Figure 1:
The Pathrunner

Accelerating Road and Pavement Condition Surveys

Doing more, doing better, and at a lower price is the challenge of any company, but this challenge is even stronger for companies working with public agencies, as the pressure on public budgets will not decrease in the coming years.

In addition to this constraint, the U.S. Department of Transportation (DOT) needs to respond to the Federal Highway Administration's (FHWA) increased need for pavement data information.

Fulfilling all these competing requirements can only be done by questioning traditional survey methods, and through the integration of new innovative technologies in the field.

With this idea in mind, Pathway Services has developed a new methodology that allows them to produce more reliable data while removing the need for Inertial Navigation System (INS) data post-processing. This improved methodology has been made possible using the new iXBlue INS designed for the mobile mapping market: the ATLANS-C.

Road and pavement condition surveys

The road and pavement condition survey industry is of prime importance to maintaining the safety and performance of a country's road network. Indeed, it provides all the required information to assess the quality of the network, the dangerous portions, the deformation of the lanes, the deterioration of the concrete and more. Put another way, it provides all the information decision makers need to manage their road network.

As U.S. legislation stipulates (23 CFR 420.105(b)): "The State DOTs must provide data that support the FHWA's responsibilities to the Congress and to the public. These data include, but are not limited to, information required for: preparing proposed legislation and reports to the Congress; evaluating the extent, performance, condition, and use of the Nation's transportation systems; analyzing existing and proposed

BY SCOTT **MATHISON**, JEAN-BAPTISTE **LACAMBRE**

Figure 2: Pathway Post-processing software.

Federal-aid funding methods and levels and the assignment of user cost responsibility; maintaining a critical information base on fuel availability, use, and revenues generated; and calculating apportionment factors."

It is clear from this statement that the required number of parameters is numerous. In order to help the States DOT's that are collecting such data, the Federal Highway Administration (FHWA) prepared a guide that defines all the information required by FHWA to be collected on an annual basis[1]. Those requirements include, among others, data concerning the road (speed limits, tolls, route signage, etc.) and the pavement (International Roughness Index, Rutting, Faulting, Cracking, etc.)

Given that the U.S. owns more than 4 million of miles of public road[2], and that a large part of it has to be scanned on an annual basis, it is easy to understand that efficiency is a key factor if the state agencies want those investments to be sustainable. The climatic constraints make the problem even more complicated since the surveyors cannot work all year long, which creates additional pressure on scheduling and completing the survey process. For example the State of California road survey requires the survey company to scan 52,000 miles of road in 8 months.

Pathway services and Inertial Navigation

Pathway Services is a survey company based in Tulsa, Ok. It has been providing services for almost 20 years, for many survey applications, such as route profile, vertical curvature of the road, cracking and faulting.

A characteristic of Pathway is its sense of innovation: it has always been looking for more efficient technologies in order to do the job faster, better, and at a lower cost. This spirit of innovation has lead to the development of survey software, as well as the Pathrunner (see **Figure 1**), a fully-equipped dedicated survey vehicle.

Today Pathway operates 23 Pathrunners, while 71 are used world-wide, by various companies or state agencies. As each of these vehicles drives about 1000 miles per week, innovation and efficiency are mandatory in order to deliver data in a timely fashion.

The Inertial Navigation System (INS) is at the core of all vehicle survey equipment, since it is the INS that allows geo-referencing of all measurements, images, etc. acquired by the equipment. It is then logical to investigate more effective inertial solutions, with four criteria in mind:

1. **Quality:** the data delivered by Pathway has to meet the specifications of the contract.
2. **Reliability:** Pathway needs to be sure to be able to detect all potential problems during the survey

3. **Fast:** The survey data delivery has to be as fast as possible, in order to meet the requirements of the contract.
4. **Price:** One of the objectives of the FHWA is to decrease the cost of maintaining the road network, while ensuring a better quality road (23 CFR 500.102: "(… this leaves transportation agencies with the task of trying to manage current transportation systems as cost-effectively as possible"). Consequently, price is one of the main concerns of the contractor.

Before using the ATLANS-C, Pathway had to post-process all the acquired inertial data, in order to ensure an accurate solution was computed. One of the main advantages of post-processing was the ability to add additional GNSS base stations using the CORS network (this post processing meant waiting 24 hours for the data to be available). Additionally post-processing allowed the removal of GPS position errors added by the GPS, removal of which dramatically improved the performance. In total, the previous requirement for post-processing meant one full day of work for an engineer to process one week of survey data.

Pathway had already tried to remove the need for post-processing, but found no equipment that allowed them to do so before employing the ATLANS-C. Removing the need for post-processing has the following advantages:

1. Removes the 24 hours delay necessary to download CORS data
2. Eliminates the cost of post processing (With PosPAC: 1 full day work to analyze each week of data)
3. Eliminating the cost of post processing software
4. Removing the needs to customize Pathway data analysis software to embed the post processing software

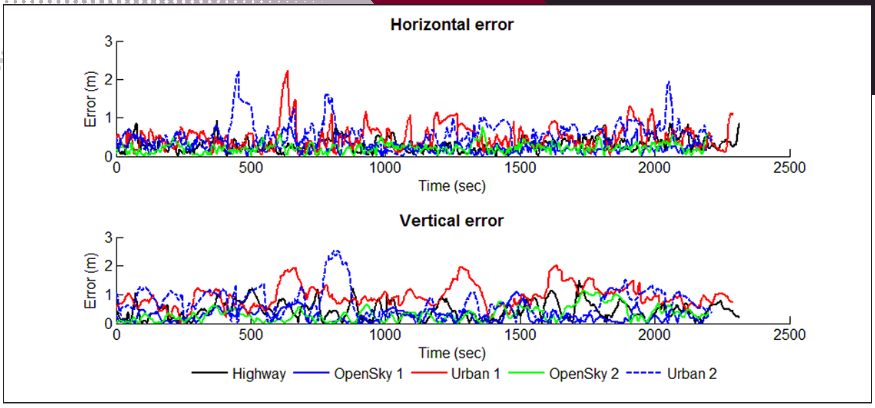

Figure 3: Error positioning in different environments.

The ATLANS-C

The ATLANS-C is the iXBlue INS designed for the mobile mapping market. iXBlue, a leading global provider of navigation solutions, has developed the ATLANS-C together with GNSS manufacturer Septentrio SN, and a new INS-GNSS coupling has been designed together by both companies to maximize the effectiveness of ATLANS-C in the road survey market[3]. In ATLANS-C iXBlue has leveraged the inertial technology used by high performance applications such as unmanned vehicle spatial systems and nuclear submarines into the mobile mapping market.

In addition to the performance, one of the big advantages of the system is its ease of use. It can be installed and calibrated in less than half a day, and the intuitive Man Machine Interface has been designed to simplify its operation. Another important feature of the ATLANS-C is the system size and compactness.

Pathway tested the system thoroughly, in various conditions, to define the true performance of the system. The four test environments were as follows:

- Open Sky: Good GNSS reception, more than 5 satellites almost always available, few multipath
- Urban: road into a city with a various small and high buildings
- Very difficult environment: skyscrapers, tunnels which implies large periods with no GNSS available, lots of multipath
- Highway: High speed trajectory (>100 km/h) with good GNSS reception

Since Pathway is mainly interested in the positioning precision, which has to remain under a few meters for most of the surveys, the first test was to estimate the positioning precision in the various environments defined above, with the GNSS used without any RTK or differential correction. To compute the reference, the same trajectory has been post-processed with an optimized forward-backward algorithm and with additional GNSS base stations. The results are given in **Figure 3**, except for the very difficult environment because the large GNSS outages prevented the computation of an accurate reference.

To improve those results, some additional tests were completed, by disabling the GNSS for twenty minutes, once again in the same environments as defined above. These results are given in **Figure 4**, and show a drift that never exceeds 7 m in the horizontal or vertical direction, thus perfectly meeting the pavement management industry standards.

Finally, it is extremely important for an INS to compute a reliable standard deviation associated with the position solution. Using such reliability indicators allows avoiding the need to manually review the whole trajectory, but only to focus on special points where the precision is potentially insufficient. The quality of those indicators has been assessed by comparing the normalized errors—in other words, the errors divided by the standard deviation—with the expected distribution. Since the error position is the norm of a 2D vector that can be considered as Gaussian, the expected distribution can be computed using the Rayleigh distribution.

Table 1 : Percentage of horizontal normalized errors that are less than X times the standard deviation

	Measured	Theoretical
X = 1	57%	40%
X = 2	91%	86%
X = 3	98%	99%

The altitude error being a 1-dimension error, it follows a normal distribution.

Table 2 : Percentage of altitude normalized errors that are less than X times the standard deviation

	Measured	Theoretical
X = 1	75%	68%
X = 2	87%	95%
X = 3	100%	99%

Figure 5 shows the details of the distribution, and demonstrates that the standard deviation provided by the ATLANS-C can be used as reliable quality indicator of the true error.

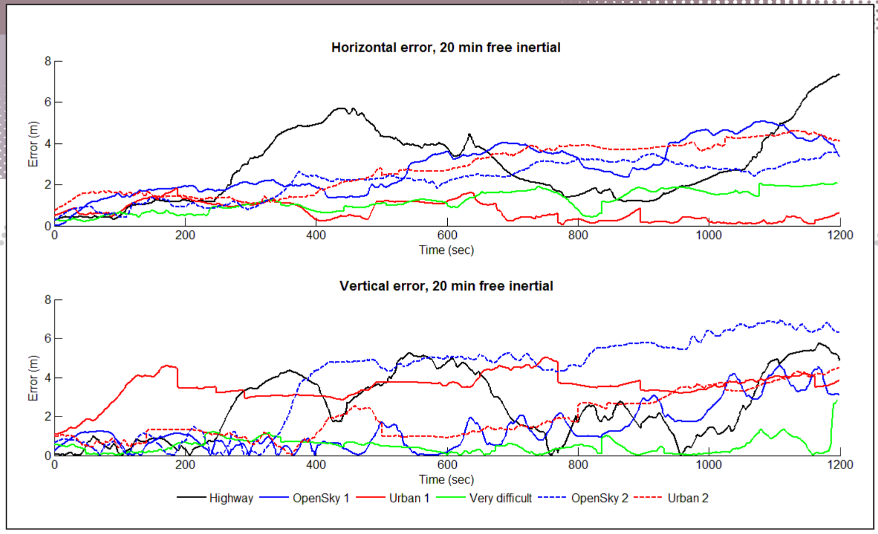

Figure 4: Inertial drift in case of GNSS outage.

Conclusion

The rise of new technologies such as ATLANS-C allows the road and pavement condition industry to meet the most demanding requirements of its customer. The ATLANS-C is a perfect example of the new capabilities emerging technologies can bring.

After operating the ATLANS-C for more than 40,000 miles, Pathway is fully satisfied with the product. It completely removed all post-processing needs, which allowed the company to dramatically reduce both the data delivery time and the survey cost.

In addition, the positioning solution computed has proven to be highly reliable eliminating the need for manual inspection, since the standard deviation data provided by the ATLANS-C are a true indicator of the system precision.

References

[1] Field Manual, Highway Performance Monitoring System, March 2014

[2] Highway statistics 2012, Office of Highway Police Information, https://www.fhwa.dot.gov/policyinformation/statistics/2012/

[3] SIGIL : A Novel GNSS/INS Integration for Challenging Environment », JB Lacambre, ML Duplaquet, JM Louge, Y. Paturel, R. Deurloo, F. Boon, K. Smolders, B. Bougard, ION GNSS+ 2013, Nashville, USA

Scott Mathison serves as Vice-President of Operations for Pathway Services Inc. He has experience in the management of data collection and data processing of more than 100,000 centerline miles and currently oversees contracts with more than 20 US State Transportation Departments.

Jean-Baptiste Lacambre is an inertial navigation R&D engineer at iXBlue. He has been deeply involved in the design of the data fusion algorithm of the ATLANS-C.

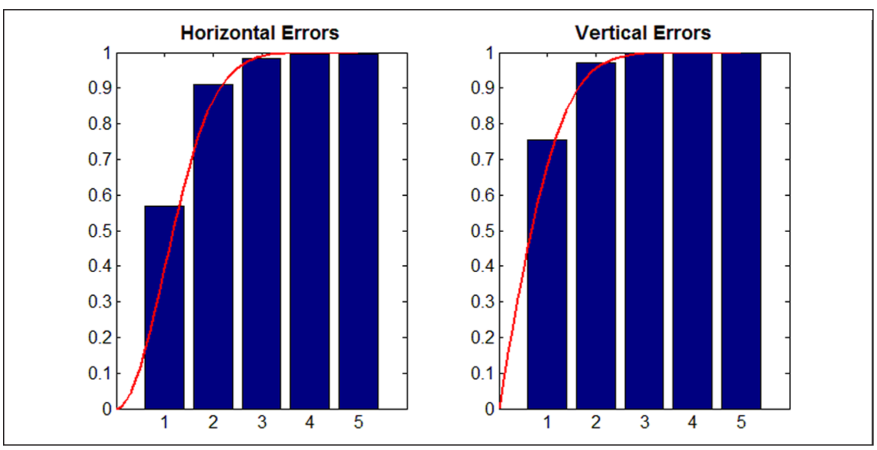

Figure 5: Cumulative distribution of normalized errors (blue: measured; red: theoretical).