Figure 1: A pavement scanning system Pave-Scanner from Siteco Srl (Italy) , with fully integrated Laser Crack Measurement System (LCMS) from PaveMetrics (QC, Canada).

ROADWAY INSPECTION

Different Surfaces, Different Requirements

Since mobile mapping data collection systems first emerged several decades ago, there have been many advances in the technologies employed. The original visual inspection methods were automated at first with the advent of video camera technology. The most recent advances include the integration of laser scanners and lidar (Light Detection and Ranging), high accuracy surface profilers and even ground penetrating radar to detect sub-surface artifacts and infrastructure. In this article, I will give a brief overview of some of the considerations and available tools for evaluation of pavement surfaces.

Standards

Over the years, many standards have emerged in classifying pavement, concrete and other roadway surfaces. There are a wide variety of international, regional and local standards existing. The ASTM 5340-12 and 6433/2003, along with the ISO 13473-2 international standards are possibly the best recognized overall standards, however many variations exist. There are other standards, such as the International Road Assessment Program (iRAP)[1] association , a charity dedicated to reduce the road casualties by improving the road infrastructure safety all over the

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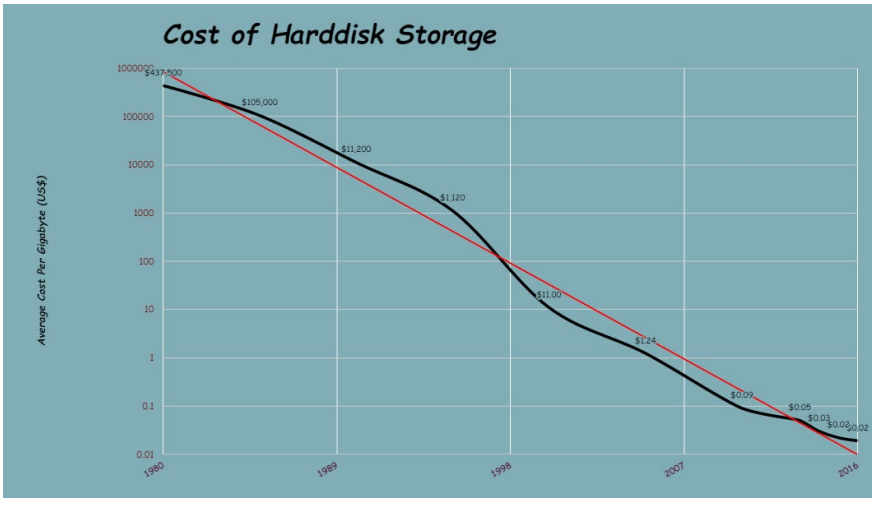


Figure 2: Historic cost of hard disk drive storage per Gigabyte since 1980.

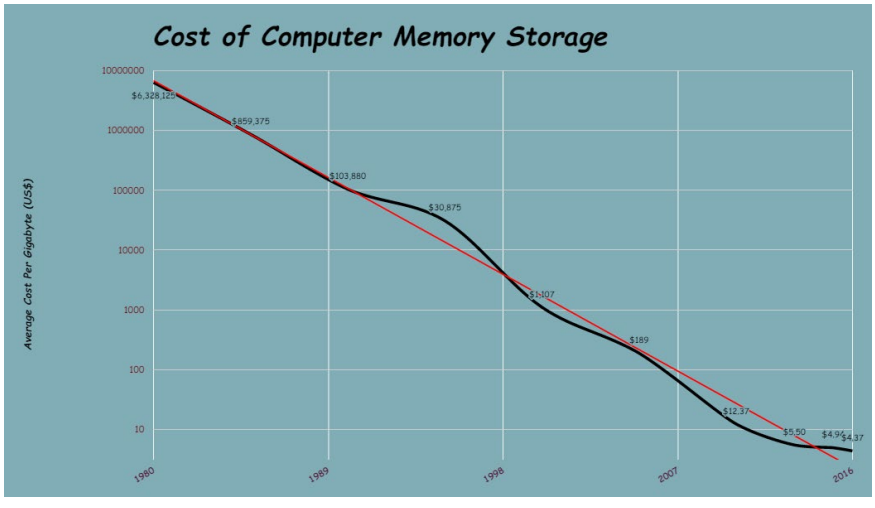


Figure 3: Historic cost of computer memory per Gigabyte since 1980.

world. The iRAP accreditation provides compliance with accuracy, standards and repeatability of inspection for equipment and software providers. The iRAP organization also provides methodology and rating facilities to allow assessment of actual roads for their safety levels. The American Association of State Highway and Transportation Officials (AASHTO)[2] similarly is dedicated to draw standard practices and safety guidelines throughout the United States. Another such association is the ERPUG [3] which stands for European Road Profile Users' Group. ERPUG a non-profit association established in 2013 and is a key source for knowledge and information on traveled surfaces, acting as a forum for the exchange of information between equipment and data providers, road owners researchers and other stakeholders.

One can imagine that roadway requirements differ from other pavement surfaces, like airport runways where the traffic is of a completely different nature. One key condition indicator, for example, is the Pavement Condition Index (PCI). This is calculated in accordance with the ASTM D 5340 standards, and inspection is typically carried out at regular interval, providing a continuous monitoring. With this ongoing database, maintenance work and budgets can be designed, and airport safety monitored for continuous improvement.

Data Collection and Measuring Systems

There are many different commercially available systems to measure and inventory roadways, associated assets like fencing, guardrails and signage, for example. Of course, the right tool, or combination of tools, is necessary to capture the appropriate data. Road surfaces require accuracies which are greater than the requirements for vegetation, sidewalks and other general assets. The most recently introduced mobile mapping system system, specifically developed for overall roadway evaluation and management is the SITECO PaveScanner[4] (**Figure 1**), which incorporates multiple laser scanners, video imaging cameras and the Pavemetrics Laser Crack Measurement System (LCMS)[5]. The highly integrated system is a seamless hardware platform and software workflow package. The latest lidar sensors from FARO, Riegl, Velodyne, Zoller + Froelich (Z+F), among others,

are fully supported for 3D infrastructure measurement and visualization. A wide variety of imaging cameras, including the popular Point Grey LadyBug 5 and a choice of multiple discrete specialty cameras, are also configurable as a part of the entire package.

Adding the Pavemetrics LCMS sensors to the traditional mobile mapper gives the additional ability to automatically measure, detect and quantify key functional parameters of pavement in a single pass, including: cracking, rutting, texture, potholes, shoving, raveling and roughness. Of note is also the ability to capture data ranging from hotmix asphalt to chipseal, porous pavement, and both tined and untined concrete. Pavement condition inspection can be carried out at 1mm resolution, across 4 meter road widths in a single pass, automatically, day or night, at 100+ km/h with fully georeferenced feature identification. This type of performance can dramatically reduce labor costs and time to complete projects.

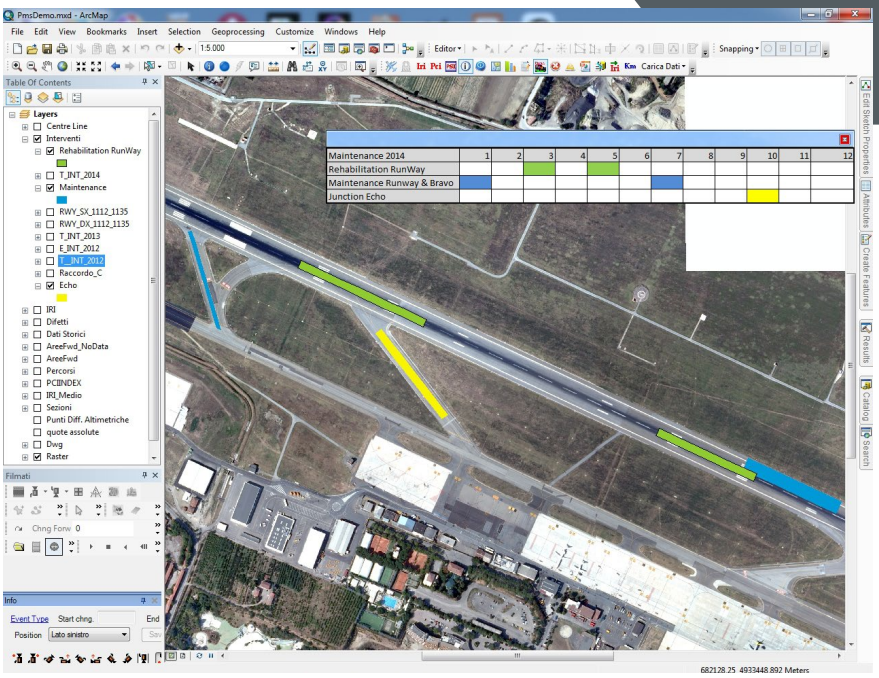
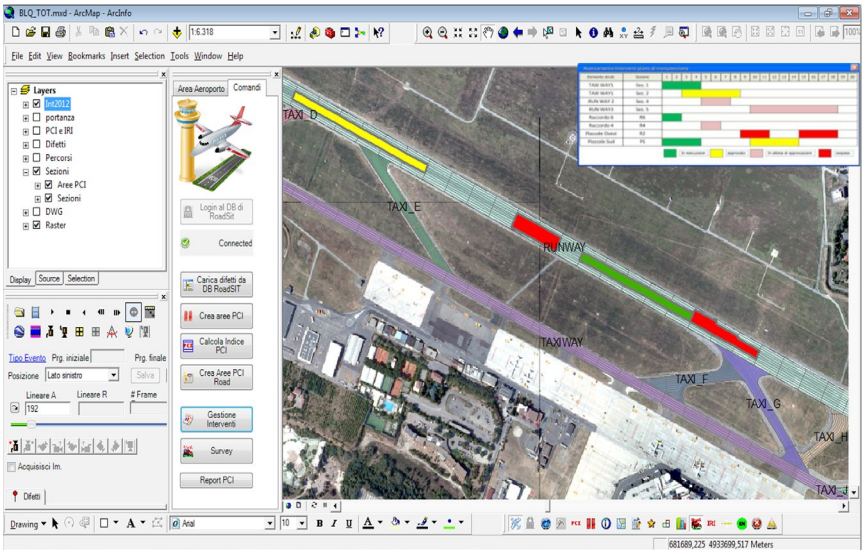


Figure 4: Airport runway rehabilitation project overview and and planning in Siteco's Road-SIT Airport PMS software running in the ArcGis ArcMap environment.



After The Data Is Collected

It must be appreciated that all of these systems generate huge amounts of data. I often have had discussions with companies wanting to upgrade from basic video collection to include range and 3D data, but they do not have the appreciation of the amount of additional internal computer, networking and storage infrastructure may be required. We are very fortunate in these days that data storage has become almost free, at least in the case of hard disk drive, which still makes up the backbone of Internet data centres and cloud-based computing (**Figure 2**)[6]. Computer memory has also dramatically dropped in cost (**Figure 3**) [7], helping to bring more powerful computers to the office desktop and field laptop. All of this has allowed easier handling of the huge datasets that are typical when adding high resolution three dimensional data to video and still imagery.

A most important aspect of mobile mapping and roadway inspections is

the software to take raw data, and put it into an accurate and usable state. The final user of this data; typically municipalities, different government agencies, various engineering professionals, infrastructure management organizations, and so on (the final end users), will need information rather than just raw data. The data flow typically starts with laser pointclouds, different sensor data and imagery being georeferenced, cleaned of artifacts and co-referenced in a database format. Important inventory is most often interactively identified and tagged with icons and descriptions for easy recall. In the case of the Pave-Scanner, a complete set of integrated functions are included to combine the extremely high resolution pavement profile and surface information. One must always follow several standard steps when working with mobile mapping systems;

- System calibration
- Mission Planning
- Mission execution, including real time QC/QA (to ensure data has actually been collected from all sensors)
- Initial post-processing to combine all sensor data and and automatically georeference the overall mission to a coordinate system
- Accuracy improvements with the use of control survey data
- Automatic artifact removal (spurious data points, image exposure, artifacts, etc.)
- Asset identification (tagging of important features to a database)
- Artifact removal (usually done at the same time as the interactive asset tagging function)
- Automatic feature identification (where possible)

> "The data flow typically starts with laser pointclouds, different sensor data and imagery being georeferenced, cleaned of artifacts and co-referenced in a database format."

Many features (cracking, rutting, texture, potholes, shoving, raveling and roughness, etc.) can be completely automatically identified and displayed according to the standards criteria, but human interaction is always needed to some extent to identify what is and what is not real. To ensure data portability to the next level of data analysis (the final end user), it is important to have a flexible software environment, since many organizations work with the most popular engineering packages such as ESRI ArcGIS, AutoDesk, MicroStation.

Different Applications, Different Requirements

While an expressway manager and construction engineer are mostly focused on pavement wear and tear, and changes in asset inventory, a railway operator has a completely different set of concerns. Again, an airport operator will have many specific concerns about scheduling, safety and project planning to minimize disruption to flight operations. All of these data end users will employ very similar vehicle data collection hardware systems, but will have a specific post processing software application to address their needs. For example, most of the Italian Motorways Companies, Etafat Engineering Company in Morocco , ASCO CO., LTD (Japan), Amberg Switzerland, among many others, employ SITECO's Road-SIT survey software combined with the specialty Pavement Management Software (PMS). Various municipalities and companies worldwide (e.g.LaCUB Communauté Urbaine de Bordeaux France, Società Autostrade, Comune di Reggio Emilia Italy, USTRA Federal Bureau of Swiss Roads, Municipality of Merida Mexico) employ the Road-SIT Asset Management package.

In the case of airports, one typically finds a tightly integrated operations, engineering, construction and budget management requirements. This will include capability of processing the data collected with any Mobile Mapping system from any manufacturer. Data from functional and structural surveys, asset and facility

Management along with budgeting systems is most commonly stored in relational databases such as Microsoft SQL. Airports Rome, Bologna and Torino are using mobile mapping integrated to their internal systems by means of Siteco's dedicated Airport Management software (**Figures 4 & 5**).

Know Where Your Assets and Features Are

What is often overlooked in roadway data collection applications is that the data should be stored in a fully georeferenced and well organized Geodatabase, accessible with GIS applications (such as ArcGIS , Opensource and most other environments).

The SITECO systems are an excellent example of being seamlessly integrated throughout the entire hardware and software workflow. Their post-processing software provides a fully automated production of all the georeferenced data sets: spherical imagery, point clouds, high resolution pavement 3d bit-maps, transverse profiles and rutting, longitudinal roughness IRI and Macrotexture data, cracking and other pavement defects geometry, PCI Pavement Condition Index according to ASTM D5340-12 and D6433/2003 standards for roads and airports.

The GIS based environment user interface provides contextual consultation of all the data sets and full control of the infrastructure maintenance status. In simple words, wherever you point, all data attributes are completely accurately referenced in the coordinate system you have chosen.

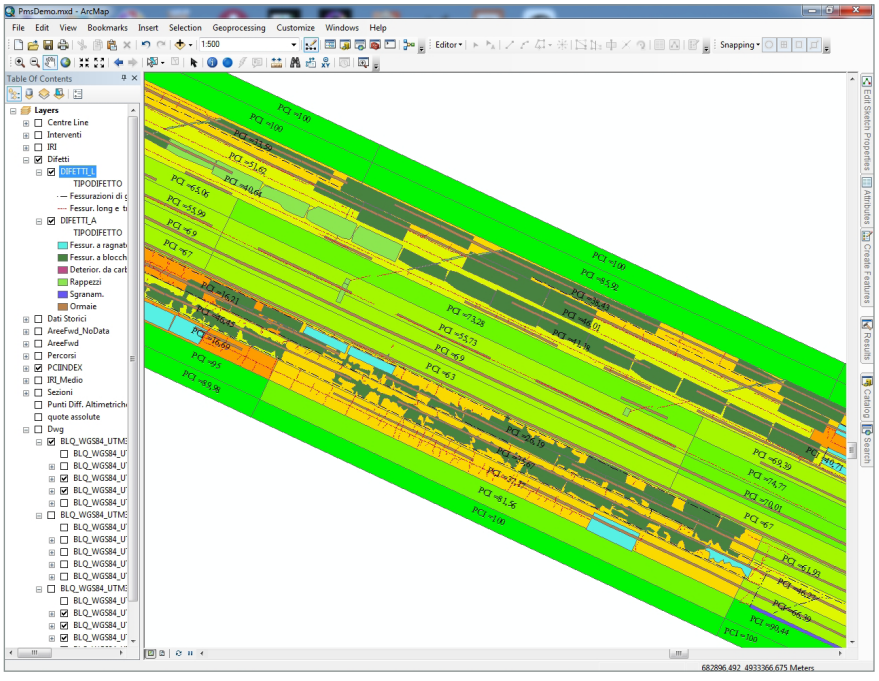


Figure 5: Surface roughness detail classification with crack identification overlaid on the pointcloud and color image.

The Future—Deeper Software Integration

While I have only been able to address the rapidly advancing applications and associated standards in the many fields using mobile mapping systems, it is clear that just as technology has enabled us to collect exponentially more data, we are witnessing a revolution in the software. This is driven by computing power, accessibility to cloud data and better software development structures, enabling specific user applications a better level of data interchange. It is becoming easier to automate process by having highly flexible data collection platform configurations delivering data to specialized expert decision promoting software.

Endnotes

[1] www.irap.net/en/
[2] www.transportation.org/
[3] www.erpug.org/
[4] SITECO Informatica S.R.L, Italy ow.ly/OnL8305Psdr
[5] Pavemetrics Inc., QC, Canada, www.pavemetrics.com
[6] Source;www.statisticbrain.com/average-cost-of-hard-drive-storage
[7] Source: www.statisticbrain.com/average-historic-price-of-ram

Brent Gelhar is a technology commercialization consultant based in Toronto, Canada. He has been involved in conceptualization, design, development and market rollout of static 3D scanners, mobile mapping systems and a wide variety airborne lidar systems while working at Optech Inc over a 10 year period. He currently is working with a variety of high technology startups, providing guidance to funding and market entry. Learn more at his website www.spatialinitiatives.org and his LinkedIn profile.