A WebGIS-based teaching assistant system for geography field practice (TASGFP)

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Abstract

Field practice is an important part of training geography research talents. However, traditional teaching methods may not adequately manage, share and implement instruction resources and thus may limit the instructor’s ability to conduct field instruction. A possible answer is found in the rapid development of computer-assisted instruction (CAI), a new teaching mode for the Information Age. A “virtual field trip” is an amalgam of Internet and multimedia techniques with great potential for geography field instruction, as it can arouse students’ enthusiasm and immerse them in learning. However, limited by available technology, virtual field trips have disadvantages in terms of content presentation, data organisation, and loss or inadequate representation of spatial information. To overcome the above shortcomings, a map-based, spatially correlated design method was proposed for a CAI system in geography. By integrating spatial information technology (Geographic Information System, Global Positioning System, remote sensing, etc) and information delivery methods (web services, databases, etc), a WebGIS-based teaching assistant system for geography field practice (TASGFP) was established, realising an effective spatial management scheme and forming a shared platform for instruction material. Its efficiency was verified through the actual application, although there remains room for improvement. Nevertheless, the TASGFP stands as an effective CAI tool in geography instruction.

Introduction

Field practice, as the name implies, is a study process where supervised learning can take place via first-hand experience outside the four walls of the classroom setting (Lonergan & Andresen, 1988). Geography education in general and field learning in particular are a critical component of geoscience education in each learning phase, from primary education to higher education (Downs, Liben & Daggs, 1988; Fuller, Edmondson, France, Higgitt & Ratinen, 2006; Haigh & Gold, 1993). Geography field practice is a distinctive and intriguing learning process, which offers students an opportunity to observe natural and geographic phenomena in a close way (Kent, Gilbertson & Hunt, 1997). By engagement in field practice, students can familiarise themselves with basic concepts, theory and research methods, and cultivate the practical ability to scrutinise, analyse and solve problems independently. Thus, geography field practice is a critical link between theory and reality (Healey, 2005). The differences between geography field practice and internship style instruction in other disciplines include its open learning environment (easily affected by external changes such as natural disasters or other emergencies and lacking effective instruc-
tion methods), high cost of trips (transportation, accommodation and equipment) and poor educational practices (on the part of both inexperienced teachers and students) (Haigh & Gold, 1993). Meanwhile, the teaching content of geography varies in complexity from physical to social subfields and the teaching objects vary from abstract to concrete; and limited by their cognitive ability as young people and the traditional instruction method, it is difficult for students to comprehend the mechanisms behind geographical phenomena by means of classroom instruction only (Downs & Liben, 1991).

Aiming to promote the effectiveness of geography fieldwork, scholars have begun to apply new instructional techniques in geoscience learning; one of these is computer-assisted instruction (CAI) (Kulik & Kulik, 1991). CAI was first used in geography instruction in the 1960s (Fielding, 1968); since then, it has become much easier to use and has been applied with almost every teaching method and in most subject areas of geography in higher education (Shepherd, 1985), including geography field learning. The advent of the Internet and new multimedia techniques gave birth to the virtual field trip, a novel mode of CAI for field instruction. Virtual field trips give

Practitioner Notes
What is already known about this topic
- Geography education in general and field learning in particular is a critical component of geoscience education (Downs, Liben & Daggs, 1988, Haigh & Gold, 1993, Fuller, Edmondson, France, Higgitt & Ratinen, 2006).
- Scholars have applied computer assistant instruction (CAI) in geoscience learning for many years, for example the virtual field trips (Kulik and Kulik, 1991).
- Because of technological limits, virtual field trips in the early stage were poor in terms of presentation and organisation of information (Foley, 2001).

What this paper adds
- Spatial information technologies such as geographic information system (GIS), global positioning system (GPS), and remote sensing (RS) was integrated with novel information storage and organization technologies such as relational databases and web services into a geography fieldwork CAI system.
- A spatially correlated design method was devised aiming to achieve more convenient, systematic, and useful support for CAI in geography field instruction. The main content of this method is taking map data as the principal element and spatially correlated teaching resource management.

Implications for practice and/or policy
- Provide a new design idea and implement mode for CAI system for geography field instruction.
- GIS, Web service, and spatial database are adopted to correlate common media with spatial data, represent all of these data on the map and manage them in the same database.
- Spatially correlated links are applied to replace traditional hyperlink. It makes instruction materials surrounded by relevant geographic information and helps students comprehend the complicated geographic phenomena.
- The TASGFP’s cross-platform mode makes the system widely deployable across institutions and users, and hence, usable as a platform for sharing teaching resources on practice bases.
students and teachers safer and more convenient access to field learning at a relatively low cost, allowing more and more geography students to enjoy the amazing experience of nature and other cultures. However, because of technological limits, virtual field trips in the early stage were poor in terms of presentation and organisation of information (Foley, 2001). Instruction materials such as pictures or texts were generally stored in file directories and organised by hyperlinked; this is an inefficient data access method that ignores spatial relationships among the information and a poor organised mode that lacks spatial operations, such as precise spatial localisation or rapid spatial retrieval. These bottlenecks hinder the further development of CAI in geography fieldwork.

To break through the bottleneck, spatial information technologies such as Geographic Information System (GIS), Global Positioning System (GPS) and remote sensing (RS) were integrated with novel information storage and organisation technologies such as relational databases and web services into a geography fieldwork CAI system. Finally, based on consideration of the characteristics of geography fieldwork and of the potential of new techniques for field instruction, a teaching assistant system for geography field practice (TASGFP) was established with the Lushan Practice Base (Lushan Mountain, Jiangxi Province, China) as an experimental site. The system implemented a spatially correlated design method aiming to achieve more convenient, systematic and useful support for CAI in geography field instruction.

Geographic fieldwork and cognitive development of college students

Geoscience and geography fieldwork

Geoscience is the study of the composition, structure and physical dynamics of the Earth (Gonzales, Keane & Martinez, 2009). Geography fieldwork can provide geographers with first-hand experience observing and measuring the Earth’s structures and processes in their natural context.

Like other scientific activities, fieldwork involves both observation and interpretation. The essential difference of field science from laboratory or theoretical science is that in the former, observation and interpretation take place in a more expansive, complicated and fluid arena. Geography fieldwork can be divided in general into three main components: data acquisition through direct observation and measurement, organising the data into representations such as maps and diagrams to generalise and interpret findings and constructing histories and proposing operational mechanisms for structures and processes to explain observation data and predict the future situation (Compton, 1985).

Geographic field practice instruction

In primary and secondary education, geographic field practice instruction (“outdoor activities”) can raise learning interest and achievement and provide students freer access to geoscience (Lai, 1999; Nundy, 1999). In higher education, in contrast, geographic instruction contexts become more systemic, professionally oriented and abstract, and so, concrete fieldwork and the concrete perspective it provides become an essential component of geoscience education and the core of geography (Jenkins et al, 1991). In developed countries such as the UK, well-planned field learning dates back to the 19th century (Ploszajska, 1998); it is now also a very common method in the USA (May, 1999). Meanwhile, in developing countries such as China, hampered by funding shortages and poor infrastructure, the importance of fieldwork has just recently become acknowledged (Egunjobi, 2009; Li, Kong & Peng, 2007). Regardless, geography field practice is key to training research talents specialising in geography and to the development of the geographic sciences (Scott, Fuller & Gaskin, 2006).

Geoscience literacy and cognitive development

Geographic field practice is key to geography research and instruction. Then, what is the pivotal factor for transfer of geoscience knowledge in the field? From the perspective of cognitive develop-
ment theory, the effectiveness of geographic field instruction depends upon learners’ geoscience literacy and cognitive developmental level, and geographic education and cognitive development are intertwined during instruction (Downs & Liben, 1991). Hence, geographic instruction should reflect students’ geographic understanding as well as their cognitive, psychological and social development.

The fundamental factor influencing geographic instruction is the student’s prior knowledge about the geographic phenomenon, that is, his or her geoscience literacy—as defined by the Earth Science Literacy Initiative (2010), is a set of basic ideas and skills that characterise an Earth science literate person. A geoscience-literate person will have a fundamental understanding of how scientific research is conducted and will be able to actively construct scientific knowledge rather than simply assimilating a canonical body of knowledge (Bransford & Donovan, 2005). Another influential factor is the learner’s cognitive developmental level, referring to the cognitive structures providing the fundamental intellectual prerequisites for understanding any domain of knowledge (Granshaw, 2011). Students can use these general cognitive skills to understand geographic concepts.

Critical thinking in geographic field instruction
Critical thinking is the intellectually disciplined process of actively and skillfully conceptualising, applying, analysing, synthesising and evaluating information gathered from or generated by observation, experience, reflection, reasoning or communication, as a guide to belief and action (Scriven & Paul, 1987a, 1987b). Critical thinking is generally associated with the higher levels of cognition—analysing, synthesising and evaluating—in ascending order of precedence and maturity (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956). Therefore, cultivating critical thinking is an important part of cognitive development.

Critical thinking enables students toanalyse, evaluate, explain and restructure their thinking, meanwhile decreasing the risk of adopting, acting on or thinking with a false belief. To promote critical thinking, students should increase their understanding of scientific theories through individual exploration of concepts and debate employing these concepts, not just rote learning (Driver, Newton & Osborne, 2000). Teachers should help students form their own conceptions, for example, through direct experience of field practice, putting geography instruction in the context of the real geographical environment (Nairn, 2005). Because of the unconstrained nature of field situations, fieldwork requires investigators to contend with incomplete data and solve problems with multiple solutions. Consequently, field experience is a rich venue for teaching students strategies for dealing with uncertainty in problem solving.

In summary, the goal of instruction is to foster expertise in a discipline. This requires well-designed curriculum pedagogy matched to students’ cognitive abilities and current understanding.

CAI in geographic field practice instruction
The constraint factor in geography field practice
Geographic field practice instruction differs from traditional classroom instruction in terms of teaching environment, content and resources, complexities that can decrease the effectiveness of field practice (Kent et al, 1997; Lonergan & Andresen, 1988). Geography field practice furnishes students with a platform to conduct teaching and learning processes in close contact with nature; however, it also poses procedural difficulties due to the features of specific teaching environments (Haigh & Gold, 1993). Ordinary instruction is done in a fixed location, the classroom, while field practice takes place in a variety of “open” locations and environments whose features may be unpredictable (Lonergan & Andresen, 1988). Teaching in field practice thus needs to consider features of locales, teachers and students and the possible interference from externalities such as weather and noise. (Fuller, Gaskin & Scott, 2003). Thus, open instruction poses a challenge both to teachers and to students (Dolmans & Schmidt, 1996).
Knowledge conveyed in the classroom is mainly abstract, while the content of field practice is concrete and real; thus, there is a huge gap between them (Kent et al., 1997). Other obstacles to effective field practice include lack of useful preparation time and lack of instruction time (Haigh & Gold, 1993).

Similarly, the range of teaching resources in use is diverse and complex, and many of them are difficult to use in the field (Dunn, 1992). Because teaching in the field largely constitutes oral instruction, it is not generally easy to develop or implement field teaching resources or materials. In addition, although many institutions may choose the same sites for field learning (the ones perceived as most promising), there is no convenient platform for them to share teaching and learning resources, and the rate of sharing is low.

Finally, geographic field practice also challenges teachers involved in class preparation, as, for example, they cannot employ blackboards or slides. Traditional instruction thus has difficulties meeting the needs of geographic fieldwork in several ways, and new technology should be utilised to achieve teaching goals in the field (Nellis, 1994; Shepherd, 1985).

CAI and virtual field trips

Starting in the 1960s, it has been proved that CAI can indeed enhance instructional efficiency and effectiveness (Atkinson, 1968; Kulik & Kulik, 1991). Furthermore, in the last 20 years, the rapid proliferation of computer technologies such as virtual reality, network technologies, multimedia technologies and system-integrated technologies has reinvigorated CAI (Armstrong & Bennett, 2005; Dykes, Moore & Wood, 1999; van Joolingen, de Jong, Lazonder, Savelsbergh & Manlove, 2005), and has enabled the virtual field trip, a new application of CAI in geographic field practice. A virtual field trip is a simulated, real-time field trip or guided exploration consisting of an interrelated collection of images, texts, videos or other information media covering a specific theme, delivered to the public via web browser (Dykes et al., 1999). The first virtual field trip program, LEARNZ, appeared in 1995 and became very popular by the 21st century (Stainfield, Fisher, Ford & Solem, 2000). Nowadays, there are different formats of virtual field trips. Some just consist of a list of links, while others allow navigation throughout the field trip. In our opinion, the best virtual field trip implementation should consist of interactive pages on the Web, selected by educators and arranged such that they can be explored in either a linear or a non-linear fashion. Virtual field trips are cost-effective for schools, as they eliminate the costs of renting transportation, insurance coverage and chaperones. Because of their simplicity to operate and lively presentation, they are suitable for elementary school students as well as older students.

In traditional virtual field trips, materials such as pictures or texts were presented as hyperlinks and stored in file directories, an inefficient data access method that furthermore ignores spatial aspects, such as spatial position and spatial relationship. Thus, there is room to apply spatial information technology to extend the functions of virtual field trips.

Spatial information technology

Spatial information technologies include GIS, GPS, RS and spatial data management (Brodnig & Mayer-Schonberger, 2000). GIS integrates functions to capture, store, manipulate, analyse, manage and present geographical data (Audet & Abegg, 1996). GPS offers high-accuracy 3D coordinates for an object, and RS gives an immersive and realistic experience of an environment that is much better than a traditional 2D map.

Besides the new possibilities provided by spatial information technology, progress in information handling, for example, databases and web services, also makes the implementation of a more efficient and stable application system possible. The database provides a unified management mode for a large amount of data, and web services offer a distribution presentation platform for multi-users through the Internet.

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Geography field practice in higher education in China and the Lushan Practice Base

Modes of geography teaching in Chinese higher education

In China, many comprehensive universities, such as Peking University and Nanjing University (NJU), already had geography departments by the early 20th century. These universities have traditionally had abundant human and material resources to support instruction in geographic field practice and have usually organised annual field trips for undergraduate geography majors, a practice also followed by other universities (Li et al., 2007). In these universities, the core undergraduate geography curriculum covers both physical and human geography, including subfields such as geology, physiognomy, hydrology, climate, vegetation, soil, tourism, environment, transportation, planning and so on (Fazhan & Zhihua, 2007). With recent developments in spatial information technology, courses on GIS, RS, GPS and other new technologies have also been incorporated into core curricula to give students a wide perspective on geography as a science. After initial theoretical instruction, students go on an integrated geography field trip in a selected area. Through this field trip, they get a better understanding of basic field knowledge and form their own opinions about the relations between theory and reality or theory and practice.

Lushan Practice Base

Field practice usually relies on a practice base, generally a natural region representative of its type. Lushan Mountain and its surroundings have these traits in exemplary form (Jiu Miao, Zong Ying, Fu Cheng & Ye Gen, 2000).

Bordering the Yangtze River in the north and Poyang Lake in the east and northeast, the Lushan region exhibits diverse geology and physiognomy—the renowned mountainous area, piedmont hills and a waterfront plain, as shown in Figure 1. Seated in a transitional zone between the central and north semi-tropics, the ecosystems of Lushan are typical and diverse, with conspicuous vertical differentiation of natural elements. Lushan has been designated a “world cultural landscape” and a “world geological park” by United Nations Educational, Scientific and Cultural Organization and its research value for human geography and physical geography has been recognised worldwide. Figure 2 shows some natural and cultural landscapes and scenic spots in Lushan. Convenient transportation infrastructure is another advantage of Lushan Practice Base. Many Chinese higher education institutions have long-established field practice bases in Lushan. Their field practice may cover many domains, such as geology, physiognomy, hydrology, meteorology, vegetation, soil, ecological environment and human geography. Fieldwork is usually divided into two stages—an outdoor investigation stage and an indoor stage of sorting field records. In general, in Lushan, the outdoor stage covers almost the whole area (Figure 3 shows...
the distribution of practice locations and routes. During the indoor stage, students concentrate on analysing samples, sorting photos and pictures, and finally preparing a summarising practice report. This may be done anywhere.

**TASGFP**

Based on a systemic analysis of the characteristics of geographic fieldwork and successful CAI applications in geography education (Brunner-Friedrich, Lechthaler & Simonne-Dombovari, 2011; Jacobson, Militello & Baveye, 2009), a WebGIS-based TASGFP was established with the support of network technology and spatial information technology. This system provides a more effective approach to storage and sharing of teaching resources to facilitate students’ access to materials and their learning.

**Design blueprint of the TASGFP**

The main design characteristics of this TASGFP are as follows:

1. **Taking map data as the principal element**

As field practice is an outdoor activity, the efficiency of instruction relies on the spatial features of practice locales, and maps are the historic medium of spatial information (Laurini & Thompson, 1992). Map data are the principal element of the TASGFP.

As shown in Figure 4, the main interface is laid out using digital spatial information on Lushan’s terrain, transportation networks, hydrological conditions, field instruction material and so on. To manage these map data, a layer control module presents each map layer according to user

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**Figure 2:** Some selected pictures. (a) Poyang Lake and Sand Mountain; (b) Guling Town; (c) Sandie Waterfalls; (d) Global Geopark
requirements. For convenient operation, the system’s other functions are also constituted as function icons at the bottom of the interface: basic map operation, object identifying, GPS location and JPEG exportation. Thus, the system’s internal details are kept unobtrusive so users can concentrate on their own tasks.

2. Spatially correlated teaching resource management

All instruction materials are associated with high-precision real-time coordinates on the map, secured using mobile GPS. A spatially correlated teaching resource management method was designed to manage the spatial correlation of these materials: first, a practice locale is located on the map by its coordinates, and then video, picture and audio teaching resources concerning related geographic phenomena are linked to the locale as a central hub (see Figure 5).

Guided by this concept, the Practice Points module is the nucleus of the TASGFP. It manages the spatial positions of practice locales and related content by arranging locale names in tabular form.

Figure 3: Distribution of practice locations and routes
Figure 4: System main interface

Figure 5: Principal design concept of the teaching assistant system for geography field practice (TASGFP)
and displaying them at the proper map coordinates when they are selected. At the same time, knowledge points related to the locale are shown. For instance, as shown in Figure 6, the practice locale Huanglong Temple involves four knowledge points, respectively related to climate, humanities, soil and vegetation. Teaching resources of various types are then connected to these knowledge points. Figure 7 shows a picture viewer that presents photos taken in practice locales using the Video Scanning module; similarly, the media players play video and audio resources derived from field practice. This is expected to be a more compelling approach than traditional hyperlinking. Last, a Practice Route module allows practice locale management, realising conversion from practice locale to practice route as needed.

In terms of instruction material in special topic, the Scenery Sites module and the Theme Knowledge module are added into the system. These modules integrate renowned scenic spots and special material (such as Lushan’s characteristic villa group) into the system and present multi-media materials on them. These enrich system content and facilitate students about Lushan Practice Base. Overall, these modules integrate discrete teaching content and allow unified management of it.

In addition, the TASGFP also provides a special function called roaming, based on the concept of a “street view map.” Along the practice route, continuous video is recorded in a walking or driving mode with exact coordinates from GPS. Figure 8 shows video of roaming scenes from a driving perspective. The actual conditions on both sides of the street are presented. The yellow car icon indicates the path along which the car moves; when the car reaches a given position, the video window presents information specific to that position.

Using these management functions, not only can the general geographic environments of practice locales be learned through the maps, but practice content can also be stored and managed. The grouping of different locales and their associated practice points into a practice route is a convenient and effective arrangement. Because the design of the practice locales determines the
Figure 7: Practice picture query

Figure 8: Virtual scene navigation
success or failure of field practice as a whole, we group practice points according to their relevance and get the distance between each practice locales. This allows better planned and more efficient field trips.

The implementation techniques of the TASGFP
To realise this design, we needed to adopt a system that handles spatial data well. GIS was selected to achieve our goal. It integrates functions of acquisition, storage, manipulation, analysis, management and presentation for geographical data (Audet & Abegg, 1996). Meanwhile, for better accessibility and operability, the TASGFP was designed as a cross-platform interactive system based on a network model. WebGIS is a GIS system designed for the network environment to meet these demands (Dragićević & Balram, 2004).

TASGFP data are complex and diverse in type, format and storage mode, and the design concept of the TASGFP is that it should be able to relate all of these data to the practice locale. To do so, a relational database is combined with a spatial data engine, ArcSDE, to store and manage spatial as well as ordinary data (Rui, Huang & Chang, 1999).

As the TASGFP is designed for both students and teachers across various institutions, it is necessary to be able to set different degrees of access. The system administrator has authority to perform any operation related to the system and database, such as revising system functions or architecture and data manipulation; teachers in different institutions can do data entry, while students can only browse and query.

The establishment of the TASGFP
The establishment of the TASGFP comprised three main phases: material collection, system implementation and system deployment.

The first phase was conducted mainly in 2010. A requirements survey was conducted before field practice, determining what kind of instruction materials should be used. A whole class and their guider from the School of Geographic and Oceanographic Science (SGOS) of NJU were selected as respondents. First, we asked them some questions about their experiences and preparations for a class field trip to Lushan. Then, their whole field trip was tracked by recording photo, video, audio and coordinate information during instruction and activities. In all, we collected 55 audio records, 644 photo records, and 45 video records, for a total of 4.08 GB of information. The second phase, architecture design and module coding, was conducted mainly in 2011. On the basis of the information collected in the first phase, a database was built on the data server and basic map data were prepared on the GIS server. Then, function modules were established to enable data operations in the data server, spatial operations in the GIS server and presentation functions in the web server. Finally, the TASGFP was deployed on the NJU intranet in 2012, accessible to staff and students across campus. To ascertain its reception, a survey was carried out among SGOS students who would attend Lushan field practice in fall 2013. The number of subject is 109. The majority of these students (80.7%) thought the TASGFP was an interesting and fruitful way to get basic information before the field trip, but could not replace the practice guidebook, which was more systematic and comprehensive.

Discussion
The key characteristic of TASGFP is the Taking Map Data as the Principal Element and Spatially Correlated Teaching Resource Management. To realise this characteristic, GIS (the main map service), web service and spatial database are adopted to correlate common media such video, picture and audio with spatial data from GPS and RS, represent all of these data on the map and manage them in the same database. On the web client, spatially correlated links are applied to replace traditional hyperlink. It makes instruction materials surrounded by relevant geographic information and helps students comprehend the complicated geographic phenomena.

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The TASGFP’s cross-platform mode makes the system widely deployable across institutions and users, and hence, usable as a platform for sharing teaching resources on practice bases. The TASGFP also unified architecture that can refer easily to other applications. Thus, the system can be applied to other practice bases simply by modifying map data and instruction data.

Although new design ideas applied in the TASGFP have overcome the drawbacks that recent field instruction CAI has faced in terms of presentation and organisation of spatial information, further improvements can still improve the system.

First, the spatial attributes of instruction have not been fully exploited nor has the power of spatial information technology. At present, instruction materials are organised and managed to correlate with spatial attributes; in the next step, spatial statistics and analysis (spatial buffers, overlays, map algebra, etc) will be integrated into our system to explore the spatial information intrinsic to the instruction materials.

Second, the method for instruction materials is mainly traditional (picture, video, audio). The only new method is roaming, which combines video and spatial information based on the concept of a “street view map.” As traditional media is poor to represent spatial information (Carr, 2002), new presentation method, such as virtual reality (Huang, Jiang & Li, 2001), should be added into our system.

Third, another potential problem for the TASGFP is setting common standards for instruction materials. As the TASGFP will be accessible to different institutions, each staff member with database management authority across these institutions can upload their own materials to share with others. It will be a challenge to set up a unified standard for efficacious management of these different materials. At present, the TASGFP has only been deployed at NJU; thus, its effectiveness as an information-sharing platform has not been fully tested nor have technical issues such as data standards. The next stage in our research is to deploy the TASGFP at multiple institutions to validate its wider effectiveness and to constantly improve the system to meet the real needs of geography field practice instruction.

Conclusion
This paper examined the characteristics and methods of geography field practice, taking integrated geography field practices in the Lushan Mountain region of China as a case site, proposed a map-based, spatially correlated design method for CAI systems in geography and established a WebGIS-based TASGFP. Spatial information, databases and web server technologies were employed to realise this shared spatial management platform for field practice instruction material. The TASGFP is just a prototype system, but there is no doubt that it can do great service to geography instruction; nevertheless, much more effort should be spent to more fully validate the TASGFP and exploit the potential of CAI in field practice.

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