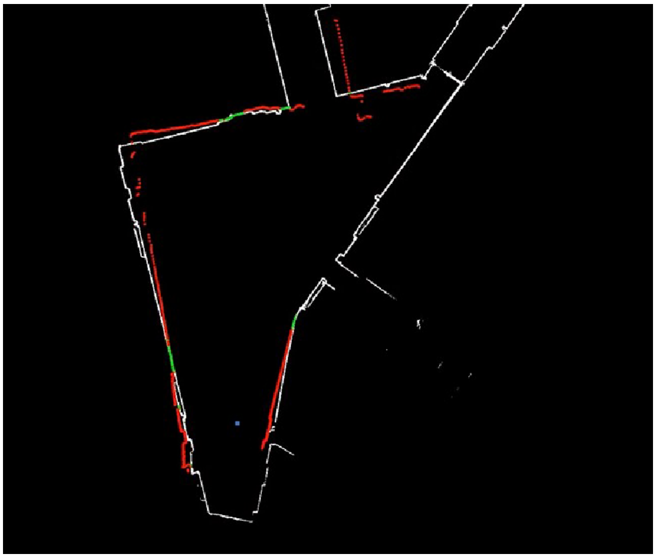


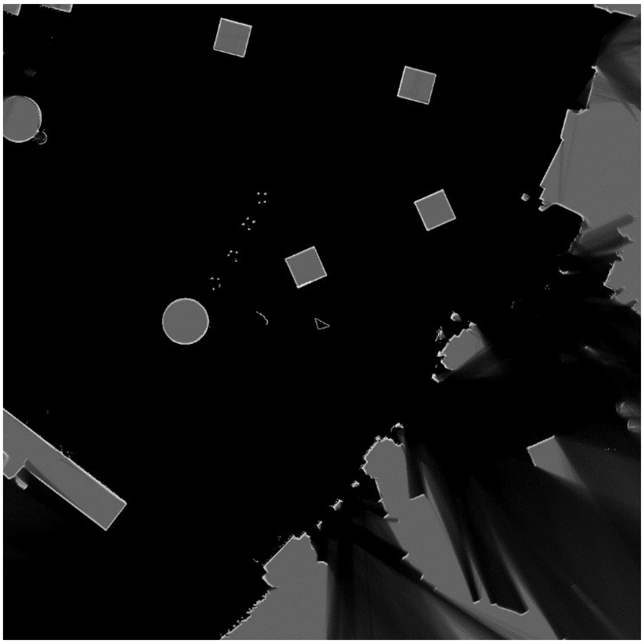


Illustration of the Localization process on the left, where the red instant measurement has to match the white map—Illustration of map result on the right.

What the Heck is **SLAM** ...?

Growth and awareness of 3D technologies such as laser scanning, reality capture and scan-to-BIM are about to accelerate with the advent of Building Information Modeling (BIM). BIM's ability to simulate planning, design, construction, and operation of a facility helps reduce costs, save time, improve processes and safety for various professionals such as construction managers, general contractors, architects and engineers and will drastically increase the requirement of accurate, high definition as-built, "as-is" digital data to populate their BIM.

BY JEROME **NINOT**

Scan to BIM is recognized as the most efficient and accurate method to obtain this information however indoor mapping has been the elusive "holy grail" due to lack of GPS or "Localization" element unattainable indoors.

Recently, there has been considerable excitement about the use of technology from the robotics and autonomous vehicle industries for indoor mapping where GPS or GNSS are not available. This technology is called SLAM. SLAM is an acronym many of us have heard of without really understanding what it represents ...it stands for **S**imultaneous **L**ocalization **A**nd **M**apping. The first SLAM principles were developed for robot localization which requires a basic objective: The ability to return to its starting point. It was determined this was best accomplished by giving the robot the ability to build its own map allowing it to find its initial point.

SLAM technology was born in the robotics industry and is used by autonomous vehicles to concurrently map and navigate through an unknown environment. To do this, SLAM algorithms utilize information from sensors (often Lidar or imagery) to compute a best estimate of the device's location and a map of the environment around it.

The principle is simple: To illustrate using a human example (robotics often use human behavior as a model) we ask to explore his environment. Once on site,

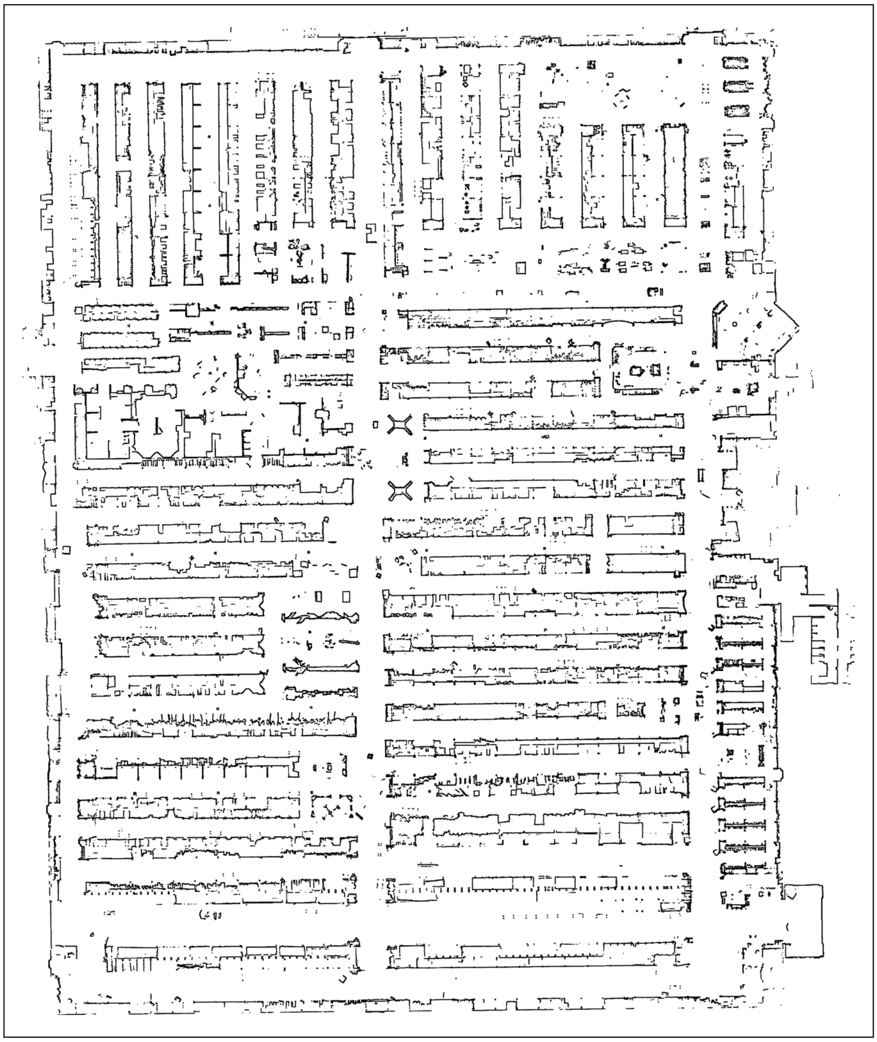
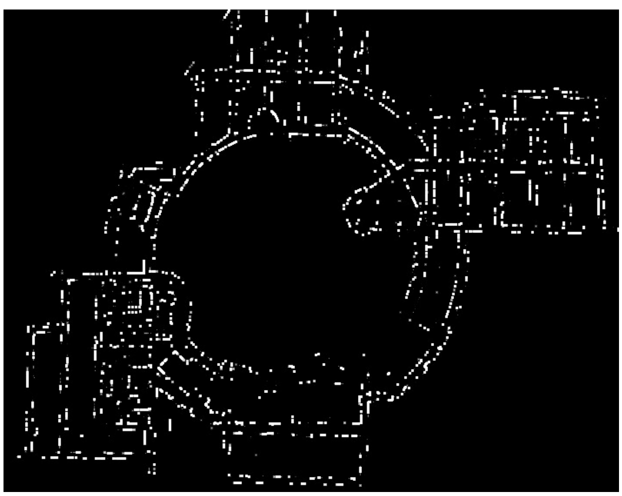


Illustration of the 2D SLAM result ➜ a floor plan obtained by connecting the 2D measurements of the laser scanner along the path

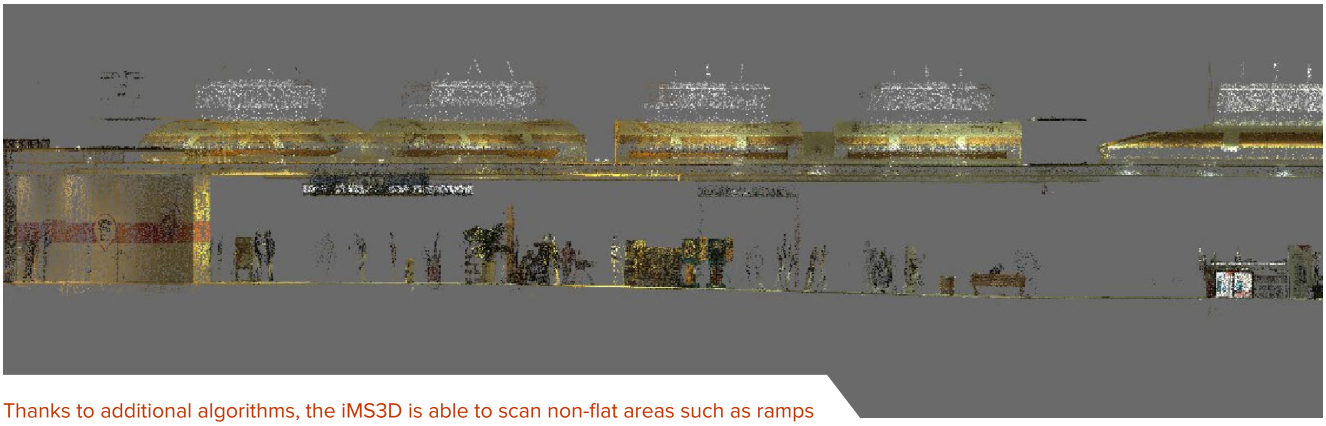
the individual must analyze his initial surroundings to be able to recognize it, allowing him to know his relative motion compared to the objects around him. This enables him to build a mental map as he moves away from the initial starting point. He is even able to know his speed by estimating the relative speed of surrounding objects. SLAM attempts to reproduce the same principle.



Measurement SLAM vs Feature SLAM

"SLAM is an algorithm developed for the robotics industry however it became evident that it can be applied to other disciplines. The principle uses either image or LiDAR based localization to determine the distance between the sensor and surrounding objects. Feature-based SLAM uses corners, shapes or contrasts to calculate the position of the sensor however in areas without characteristics and objects to locate such as tunnels or caves this approach falls short," said Jerome Ninot, president and founder of Viametris. "Measurement-based SLAM uses all points from the LiDAR point cloud and finds the best position of the sensor by minimizing the difference from frame to frame. The advantage of this approach is the ability to scan any type of environment plus it is easier to merge it with other approaches such as integrating IMU's or DMI's and ground control points to achieve greater accuracy in areas not suited to SLAM."

SLAM is often perceived as the "miracle solution," an ideal localization solution compared to complicated solutions where GNSS signals are unattainable. It is true that this principle responds positively to many issues in the measurement and mapping world but it is not a panacea as there are limits to SLAM. Especially, the principle on which SLAM operates: localization is relative to surrounding objects. These said



Thanks to additional algorithms, the iMS3D is able to scan non-flat areas such as ramps

objects must be spatially distributed to eliminate ambiguous positions and this is relative because the environment's measurement is done through a sensor, most often a laser and sometimes cameras, and these sensors are not able to perceive everything and sometimes generate "noise" in their measurements.

SLAM localization solution developers integrate a personal touch to this simple, generic principle and why every SLAM has its own strategy, making each of the available solutions different and contribute to the measurements and the ambiguity it represents," said Ninot. "Therefore, these measurements must offer enough discriminating information to allow an accurate calculation of the motion from the starting point. To further optimize the trajectory and limit any IMU drift, a closed loop is performed such that the start and finish environments are accurately matched together."

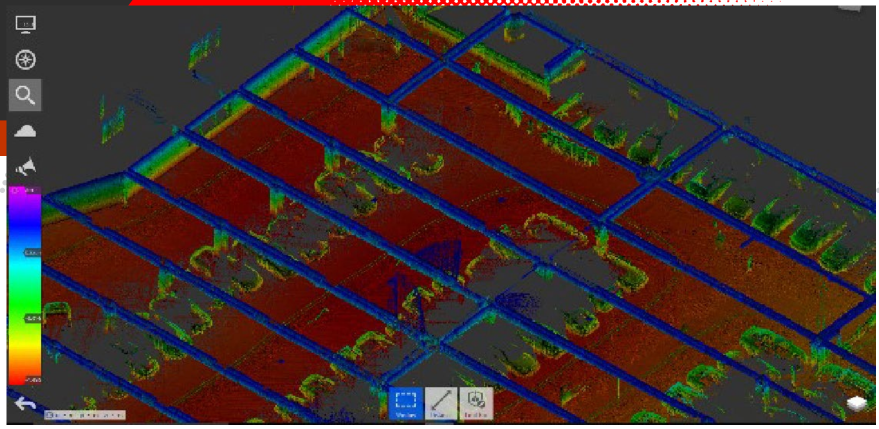
iMS 3D: indoor mapping solution

SLAM by itself does not produce a point cloud … for the iMS 3D it initially calculates a 2D trajectory issued from two-dimensional measurements.

Additional algorithms then generate a 3D trajectory from the coupling of additional embedded sensors. To enable fast and accurate indoor mapping and mapping in challenging surroundings, Viametris implemented SLAM to develop mobile 3D measurement systems for building interiors. The entire process chain allows the technology to accurately map the environment in 3D, even on irregular terrains and the resultant point clouds can be exported in standard formats and exploitable in CAD, GIS and BIM software. The iMS 3D can even incorporate survey or other scan/measurement data to further increase the accuracy of the SLAM and 3D point cloud data.

Viametris was created in 2007 in Laval, France to capitalize on the results of its founder's, Jerome Ninot, doctoral thesis, (Recognition and Automatic Image Analysis for Road Environment Scanning). Their challenge was to find solutions to improve acquisition processes and data management for Lidar based mapping, point cloud management in general, and integration of subsequent data collection.

Tunnel scanning is difficult to handle with only SLAM approach—Features inside are too small to eliminate the ambiguity



Examples of renderings from the IMS3D with point cloud coloration. The 3D trajectory allows to scan irregular terrains.

To enable fast and accurate indoor mapping and mapping in challenging surroundings, Viametris developed the first mobile 3D measurement system for building interiors in 2011. The IMS3D is a cart mounted system with sensors that acquires 3D point clouds and 360 images with centimeter accuracy simultaneously at walking speed. The IMS3D captures up to 500,000 SQ FT per day and calibrates imagery with point cloud data even in GNSS-denied areas using SLAM technology. In 2015 Viametris released the second version of the IMS3D as well as the IMS2D, a portable handheld 2D interior scanner.

SLAM in underground terrain: the solutions

As previously outlined, SLAM technology remains inappropriate in certain situations. The SLAM approach is particularly unsuitable in tunnels as the environment doesn't provide enough objects (acting as anchor points) to eliminate ambiguity particularly in the tunnel's longitudinal axis. However, the data acquired is sufficient to generate an orientation and lateral position in relation to this axis. To solve this issue which occurred during a project in partnership with a French survey company, Viametris developed a SLAM mapping method enriched with an odometer (DMI for Distance Measurement Instrument) allowing to fill the lack of information provided by the SLAM alone. Making SLAM suitable for tunnels and areas lacking enough objects for orientation.

Viametris has over five years' expertise in measurement SLAM which has brought improved accuracy in finding details. With constant improvement in the SLAM algorithm, indoor mapping capabilities have improved by adding components such as IMU, DMI or GPS for outdoor mapping (vMS3D, a mobile mapping system with Hybrid SLAM/INS approach). Post processing software goes a long way to improving results of the survey which would not have been possible five years ago, due to computing power advances in the last few years.

The main advantage of SLAM for 3D mapping applications is that scanning can be undertaken while moving and without the need for GPS. This facilitates rapid and accurate 3D acquisition of complex environments and is particularly effective for indoor mapping or surveys of enclosed environments that would not be possible using current GPS based mobile mapping solutions. SLAM may very well be the "Holy Grail" that has eluded indoor mapping applications.

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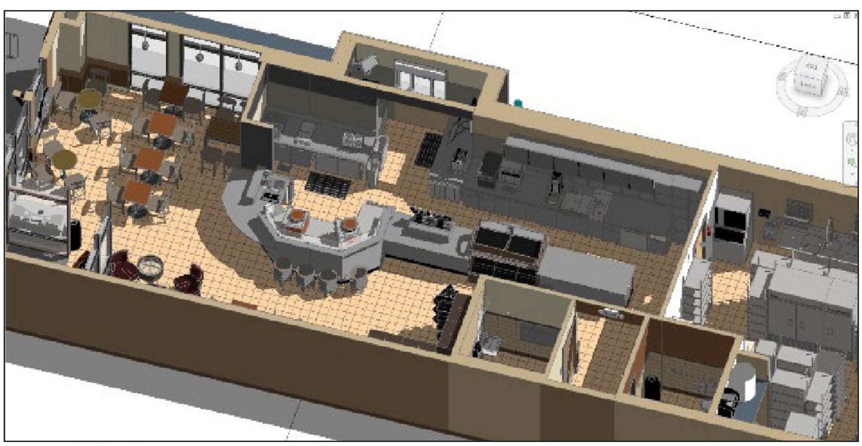

These screenshots show the results created from drawing steps in Autocad and Revit.