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Data Maintenance Models for Water Supply Networks Oriented to Personal Mobile Communication Devices

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Abstract: Personal mobile communication devices (PMCDs)enable all filed workers of water supply enterprises to play an active role in data maintenance for pipe networks and hence remarkably improve work efficiency, data veracity and data integrality. This paper designs a work flow and a software system for data maintenance for water supply networks. In order to meet the demand that PMCDs should work in both on-line and off-line mode, the authors present a constrictive lightweight data storage model and an information transfer model. For co-working with the above two models, a modification operation model is proposed which classifies and encodes the data modification operations and specifies the data content to be stored and transmitted for every operation.

Key words: Water supply networks, geographic information systems (GIS), data maintenance, personal mobile communication device (PMCD)

INTRODUCTION

Urban water supply networks are the most important assets for water supply enterprises. Adoption of Geographic Information System (GIS) technology for managing water supply networks has become a routine in water supply industry. Because of strongly leaning on pipe network GIS, daily water supply operation has an increasing requirement for keeping data accurate and up-to-date. Traditionally, there are two ways for data maintenance of water supply networks. The first is to fill in data problem sheets in field work (such as inspection, leak detection and emergency repair) and then submit them to the department of data management. The second is to produce survey forms after finishconstructionsurvey and add them to pipe networks database by officeoperators. In both ways, paper documents or draft maps are used which do not accurately reflect the pipe networks situation. Besides, this work flow spends long time and heavy work cost.

With the pervasion of mobile devices with graphic display interface (such as intelligent mobile phones and tablet computers), they provides platforms for pipe network management and have been applied to pipeline inspection, maintenance, emergency repair and other affairs (Weng *et al*., 2012; Zeng and Xu, 2011). What's more, the application of mobile devices in earth observation filed has attracted researchers' attention (Ferster and Coops, 2013; Pundt, 2002). Combination of professional survey equipment and mobile devices has been applied to data acquisition by public utility sectors (Montoya, 2003; Zhou *et al*., 2012). In fact with the help of PMCDs and mobile internet, data maintenance may be conducted not only professional survey persons but also the whole staff of the enterprise which can remarkably improve work efficiency of data maintenance. However, up to now there are few researches on public oriented workflows and system models of data maintenance for water supply networks.

For pubic masses, mobile data maintenance system can not only work in off-line mode because they don't often take their mobile phones to the database center to synchronize data. On the other hand, the system can not stay in permanent on-line mode either due to the limitation of PMCDs' running speed and communication bandwidth. So a requirement is proposed which mobile data maintenance system can switch freely between off-line and on-line mode and the data storage model. Thus the information transfer model should meet the following goals: (1) Compact storage and efficient access for off-line pipe networks data; (2) Make the data transferred between the mobile devices and the server as small as possible; (3) Keep the consistency of the off-line data and the server data.

In order to meet the demand of using PMCDs to maintain pipe networks data, this paper designs a public oriented workflow and corresponding software system. Besides, a constrictive lightweight data storage model and an information transfer model are presented. For co-working with the above two models, a modification

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operation model is proposed which classifies and encodes the data modification operations and specifies the data content to be stored and transmitted for every operation.

WORK FLOW AND FUNCTION SYSTEM

While using PMCDs, field workers modify the spatial data and attribute data of pipe networks and upload the modifications to the database server. The pipe networks database will immediately update once the auditor approves these modifications. Fig. 1 shows the comparison of between traditional data maintenance work flow and the mobile GIS supported one.

According to the above work flows the data maintenance tools for water supply networks on PMCDs are mainly divided into three modules: Display and query, modification and transmission, Fig.2 .

Display and query module provides tools for field workers to understand the topography and space distribution of pipe networks, find the data faults by comparing the actual situation with the GIS information or arrive at construction sites and locate related pipe facilities.Modification module provides complete tools for field worker to modify or extend the current pipe networks data.

Transmission module is mainly in charge of the communication between mobile devices and servers in database center: Transmitting the modification records are transmitted to the servers, receiving the modification tasks and real-time instructions from headquarters, downloading the latest geographical background map and pipe networks data.

MOBILE DATA STORAGE MODEL FOR WATER SUPPLY NETWORKS

Usually on mobile devices the geographical background map is stored as bitmap tiles, while pipenetworkdata is stored in vector mode with SQLite database. Storing pipenetworkdata with data tables are vital for management and access efficiency.

Water supply networks are composed of pipenodesandpipelines which are separately stored in two GIS feature tables.

In the line table, the spatial data is binary data which comprise of all coordinates on the pipe line. Line ID, topology, legend and attribute of a pipeline is also stored in this table as a data record. The topology is composed of IDs of from-node and to-node. The legend is composed of the ID of graph pattern, the width and the color. The attribute is composed of diameter, material, age, etc.

In the node table, spatial data, node ID, legend, typecode and attribute of a node is stored as a data record. The spatial data is composed of coordinates and elevation. The legend is composed of the ID of graph pattern and the angle. The attribute is composed of caliber, intactdegree, age, etc. Considering water supply network management, nodes need to be classified as valve, watermeter, hydrant, fitting, etc. Different kind of node has different extent attribute. For example, valve property includes style, switchstate, work status and so on and for watermeter important attribute may include metertype, customer type, steelseal number, measuringrange and so on. Different data tables are used to record the extent attribute of different kind of nodes

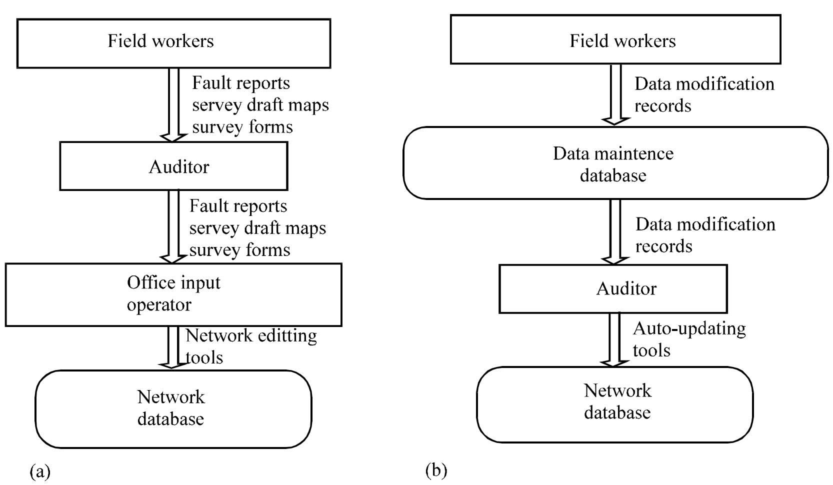

Fig. 1: Comparison of work flows (a) Traditonal work flow and (b) Work flow based PMCDs

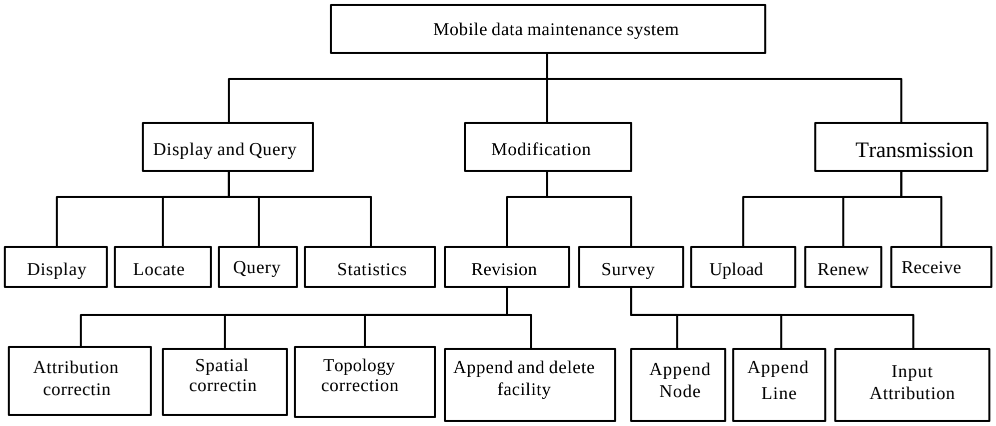

Fig. 2: Framework of systemfunctions

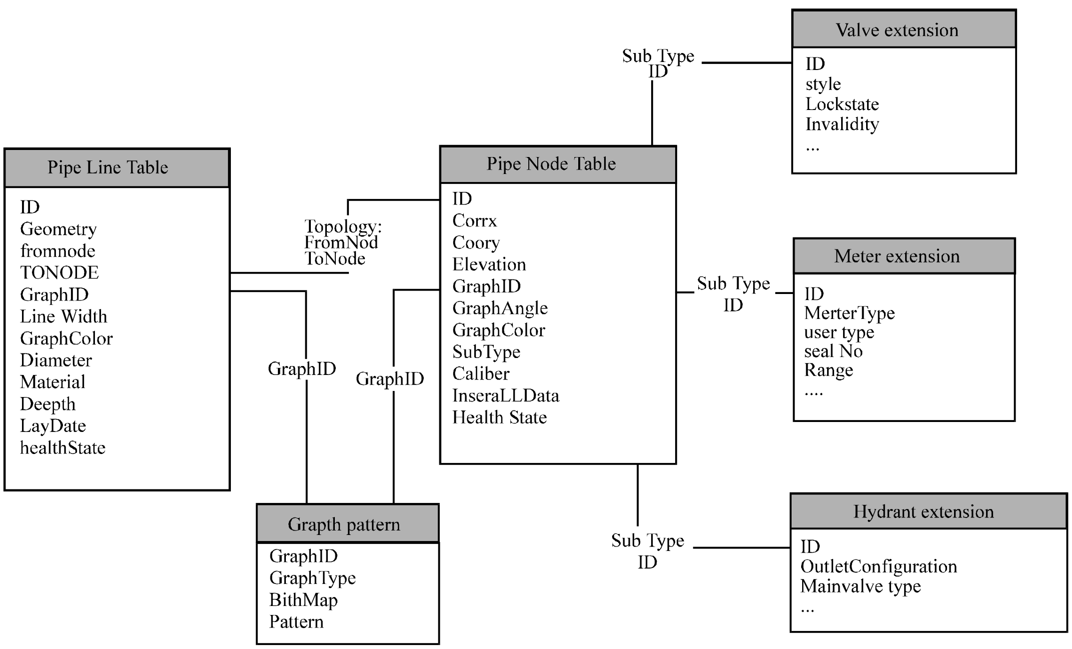

Fig. 3: Data storage model in mobile devices

and take unique facility ID as the keyword to relate to the main node table, as shown in Fig. 3.

By this constrictive lightweight data storage model, facility ID, spatial location, legend, topology and attribute are converged with a facility data record, thus mobile devices can modify pipe data byoperate the data recordasa whole unit. This storage model avoids frequentlyjoiningoperation between data tables and thus improvesqueryefficiency and also is beneficial to form and transmit operating records.

MAINTENANCE TRANSACTIONS AND THE INFORMATION TRANSFER MODEL

A mobile device maintains pipe network data in a transaction mode. A transaction is a cluster of operations to modify pipenetworkdata which is managed by maintenance data table named TRANSECTION_TABLE in a SQLite database that is showed in Table 1. And maintenance rules are seen in OPERATION_TABLE as shown in Table 2. A

Table 1: Structure of the maintenance transaction table

Field Name	Field type	Description
TransactionID	Integer	Transaction ID
Submitter	Integer	Personnel No.
Description	Text	Transaction description
SubmitTime	Text	Submitted time
ReceiveTime	Text	Respond time
UpdateTime	Text	Database update time
RejectCode	Integer	Rejection code
RejectDescription	Text	Rejection reason

Table 2: Structure of the modification operation table

Field Name	Field type	Field description
OperationID	Integer	Operation ID
TransactionID	Integer	Transaction ID
EntityID	Integer	Operated object ID
UndoData	Blob	Binary, recovery data
AttachData	Blob	Binary, correlation data

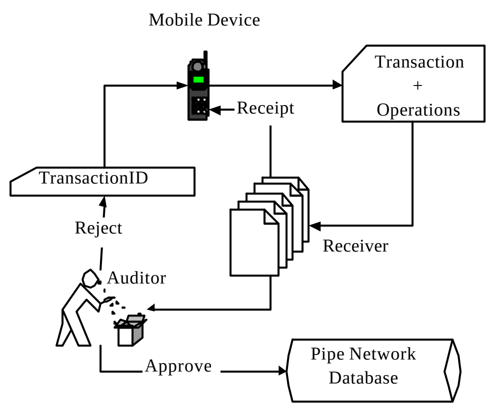

Fig.4: Data maintenance transaction process and the information transfer model

transaction begins, finishes and quits through manually control of the field workers.

Once a fieldworker submits a transaction, the offlinedata related to the transaction will be updated and the maintenance transaction record as well as the related modification operation records and will be sent to the server by the mobile device. Then a receipt will be sent back to the mobile device after the server receives the whole transaction information.

A field worker does not have to stop working and can begin a new transaction even if mobile device do not receive a receipt. If communication iscutoff over a long period of time, the transaction table may accumulate a queue of transactions that wait to upload. The system tries to upload these transactions in three times: 1) When a new transaction is submitted. 2) After 30 minutes. 3) The mobile device connects with the server by localareanetwork when brought back to the headquarters. Database in server also has a same maintenance transaction table. A transaction record will be added to this table after the server receives it. If the auditor approved it, the pipenetworkdatabase will be updated and the time of updating will be send back to the mobile device. If it is rejected, the transaction ID, the reason code and correlated description will be sent to the mobile device, then the latter recovers offlinedata with invertedsequence. Fig. 4 shows the transaction process and the information transfer model.

MODIFICATION OPERATION MODEL

All modification operations carried out by mobile devices are recorded in the modification operation table named OPERATION_TABLE as showed in Table 2. In OPERATION_TABLE, every record includes operation ID, transaction ID, entity ID, recovery data and correlationdata. Meanwhile, there is a modification operation table in server which is similar to the table in mobile device except that it has not recovery data. After maintenance transaction and modification operation records are uploaded to the server, pipenetworkdata in server will be updated according to the information.

Field workers can modify pipe data by appending/deleting facilities, modifying attribute, spatial data and connectionrelationships. In fact as showed in Table 3, mobile devices only need to support twelve basic operations. Every operation has different recovery data and different correlationdata. The recovery data playsarolethat reserves previous data so that pipenetworkdata can be recovered after a transaction is rejected. The recovery data field exists only in mobile devices but not in server database. The correlationdata and operation ID provide enough information for server so that pipenetworkdata can be updated correctly. It is also worth notice that correlationdata should be as small as possible in order to reduce data transmissionflow.

Table 3: Structure of modification operation model

Operate ID	Object ID	Recovery data	Correlationdata	Description
OP_ADD_NOD	Node ID	NULL	Data record of new node	Append isolated node
OP_DEL_NOD	Node ID	Data record and extent attribute of the deleted Node	NULL Delete isolated node	
OP_ADD_ LIN	Line ID	NULL	Data record of new line	Append line
OP_DEL_ LIN	Line ID	Data record of the deleted line	NULL delete line	
OP_ADD_NOD_ON_LIN	Node ID	NULL	Data record and extent attribute of the node	Append node on line.
OP_MOD_NOD_ATT	Node ID	Previous data record and extent attribute of the node	New attribute of the node	Modify attribute of node
OP_MOD_LIN_ATT	Line ID	Previous data record of the line	New attribute of the line	Modify attribute of line
OP_MOV_NOD	Node ID	Previous data recorder of the node	New coordinate of the node	Move node
OP_MRG_NOD	Settled Node ID	Node's original data record and all adjacent line Ids	merged node ID	Merge two nodes
OP_SPT_NOD	Split Node ID	NULL	All adjacent line IDs of the new node	Split two nodes
OP_MRG_NOD_TO_LIN	Node ID	Node's original data record and all adjacent line IDs	Coordinate of new node, previous line ID and data record of new line	Merge node to line
OP_SPT_NOD_FR_LIN	NOD ID	Data records of the extended line and the deleted line	Extended line ID and deleted line ID	Spit node from line

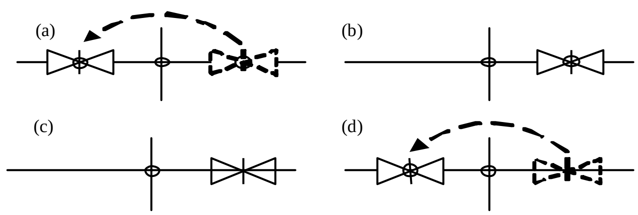

Fig.5: Modification of connected relation

In Table 3 the last four operations are used to correct wrong connection relations of water supply networks. Fig. 5a shows a modification after finding wrong connection of a valve. Fig. 5bshows a valve that should be on the left side is placed on the right side of the cross. For the situation, the worker carries out the operation OP_SPT_NOD_FR_LIN to separate the valve node from pipe lines which isolates the node and merges two pipe lines as showed in Fig. 5c. Then the worker carries out OP_MRG_NOD_TO_LIN operation, picks the valve and places it in suitable location on the left side which makes the left pipe line becomes two parts as showed in Fig. 5d.

If a transaction is accepted, thedataupdating module in server searches all modification operation records of the transaction and conducts the following works: Fetch operation ID, entity ID and correlationdata, then divides the correlationdata into separative variables according to operation ID so that the correlative data updating function is called to update pipenetworkdata. On the contrary, if a transaction is refused, the worker will receive a message with transaction ID and find all modification operation records from OPERATION_TABLE. For every operation the mobile system fetches operation ID, entity ID, recovery data and correlationdata. And then it divides correlationdata into separative variables according to operation ID so that correlative recovery data function is called to make offlinedata recover to the original status.

CONCLUSION

Since PMCDs can provide efficient way for field workers and the mobile internet provides a channel for data transmission, data maintenance based on mobile devices for water supply networks can offer great convenience for field worker and remarkably shorten the time for updating data. Under the condition that the currency of pipe networks data is guaranteed, mobile terminal can play a much more active role for management and service of water supply enterprises with the help of mobile Internet, location service of GNSS and GIS technology. Business such as installation, inspection, maintenance, repair, leak detection, reading and customer service can be greatly enhanced by using mobile devices.

REFERENCES

Ferster, C.J. and N.C. Coops, 2013. A review of earth observation using mobile personal communication devices. Comput. Geosci., 51: 339-349.

Montoya, L., 2003. Geo-data acquisition through mobile GIS: and digital video: An urban disaster management perspective. Environ. Model. Software, 18: 869-876.

Pundt, H., 2002. Field data collection with mobile GIS: Dependencies between semantics and data quality. GeoInformatica, 6: 363-380.

Weng, Y.H., S.S. Fu and J.D. Grigsby, 2012. Geo Tools: An android phone application in geology. Comput. Geosci., 44: 24-30.

Zeng, W. and S. Xu, 2011. Design and development of mobile GIS based water supply pipeline walking system. Water Resources Hydropower Eng., 42: 92-95.

Zhou, J.C., G.W. Wang and L.S. Bai, 2012. Mobile GIS technique application in urban pipeline detection: Esearchand exploration. Bull. Survey. Mapp., 6: 81-83.