Minetech, Volume 22, No. 5 & 6, P 17-25 Sep.-Dec., 2001

APPLICATION OF GEOMATIC INFORMATION TECHNOLOGY IN MINERAL INDUSTRY

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भारतीय खनिज उद्योग में कम्प्यूटर का उपयोग अस्सी के दशक से ही प्रारम्भ हुआ। नब्बे के दशक में उदारीकरण की हवा ने इस उद्योग को अपने व्यापारिक तौर-तरीकों को नई दिशा देने के लिए बाध्य किया। लागत के इष्टतमीकरण, बरबादी पर अंकुश, कार्य कुशलता में वृद्धि आदि ऐसे प्रमुख मुद्दे हैं जिनका दैनिक आधार पर सतत् प्रबोधन खनिज उद्योग में आवश्यक पाया गया।

प्रबोधन और विश्लेषण के क्षेत्र में कम्प्यूटर की बहुउपयोगिता ने खनिज उद्योग को इसके व्यापक प्रयोग के लिए प्रोत्साहित किया। गत दस वर्षों के दौरान कम्प्यूटर ने खनिज उद्योग के प्रत्येक संभावित क्षेत्र में अपनी उपयोगिता को स्थापित किया है। प्रस्तुत आलेख खनिज उद्योग में जियोमैटिक इनफार्मेशन टेक्नालॉजी के प्रयोग पर प्रकाश डालता है।

INTRODUCTION

The 'computers' have a chequered history dating back from the days of 'Abacus', the calculating machine. The application of computers in the Indian mineral industry was limited to the role of 'Abacus' till eighties.

In the nineties when the industry had to set sail in the winds of economic liberalisation unleashed by the government of India, the compulsions rather than opportunity forced the industry to take a re-look at their existing business model.

The main focus of business restructuring centred around input cost optimisation, waste minimisation and operational efficiency; because it was clear that there were only two options left: either 'compete' or 'close'. Thus the use of computers and computer applications got a shot in the arm on the eve of rendezvous of the Indian market economy with the global economy.

Computers coupled with the application packages are the modern day magician's wand. They can do almost anything right from deposit identification and evaluation to mine closure planning.

During project initiation, the activities which involve computerisation are data acquisition and management; interpretation of geological data; geostatistical evaluation and techno-economic feasibility studies. The project implementation also relies heavily on computerisation in the fields of mine planning and design; environmental impact assessment and environmental management plan; plant design; mineral beneficiation; hydro-metallurgy; smelting; refining; packaging; and ultimately distribution.

Computers also lend a helping hand in process monitoring; maintenance scheduling; inventory management; quality control; safety and security surveillance; identification of waste disposal sites; effluent / emission management and a host of other related activities.

The management information system (MIS), the heart of any modern project, is simply unthinkable without computers.

To remain competitive, cost optimisation is imperative at every opportunity. An efficient management information system not only optimises inventory level but also helps in keeping the overheads and circulating capital requirement to the minimum, thereby controlling the interest outgo on the borrowings.

Now a days with the advent of satellite imageries, deposit identification has become an easy table-top job. All that one needs is the imageries and corresponding software for analysing the same. Once the mineral bearing areas have been demarcated, in-situ reserve estimation can be carried out using computers. The global positioning system (GPS) coupled with a geographical information system (GIS) can help to achieve the same thus helping in improving the bottomline irrespective of topline growth.

THE GLOBAL POSITIONING SYSTEM

The Global Positioning System has three segments :

1) Space segment-the satellites,

2) Control segment-the United States Department of Defence, and

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3) User segment-GPS for positioning and timing purposes.

The U.S. Department of Defence (USDOD) operates and maintains a satellite system for both military and civilian applications. Using six different tracking sites around the globe, the USDOD ensures integrity of the overall system by continuously monitoring the health and position status of all the satellites. The United States Coast Guard provides information to the public regarding civilian use of the system.

The GPS system consists of a constellation of 24 satellites orbiting the earth at an altitude of about 20,000 km. (about 12,000 miles) above the earth. The satellites travel in one of six different orbits, and each satellite orbits the earth roughly twice a day.

In very general terms, a GPS unit computes its position based on radio signals received from several different satellites. The satellites have highly reliable clocks, so the timing of these satellite signals is known very accurately. The GPS receiver calculates the distance to each of the satellites, based on the travel time of the signal and the speed of light (speed of the signal), then uses these distances to calculate the receiver's location on earth.

There are four basic levels of accuracy or types of solutions that can be obtained with real-time GPS system.

a) Autonomous (15 - 100 meters)

b) Differential GPS (DGPS) (0.5 - 5 meters)

c) Real-Time Kinematics Float (RTK Float) (20cm - 1meter)

d) Real-Time Kinematics Fixed (RTK Fixed) (1cm - 5cm)

The value in the bracket shows the horizontal error estimate vertical error tends to be 2.3 times more than the horizontal error. The reason behind the difference is GPS satellites broadcast on two different frequencies, and each frequency (or carrier wave) has some information, or codes, on it. We can think of it as two different radio stations broadcasting several different programs. The signals and the contents are given below :

L1 Carrier	L2 Carrier
19 cm wavelength	24 cm wavelength
C/A code	P code
P code	Navigation message
Navigation message	

The P code is reserved for direct use only by the military, but the other information is available to the public. The C/A code is used for rougher positioning; but for the centimetre-level answers, we also need the carrier phase. Single-frequency (L1 only) carrier phase is suitable for many applications, but dual-frequency (L1/L2) receivers offer a significant advantage for real-time applications.

The navigation message (usually referred to as the ephemeris) tells operator where the satellites are located, in a special co-ordinate system called WGS-84. If we can measure the distance to the satellites, and if it is known where the satellites are at any given time, then one can compute the location here on earth.

Autonomous Positions

Uses... C/A code only

Requires... Only one receiver

Data from at least four satellites

Provides... An accuracy range of about 15-100 m

This solution is designed for application who just need an approximate location on the earth, such as a boat at sea or a hiker in the mountains. But for mining purposes, this level of accuracy generally isn't sufficient.

Real-Time Differential GPS (DGPS) Positions

Uses... C/A code only

Requires... Two receivers

A radio link between the two receivers

- Reference receiver at a known location broadcasts RTCM corrections
- Rover receiver applies corrections for improved GPS positions

Data from at least four satellites - the same four at both the reference and rover (*common* satellites)

Provides... An accuracy range of about 0.5-5 m

Much better results can be obtained with DGPS over autonomous positions, because one can have a known position at his reference receiver. For this purpose radio link between reference receiver & roving receiver is required.

The reference receiver sends corrections to the rover for accuracy half a meter (about 1.5 feet) horizontally under ideal conditions. The corrections are called RTCM, because they are in a standard format specified by the Radio Technical Commission for Maritime Services. (RTCM) under normal conditions, the DGPS horizontal accuracy range is about 0.5m-5m (1.5-15 feet), depending on the quality of receiver and antenna used.

RTK Float Positions

Uses... C/A code and carrier waves

Requires... Two receivers
- Reference receiver at a known location tracks satellites and then broad-casts this satellite data over a radio link in a format called CMR
- Rover receiver receives data from both satellites and reference station

A radio link between the two receivers
data from at least four common satellites

Provides... An accuracy range from about 20 cm to 1 meter (about 0.5 to 3 feet)

The RTK solution uses more of the satellite signal than the autonomous of DGPS solution. The CMR data is carrier phase data. The float solution is actually an intermediate step towards the most precise answer.

RTK Fixed Solutions

Uses... C/A code and carrier waves

Requires... Two receivers
- Reference receiver at a known location tracks satellites and then broad-casts CMR data over a radio link
- Rover receiver receives data from both the satellites and the reference station

A radio link between the two receivers.
Initialisation, which is achieved most easily with dual-frequency receivers
Data from at least five common satellites to initialise on-the-fly (in motion)
Tracking at least four common satellites after initialising

Provides An accuracy range of 1-5 cm (0.5-2 inches)

This is the solution which is being used in mine. Hence it can be observed that with each increasing level of precision, there are more requirements. The most important unique requirement for the RTK fixed solution is something called an initialisation.

GPS Calibration

To obtain precise positions in mine, and it's called for a site co-ordinate calibration. The satellite positions are actually in a references system called WGS-84. This reference system, or datum, isn't very meaningful, because mine most likely has its own co-ordinate system.

The GPS calibration is a mathematical definition of the relationship between the satellite co-ordinate system and mine's co-ordinate system. A GPS survey that includes mine's survey control points must be conducted before operating with GPS on any machine. The calibration can be conducted by the GPS installation team, or by a qualified consultant. Once the calibration is defined, GPS positions will be transformed to mine's local co-ordinate system.

Factors Affecting GPS

There are a number of potential error sources that affect either the GPS signal directly or it is ability to produce optimal results :

a) Number of satellites

b) Multipath - reflection of GPS signals near the antenna

c) Ionosphere - change in the travel time of the signal

d) Troposphere - change in the travel time of the signal

e) Satellite geometry - general distribution of the satellites

f) Satellite health - availability of the signal

g) Signal strength - quality of the signal

h) Distance from the reference receiver

i) Radio frequency interference - interference with the signal

Some of these can be accounted for mathematically, and others can be minimised with careful planning.

Number of Satellites

For DGPS or RTK solutions the same four satellites must be tracked at both the reference receiver and rover stations. Also, to achieve centimetre-level accuracy, a fifth

satellite for on-the-fly RTK initialisation is required. This extra satellite adds a check on the internal calculation. Any additional satellites beyond five provide even more checks, which is always useful.

Multipath

Multipath is simply reflection of signals. The signals may be reflected by surfaces near the antenna, causing error in the travel time and therefore error in GPS positions. Flat surfaces, particularly metallic (such as the roof of machine cabs) are potential sources of multipath. The highwalls in mines can also reflect signals. Groundplanes (which look like pizza pans) on GPS antennas are designed to minimise the effects of multipath. Also, firmware (software within receivers) and hardware changes can help to minimise these effects.

Ionosphere

The charged particles of the ionosphere, alters the speed of the signal. If reference and rover receivers are relatively close together, the effect of the ionosphere tends to be minimal. Also, if any body is working with the lower range of GPS precision, the ionosphere is not a major consideration. However, if rover is working too far from the reference station, it may experience problems, particularly with initialising RTK fixed solution.

Troposphere

The troposphere is essentially the weather zone of atmosphere, and droplets of water vapour in it can affect the speed of the GPS signals. The vertical component of GPS is particularly sensitive to the troposphere. Mathematical models in receiver's firmware are designed to minimise this effect, which can be within a few centimetres (a few inches) or more.

Satellite Geometry

Satellite geometry (the distribution of satellites in the sky) affects the computation of position. This is often referred to as Position Dilution of Precision (PDOP). PDOP is expressed as a number, where lower numbers are preferable to higher numbers. The best results are obtained when PDOP is less than about 7. PDOP is determined by geographic location, the time of day one is working, and any site obstructions which might block satellites.

Satellite Health

While the satellite system is robust and dependable, it is possible for the satellites to occasionally be unhealthy. GPS receivers have safeguards to protect against using data from unhealthy satellites.

Signal Strength

The strength of the satellite signal depends on obstructions and the elevation of satellites above the horizon. It is advisable to avoid obstructions between GPS antenna and the sky to the extent possible.

Distance from Reference Receiver

The effective range of a rover from a reference station depends primarily on the type of accuracy required. For the highest real-time accuracy (RTK fixed), rovers should be within about 10-15 km (about 6-9 miles) of the reference station. For DGPS solutions, rovers can work effectively at considerably longer distances from the reference station, provided the radio link with the reference station is maintained.

Reference Station

The reference station is the starting point for a mine's GPS system. The co-ordinates of this station must be known before using GPS on any machine. Else a proper site needs to be selected for the reference station, and then a GPS survey performed to obtain the known co-ordinates.

Once it is fixed, GPS reference station can perform two functions simultaneously :

1) Receive data from the satellites, and

2) Broadcast GPS data to the rovers in the mine.

Based on this information from the reference, rovers produce precise positions in mine's local co-ordinate system. If a rover cannot receive the reference station's broadcast, then the rover's computed position is at the autonomous level of accuracy.

One reference station can support unlimited rovers. The primary constraint is distance, because accuracy may suffer if working too far from the reference station. This maximum distance will vary with accuracy requirements and environment.

Reference Station Equipment

Reference station includes these basic components:

a) GPS receiver and antenna,

b) Radio and radio antenna,

c) Power supply, and

d) Cables.

GPS receiver has ports for power, GPS antenna, and radio connections. GPS data travels through the GPS antenna to the receiver, then through the radio to the mine. A typical configuration is illustrated here :

Reference Station at the Mine Office

The GPS reference station should be located where there is guaranteed accessibility, power, and protection from the elements. GPS antenna and radio equipment should be located on the roof top of building, but reflective surfaces have to be avoided (sources of multipath). Also, cable length needed to connect rooftop antenna to indoor receiver and radio should be minimum. A line amplifier may be necessary if cable length is too long.

Radios

To maintain constant communication between reference station and rover, radio is needed at the reference station and at each rover. The basic equipment required with radio are : a) Radio, b) Radio antenna, and c) Cables.

The radios are cabled directly into GPS receiver. Power may be provided to the radio through the GPS receiver. At reference site, GPS data is broadcast through the radio. At rover site, the reference GPS data is received by the radio and routed into the rover receiver, where it is processed together with the rover's GPS data.

Frequency and Bandwidth

Most radios used in GPS fall within one of the following frequency ranges :

a) 150 - 174 MHz (VHF)

b) 406 - 512 MHz (UHF)

c) 902 - 928 MHz (spread spectrum)

The lower-frequency radios (150-174 MHz) tend to have more power, due to design and legal issues (not physics). However, the bandwidth, which determines the amount of data can be transmit, is narrower in these lower ranges.

In the nominal 450 MHz and 900 MHz ranges, the bandwidth is wider. This has positive effects both on the amount of data transmitted and on the number of repeaters possible within radio network.

Radio Range

To guarantee steady, uninterrupted transmission over radio, one should be aware of some of the factors which affect radio's effective range.

a) Antenna height - raising height is the easiest and most effective way to increase range.

b) Antenna design - radiating patterns vary, depending on the antenna design.

c) Cable length and type - radio signals suffer loss in cables. Therefore length should be kept to a minimum and low loss cables should be used.

d) Output power - doubling output power does not double effective range.

e) Obstructions - buildings, walls, & even machines can block or interrupt radio transmission.

BENEFITS OF GPS IN MINING

The GPS a satellite based system has a number of key features that directly benefit mining. Some of the features of GPS which has made it the optimal positioning technology for the mining industry are :

a) World wide coverage and application : 24 GPS satellites circle the globe twice daily so GPS signals are available around the world 24 hours a day and a system bought for a mine in northern Canada can be used in Australia or Brazil or South Africa, anywhere in the world.

b) Services an unlimited number of users : GPS is like a radio or TV broadcast, that it can have an unlimited of listeners or viewers. Hence, is no limit to the number of mines that can use the GPS signals.

c) All weather operation : similar to a mine, a GPS can also operate virtually under any temperature or weather condition, right from the snowy, frigid extremes of the North and South poles to the tropical rains in equatorial regions.

d) Accurate three-dimensional positioning : GPS can provide horizontal and vertical positions accurate to within 1-5 cm (0.5 - 2 inches).

e) Accurate timing : GPS signals provide very accurate time, so one can track not only where, but when, i.e. a is truck loaded or a blasthole is drilled.

f) No survey line-of-sight restrictions : GPS receivers need only unobstructed view to the sky i.e. the satellites. Hence, stockpiles and other physical obstructions between survey points in the mine are not a problem.

g) 24-hour availability : satellite data is available continuously, 24 hours a day. Hence, work can proceed without interruption provided a clear view of the sky is available.

h) Dynamic positioning system : GPS receivers provide accurate positions even when they're moving at high speeds, like on trucks / vehicles.

i) Free service : the service of GPS system are provided free of user charges.

Mining Applications of GPS

A GPS is a versatile tool for the integration and automation of various mining activities. It not only helps in saving time and reducing the need for surveyors, it also gives precision information. The major activities which can reap the benefits of GPS area :

a) Geologic mapping : GPS can be used to help create geological maps.

b) Topographic surveys for volumes : GPS can be used for more efficient volume surveys.

c) Drill guidance : GPS can be used for guidance to blastholes and for determining collar elevations. One can operate effectively without survey stakes.

d) Shovel and loader operations : GPS based positions may be combined with mine map information for both ore grade and design grade.

e) Bench height control : GPS provides not only just horizontal but also vertical positions, so elevation can be accurately monitored in any bench.

f) Ore control : GPS positions combined with on-board displays can help locate exactly what and where the digging machines are, and where digging is going. This visual aid saves time and reduces waste or dilution of high-grade ore.

g) Vehicle tracking and dispatch : GPS can provide positions of all trucks, and with a radio link, these positions can be relayed to dispatch office. Computers with specially designed software can determine the most efficient route for each truck, enabling dispatch personnel to visually monitor the movement of material and other production issues.

h) Material tracking : GPS can inform from where a load of material came and was dumped, while support software can tell the content of the material, thereby optimising inventory management.

i) Haul road grading and maintenance : GPS helps in maintaining the most current information about haul road grades and conditions.

j) Earthmoving : GPS can be used to provide guidance to dozer operators, so the operator can optimise each movement.

k) Elevation control for rehabilitation work : GPS can provide precise elevations without the need for surveying, allowing machine operators to know when they have moved enough earth to meet tolerances.

For each of these applications, a single GPS reference station can support unlimited mobile GPS receivers within mine. GPS receivers can be installed on all machinery (trucks, shovels, loaders, graders, blasthole drills, compactors, and dozers) and outfitted for each surveyor to maximise the use of permanent reference station. And GPS installation can easily grow with need : simply add receivers to machines or crews as mining assets expand. Inside the machine cabs, specially designed computer monitors display site files of design data and ore grade. This information is combined with GPS positions to provide at the central office real-time pictures of all mine's activities. The display is easy for operators to follow, with design grades or ore grades highlighted by colour or other graphical tools.

For mine management, GPS provides more than machine guidance. Using software which has been designed specifically for the mining industry, one can track not only the location, but also the performance of machines. Information about areas recently worked is sent by way of a radio link to mine's base of operations. This provides real - time updates of quantities and terrain data. With such current information, management operation can be effectively planned.

GPS system can also improve the efficiency of mine's communications or radio system. With the proper system in place, which not only transmit GPS data, but also important information about the status and health of equipment and critical production information.

In this paper, emphasis is given to illustrate a broad overview of how each operation works in a total system.

Blasthole Drills

Guidance and Location

Technology to support blasthole drills has changed dramatically in recent times. Blasthole drill systems used in mines today provide drill monitoring, material recognition, drill control and drill guidance. GPS provides positions necessary to support drill guidance ,and it can be used in drill control to produce collar elevations .GPS positions can also supplement material recognition systems.

The pieces of equipment used on blasthole drills are : a) GPS receiver, b) GPS antenna, c) Radio and radio antenna, d) Cables, e) Power supply, f) Display for operator, g) On-board computer (may be integrated with display) and software, h) Interfaces to third-party systems

and i) Sensors to monitor drill and aid in material recognition.

GPS antenna should be mounted on top of the drill mast, either directly over the drill bit centreline, or offset to one side. If antenna is offset, one will need to know the magnitude of the offset, and need a system for heading determination.

GPS receiver and radio should be securely mounted either inside the cab or in a protective housing outside the cab. Cabling must be protected throughout, both against physical wear and RF interference. It is important to keep all equipment and cables protected from dust and the elements. Display is inside the cab, in a convenient location for viewing. Also, any supporting computer equipment is normally inside the cab or in the same housing as the GPS receiver.

To navigate to blastholes, first load a digital map of the blastholes into the on-board computer. This map (a computer file) contains design co-ordinates and drilling instructions for blastholes. Depending on system configuration, one can load the design information onto another computer, or information can be sent over the radio link from office.

As soon as system is powered on, GPS positions are computed using the reference station GPS data and the machine's GPS data. System then provides information to guide to each blasthole.

Once the drill is level, GPS can be used to determine the collar elevation. This, combined with other technology, can help to determine the correct depth of drill hole. As machine complete each hole, updated information about progress can be sent back to the office over the radio.

Shovels, Loaders, Dozers and Graders

Plan and Profile

Technology to improve and monitor earth moving equipment performance is being developed at a rapid rate today. Computers provide large amounts of information about material and engineering designs, and GPS provides the necessary positioning.

The pieces of instrument required on shovels, loaders, dozers, graders are :

a) GPS receiver

b) GPS antenna

c) Radio and radio antenna

d) Cables

e) Power supply

f) Display for operator, with on-board computer and software

GPS receiver can be placed inside the cab or outside in some other protective housing. Cable lengths may, however, limit mounting options outside. A display and computer are also in the cab. The display should be mounted in such a fashion so that it is convenient for viewing and not obstructing vision.

GPS antenna should be mounted in any convenient spot which is free of obstructions, and to reduce multipath, particularly above reflective surfaces. This may be on top of the machine cab or at the rear of the housing.

Radio antenna does not need to be in the same location as GPS antenna, but should be kept free of obstructions as much as possible. If radio is physically separate from the radio antenna, the radio is normally housed inside the cab. On the other hand, in a radio system where the radio and antenna are integrated into a single unit, the same will need to be mounted outside.

To start with machines begin with a design file which is typically a map of ore grades, bench design grade, or road design. This file is loaded into on-board computer, either physically or over the radio link with office.

GPS receiver computes positions from the minute it is powered on and receiving communications from the GPS reference. The positions are used together with the design file to determine such information as ore grade or bench elevation.

On a shovel, for example, it begin with a display showing different grades of ore at the current ground elevation. As digging starts, the colours or other display contrast may change, because exposing new material of possibly different grade. When operator are able to monitor the ore grade on the display in front of him, he can minimise wastage of good ore.

With dozers, the design file may be a bench design, or a digital model of an area to be rehabilitated. As dozer move material, operator can see directly on his display when he is approaching grade. Loaders may work with similar information.

Motor graders usually work with road design files. operator begin with a design and profile for the road, and he works the road until ground elevation meets the finished grade. He can watch this directly on his display, because the current ground elevation will slowly change as it works and approaches the design.

Depending upon the initial design file, the appropriate updated information is sent back to the mine office either at timed intervals or upon request. At the office, Mining engineer are then able to make, timely engineering decisions with the most current information available.

Haultrucks

Vehicle Tracking and Dispatch

The application of GPS to haultrucks is significantly different than other machines, because less accuracy is required. A DGPS solution is sufficiently accurate to produce positions on haultrucks as they move material around the mine.

The pieces of equipment required for haultrucks are :

a) GPS receiver

b) GPS antenna

c) Radio and radio antenna

d) Cables

e) Power supply

f) Display for operator with on-board computer and software

GPS receiver can be mounted inside the cab, together with radio (if it's physically separate from the radio antenna). Otherwise it can be mounted in any convenient spot which is free of obstructions and away from or above reflective surfaces, to reduce multipath. Radio antenna does not need to be in the same location as GPS antenna, but it should be still be kept as free of obstructions as possible. Computer and display should be placed in such a way that it does not obstruct vision.

When system is on, receiver automatically starts to track satellites. At the same time, it should receiving GPS data from the GPS reference station through a radio link. Now, depending on the receiver in truck, the reference data will either produce positions in the order of several centimetres (a few inches) or in the range of 0.5 m to 5 meters. The position is not only computed on truck, but it is also sent back to central dispatch. In this way, dispatch office constantly monitors movements of all the trucks.

With special software, a central dispatch computer determines the most efficient assignment for all the trucks in the mine. If multiple trucks are needed at a particular location, the computer determines which trucks are closest and best suited for the call. This assignment is either made by voice radio or over the data radio link.

CONCLUSION

GPS system have been used for over ten years now with great success to provide accurate, reliable positions in many applications. As GPS matures into a viable machine-guidance system, the benefits of GPS are being realised in mines all over the world

Bringing GPS into mine or onto job site is now a straightforward procedure, with a variety of tools available to provide nearly any level of accuracy required. A single reference receiver can service all positioning needs, whether they are DGPS or RTK requirements, and radio links provide the means of communications between the components. Using GPS as the integrating technology, mine operator can monitor the progress and productivity of his operation, and will be poised to grow with the powerful management information systems available in industry.

As the sustainability of an organisation depends on its ability to adapt to the situation and circumstances by

1) being able to read the weather cock accurately well in advance,

2) always remaining one step ahead of the competition,

3) reduce cost,

4) increase efficiency, and

5) innovating new marketing strategies. To achieve all these, one needs either a magicians wand or an efficient management information system (MIS). If the mineral industry has to achieve sustainable development, there is very little option other than embarking on a massive computerisation in all spheres of activities.

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