, and verifying a set of representative scenarios from stakeholders across the organization. The scenarios then become the target for further analysis focused on providing IT capabilities to support identified scenarios.

The advantage of scenario-based requirements elicitation is that it focuses on support of concrete, specific, and understandable activities, rather than on more general, abstract statements of needs [3, 4]. A scenario consists of one or more organizational stakeholders engaging in an activity supported by technology. Scenarios provide an authentic basis for imagining technology integrated into these activities as they are carried out in a specific context.

The SUMMIT methodology and supporting software application was developed as an approach to scenario-based design and evaluation [2]. The method combines scenario-based techniques with task analysis and utility-based interaction model to provide a structured view of the actual and potential contributions derived from technology use. The SUMMIT software application is essentially a database designed to model how people, activities, technologies, and information work together within a domain. The central elements of a SUMMIT model are shown in the figure below and described in the section following.

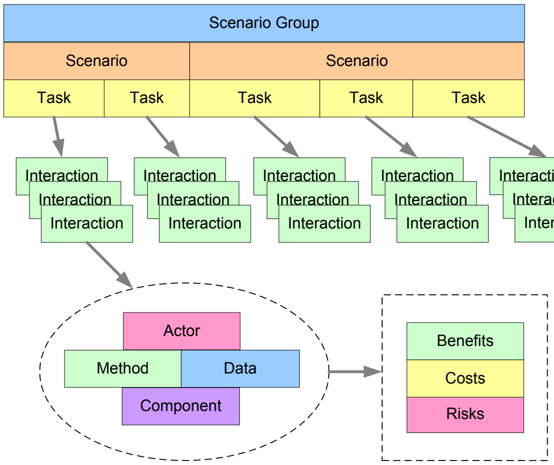


Figure 2 – The SUMMIT Modeling Concept

SUMMIT is designed to support top-down, bottom-out, and middle-first model creation so that important requirements and design information can be captured when and where possible. A sequential version of the method might include the following steps.

1. Identify and create *scenario groups*.
2. Identify and create *scenarios of use*.
3. Decompose scenarios through *hierarchical task analysis*.
4. Identify *technology interactions* at the lowest level of the task analyses.
5. Identify the *benefits, costs, and risks* (*utility factors*) associated with each technology interaction.
6. *Quantify* (if possible) the utility factors for each technology interaction.

The figure above shows how SUMMIT is used to decompose and structure a scenario into specific, discrete tasks and individual technology interactions consisting of an actor (user), method (process step), component (technology), and the data required to support the interaction. Each interaction is augmented with a set of utility factors consisting of the benefits, costs, and risks associated with providing technology support for the interaction. Important to note is that utility factors can be aggregated across interactions, tasks, and scenarios to provide a broad picture of where a particular architecture design carries the most potential utility.

SUMMIT can be used to capture and model both current, actual scenarios and envisioned scenarios of use. In the case of the former, the approach focuses on evaluation of the current situation. In the latter case, the focus is on identification of new technology requirements and selection of those requirements that promise the highest potential utility relative to the goals of the organization.

This process results in a model that explicitly relates elements of an *information ecology* to the actual and envisioned situations (scenarios) where those elements are needed and employed. For example, the model shows how a technology such as a computer-aided dispatch (CAD) system is part of the emergency scenario, including who uses it for which scenario sub-tasks and the potential benefits, costs, and risks associated with its use. One of the strengths of the SUMMIT approach and software tool is that these relationships are made *explicit* and *navigable* in the model. Users of the tool can start with a scenario, then navigate to the actor, tasks, technologies, data, etc. that are planned to engage in the scenario. Conversely, they can start with a lower level model element such as a specific technology component or data element and then work ‘up’ to model the kinds of scenarios and tasks the technology or data are intended to support.

A unique aspect of the SUMMIT approach is that it explicitly incorporates utility-theoretic ideas by linking utility factors (benefits, costs, and risks) to technology interactions that may involve one or more actor collaborating to perform a low-level, discrete task. Utility factors may be modeled as categorical data, or as categories with either actual or relative values depending on the availability of such data. Utility factors are central to the SUMMIT approach and to the training proposition presented here because they enhance training on tasks to include information on why a particular task is performed in a particular way (the benefits), the resource constraints attending task performance (the costs), and what might go wrong in the process of completing the task (the risks).

IV. SUMMIT FOR MODELING

Centre LifeLink EMS (LifeLink) is a not-for-profit healthcare organization providing emergency medical services, non-emergency ambulance transportation, healthcare training, and search-and-rescue operations. The organization serves several municipalities populated by about 80,000 people in Centre County, in central Pennsylvania. LifeLink staff includes EMTs, paramedics, billing and other back-office personnel, trainers, and administrators. Many LifeLink staff are in permanent, paid positions except for EMTs who include both full and part-time paid personnel, and part-time volunteers. The area served by LifeLink includes a very large student population, a large population of retirees, several nursing homes and assisted living facilities, and a mixture of rural and suburban residences and businesses.

LifeLink is currently in the process of upgrading their information technology infrastructure including computing and communications hardware and software, and a range of application software packages. Major application software requirements include patient care reporting, billing, ambulance operations and maintenance, staff and event scheduling, staff certification management, and training coordination. At present most of LifeLink’s hardware and software infrastructure has been upgraded and the focus has shifted to understanding requirements for application software packages.

The SUMMIT method and tool set is being used to model operations at LifeLink and to help identify requirements for application software. The project's objective is to identify key activity scenarios within the organization, to create a structured representation of the activity involved in these scenarios using task analysis, and to identify those current and prospective technology interactions with the greatest potential to contribute to the organization's mission. Current, early-phase efforts are focused on patient care reporting and the integration of ambulance operations with the billing department.

Figure 3 below demonstrates how SUMMIT decomposes a scenario, in this case an ambulance call for a patient experiencing a seizure, into a structured representation of the activities that take place as part of the scenario. The sub-task Capture Incident Location is modeled as an interaction, the lowest or terminal level of the hierarchical task analysis (HTA). In this case the interaction is envisioned, something the organization wants but does not currently have, and consists of an actor, the EMT, using a smartphone application to capture the incident location through voice recognition.

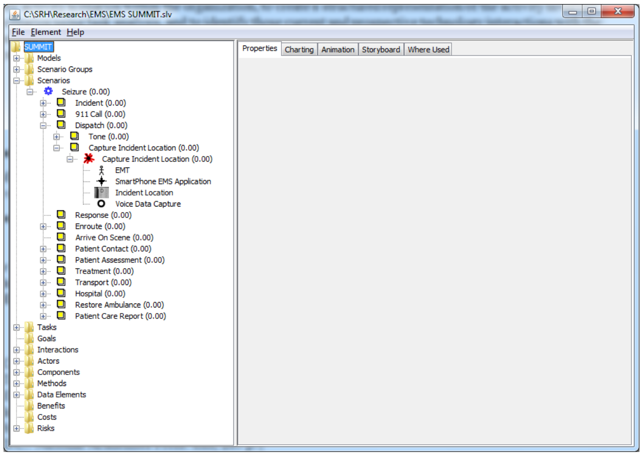


Figure 3 - SUMMIT Task & Interaction Analysis

Moving forward the project will involve capturing and modeling a catalog of scenarios representing a broad spectrum of Lifelink's ambulance operations. A series of interviews and focus groups are scheduled for the fall of 2013. One-on-one interviews are used to identify scenarios and to decompose them into task analysis and discrete technology interactions. Focus groups are used to elaborate and validate the results of the interviews and interaction analyses. The current goal is to have a comprehensive model developed by October of 2013 to support selection of a new patient care reporting package for implementation by January 2014. Interaction utilities (benefits, costs, and risks) will be used to weight the relative importance of capabilities offered by competing vendors.

V. SUMMIT FOR LEARNING

One early result from walkthroughs with EMS personnel at Centre LifeLink is the potential for SUMMIT models to be used as a training device. The SUMMIT approach and tool represents a unique integration of several different theories related to learning and practice in the emergency response domain. First, the use of 'real world' scenarios and scenario-based problem solving are widely used in medical education and training and so are familiar to any practitioner with EMT or higher certifications. Scenarios have long been employed as a means to comprehend complex situations [4]. More recent work shows how important scenarios are in helping to understand and communicate the role of interactive technologies in both individual and collaborative human activity [3]. Scenario-based training can be particularly powerful as a means to ground practice in the specific details of local events. Scenario narratives are stories that are able to avoid abstractions and generalizations that, while sometimes both necessary and useful, can serve to mask factors that determine the effectiveness of a response in a particular context.

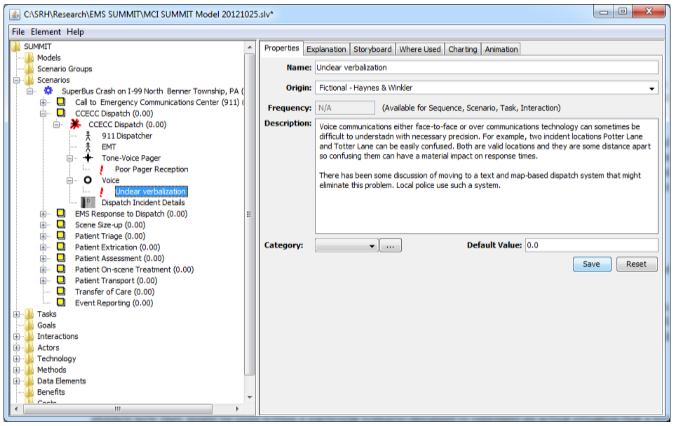
Task analysis is a widely used method for developing training and other educational content [5]. One of the underlying tenets of task analysis for instruction is that complex tasks may be best learned by decomposing them into successively simpler components which can be more easily learned. Graphical displays of task analyses as inverted trees or outlines serve to retain the position and role of an atomic task element within the context and flow of the more complex whole. A completely elaborated task analysis also shows how output from one task may serve as an input into other tasks downstream within an activity. The hierarchical structure of a task analysis supports both top-down and bottom-up learning and in this way can support a wide range of learning styles. Protocols used to guide emergency response in the United States are essentially task analyses, they detail the normative sequence of activities a responder must follow in a given category of event and are a key element of most state-specific EMS training programs. In SUMMIT, a loosely structured but detailed scenario can be decomposed into a task analysis that accounts for important local determinants of emergency response success.

We have begun development of a SUMMIT model for mass casualty incident (MCI) training. A mass casualty incident is, technically, any emergency where the effects of the incident are beyond the capabilities of available resources. For example, a motor vehicle accident with three injured people qualifies as a mass casualty incident when the available response resource is a single ambulance with a two-person crew. Normally, however, we think of MCIs as large-scale incidents or emergencies with at least tens, if not hundreds or even thousands of victims and other people affected. For the remainder of this paper we will assume the latter, less formal understanding of an MCI.

Preparedness and training for mass casualty incidents is problematic not least because of their relatively low frequency. Thankfully, large-scale MCIs are rare. Most local emergency response districts will never need to operationalize their MCI plans and training except for field exercises and table-top simulations. Because of this MCI preparedness may be considered a kind of organizational *vigilance task.* In psychology, vigilance tasks are those activities, such as air traffic control, that require constant training, preparedness, and monitoring for occurrences that are relatively rare [6]. In summary, this theory posits that because they are rare, preparedness for MCI decays or *decrements* as a function of this lack of practice. Some more recent work expands on this idea to claim that learning and skill are functions of the evolution of declarative knowledge (knowing that) into procedural knowledge (knowing how), the latter being essential in effective practice in stressful and time-constrained domains [7].

For our first MCI SUMMIT training model we have chosen a scenario involving a major bus accident. A national "superbus" company runs a service between a local rendezvous and pickup location and mid-town Manhattan. The vehicles the company runs are large, double-decker tour buses that can carry as many as 80 passengers. The route between the local pickup location and New York City includes mountainous terrain and the potential for severe weather. Accidents with tour buses do occur. For example, a recent bus crash in Oregon, in the United States, resulted in nine deaths and over 20 passengers injured. Even a relatively small-scale MCI such as this would challenge the emergency response system of Centre LifeLink EMS, as it would most rural and semi-rural emergency medical response organizations.

Though space restrictions preclude a complete depiction of the evolving SUMMIT MCI model, the figure below provides a glimpse of its general structure.


C:\SRH\Research\EMS SUMMIT\MCI SUMMIT Model 20121025.slv*

Name: Unclear verbalization

Origin: Fictional - Haynes & Winkler

Frequency: N/A (Available for Sequence, Scenario, Task, Interaction)

Description: Voice communications either face-to-face or over communications technology can sometimes be difficult to understadn with necessary precision. For example, two incident locations Potter Lane and Totter Lane can be easily confused. Both are valid locations and they are some distance apart so confusing them can have a material impact on response times.

There has been some discussion of moving to a text and map-based dispatch system that might eliminate this problem. Local police use such a system.

Category:

Default Value: 0.0

Figure 4 - Example SUMMIT Training Data View

The abbreviated example in the SUMMIT data view above provides an overview of the tools implementation, navigational scheme, and user interface. The example shows a SUMMIT interaction, designated by a red 'splat' icon labeled *CCECC Dispatch*. In the example this interaction is the only activity element of a SUMMIT task with the mirror label CCECC Dispatch (the yellow, square icon). Task may have one or many interactions as components. In this case the single interaction designates the task as the terminal node of a task analysis branch, which in turn is part of a sequence of tasks that are expected to be performed in the event of the SuperBus Crash scenario (the blue gear-shaped icon). Moving down the hierarchy shows that the actors expected to be included in the CCECC Dispatch task are the 9-1-1 Dispatcher and an EMT. These actors use a Tone-Voice pager technology to communicate Dispatch Incident Details using the Voice communication method.

An important dimension of the SUMMIT approach is the tagging of interaction elements with utility factors, the benefits, costs, and risks. The abbreviated example above shows two such utility factors. The tone-voice pager has poor pager reception as an associated risk and the voice method of communication carries the risk of unclear verbalizations. The benefits, costs, and risks associated with interaction elements are designed to convey contextual information to the learner, information that goes beyond the more simplistic declarative content to include *why* the interaction takes the form that it does (the benefits) as well as the various constraints involved (costs, risks). Utility factors represent the designers' understanding of a particular human activity and how it can be supported with technology. In this way they expose the design rationale underlying design of the interaction, and thereby enhance both technology use and general task performance by the actors.

VI. MEANINGFUL USE AS UTILITY

The objective underlying the meaningful use metric is to provide a measure of an organization's real use of technology within their stated mission and subject to all of the contextual forces that impact their ability to realize this mission. SUMMIT provides an approach to capturing and representing meaningful use by demonstrating the use of technology within specific and authentic scenarios and by showing how a technology is integrated into actual work and task flows that occur as part of these scenarios. Modeling technology-supported activity as an interaction of actors, data, methods, and (technology) components with associated benefits, costs, and risks can help make clear whether a particular technology has the potential to make a positive contribution to task performance.

Consider the hypothetical case of a hand-held, book-sized tablet designed to support EMS operations and patient care. A particular interaction such as *capture patient demographic information* can be modeled as an interaction with an EMT as the *actor*, patient demographics as the *data*, the tablet's soft keyboard as the focal technology *component*, and finger-actuated typing as the *method*. Among the benefits associated with this interaction are the time saved by capturing this information directly in an electronic medium and the accuracy and completeness associated with using an electronic form as a prompt for data capture. In SUMMIT both of these can be made explicit, quantified, and then subjected to scrutiny by stakeholders in the domain. Similarly, risks such as the fragility of the device, the fidelity of a finger-actuated soft keyboard, and both real and perceived data privacy can be captured, measured and validated.

VII. MOVING FORWARD

In SUMMIT, meaningful use is modeled and measured not just as a function of the number of times an EHR system is used to support healthcare operations, represented as a percentage per government guidelines, but also using either the actual or estimated benefits derived from system use. Using scenarios, task analyses, and technology interactions in a hierarchy of activity helps ground these measures in the work that healthcare organizations actually do, and in the goals and priorities such organizations value.

Modeling meaningful use as a function of the benefits, costs, and risks that derive from technology interactions may provide a rich representation of how interactive technology supports human activity in the healthcare domain. Some significant challenges remain, however. Among the most difficult is developing methods to identify and measure the benefits derived from new interactive technologies. In comparison, capturing interaction costs and risks are relatively straightforward. Costs are typically pre-quantified in the prices of the technologies themselves, deployment consulting, training, and employee downtime. Risks can be reasonably estimated using either historical data or through interview, focus group, and survey data collected from stakeholders. The benefits of interactive technologies to knowledge-intensive work such as occurs in healthcare are far more difficult to obtain. Clearly we need to move beyond decreased task time and decreased task errors as the only objective measures of technology effectiveness. In healthcare especially we need better tools to help understand how interactive technologies contribute to patient situational awareness, decision making, and analysis of treatment outcomes.

Emergency medical services personnel train for the use of MCI-related technologies and data, but the SUMMIT model makes clear and explicit how they might be used within a particular scenario designed to represent an actual situation that a local EMS responder might encounter in practice. Many of the claims made in this paper are so-far theoretical conjectures and a priority moving forward is to begin the process of validating the approach and obtaining evidence of its relative effectiveness for justifying information technology investment, as a resource for learning. The initiative to use SUMMIT as a training device emerged from feedback received from local EMS personnel during walkthroughs of models created to support technology selection decisions. We are planning to develop a series of SUMMIT models as training aids for EMS personnel and evaluate the approach through, in the first instance, guided walkthroughs with practicing EMTs and paramedics. Our goal is to deploy SUMMIT models as evolving resources that EMS personnel can use in interactive reviews of those emergency scenarios deemed most important for ongoing training and continuous quality improvement. Early, informal walkthroughs of the approach have shown promise and we have been encouraged by practitioners to further develop the models.

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