Voyant Photonics ICP Specs

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Introduction

Voyant Photonics is an NYC-based developer of LiDAR-on-Chip (LoC) technology used for machine perception across industries. Founded in 2018, its cutting-edge Frequency-Modulated Continuous-Wave (FMCW) LiDAR technology powered by silicon photonic chips is developed by co-founders Dr. Steven Miller and Dr. Christopher Phare out of Columbia University's Lipson Nanophotonics Group.

With growing demand for machine perception in Automotive, Robotics, Drones, Factory Automation, and other industries, LoC has many applications and potential customers. Voyant Photonics is uniquely positioned to acquire several specific customer groups due to its technology's differentiation from competitors.

Solution Map

The most common application of LiDAR technology is in Autonomous Vehicles (AV). There are three main ways of achieving Full Self-Driving (FSD) capabilities: Light Detection and Ranging (LiDAR), Radio Detection and Ranging (RADAR), and Artificial Neural Network (ANN). While the majority of the AV industry uses a mix of the three technologies, Tesla uses only ANN with its Tesla Vision technology (see Figure 1).

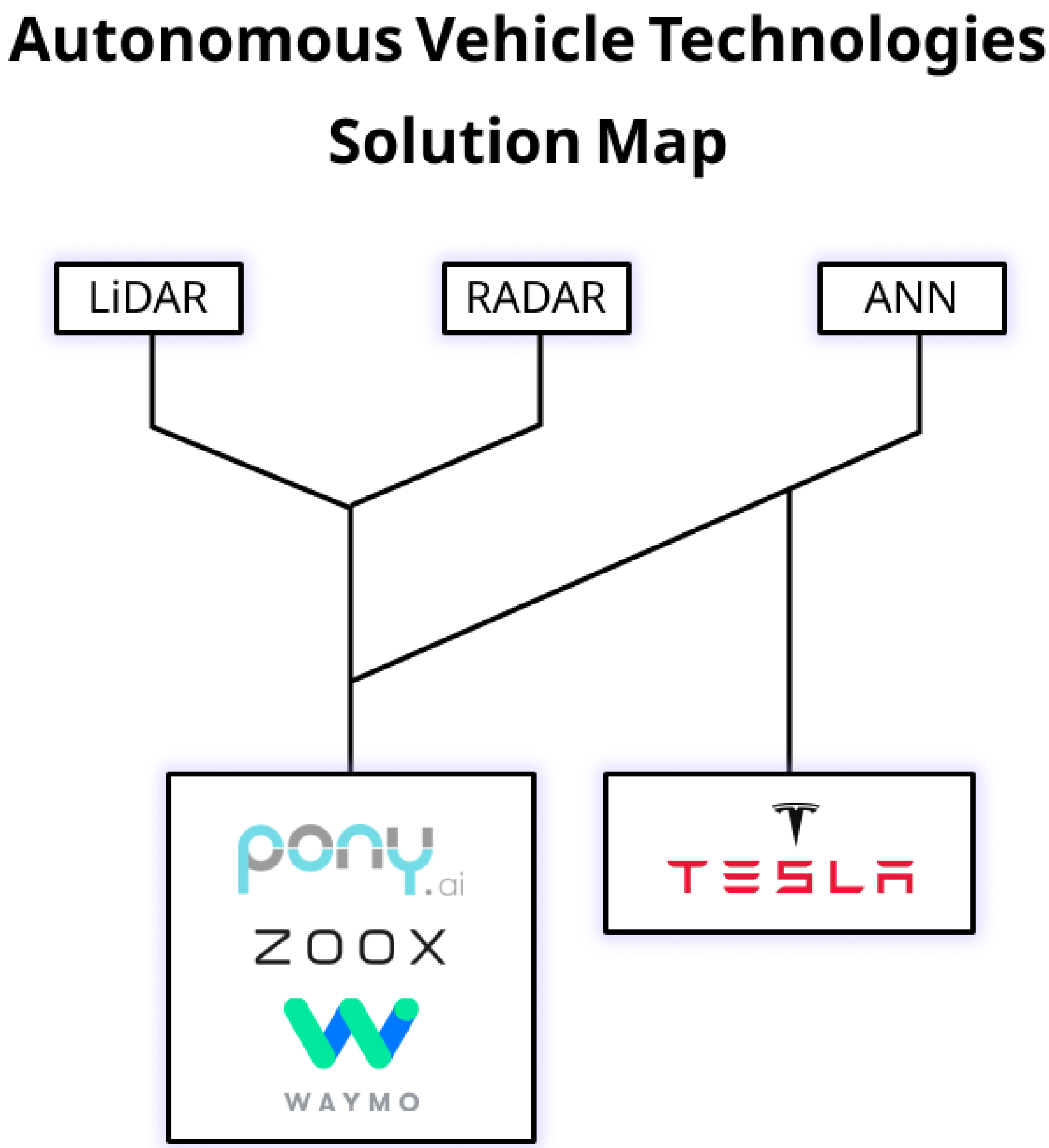

Figure 1: AV Technologies Solution Map, by Koko Xu

Technology Overview

LiDAR

Traditional LiDAR technology uses lasers to detect object distance by measuring the Time of Flight (ToF) between “pulse” and “return”. This approach is ideal for medium-range object detection and is highly accurate. However, it does not perform well under weather conditions such as fog, rain, and snow. Traditional LiDAR is very expensive.

RADAR

RADAR technology takes a similar approach as LiDAR but shoots radio waves instead of photons. RADAR is good for long-range object detection and performs under all conditions, but provides very low-resolution data. RADAR is relatively cheap.

ANN

ANN mimics the human visual cortex, using Computer Vision (CV) and Machine Learning (ML) to train the Neural Network to identify objects and perceive depth. ANN works in all human-able conditions and beyond, with the system improving over time with more data. ANN is time-consuming to develop and depends on a large, varied, and real dataset.

Technology Breakdown

Voyant Photonics is revolutionizing LoC technology with advancements in size, price, and functionality. These advancements have the potential to make FMCW LiDAR the mainstream over ToF LiDAR, as they resolve multiple barriers holding FMCW LiDAR back in the past.

1. Size

Voyant's LoC technology is built on a single semiconductor chip using off-the-shelf subcomponents and established manufacturing processes. This breakthrough allows Voyant's LiDAR to be drastically smaller than competitors', with each chip a fraction of the size of a pinky fingernail and a ready-to-use case no longer than 5cm. The small size allows for Voyant's LiDAR technology to be implemented in devices that couldn't before such as small robots and smart homes. It also solves the problem of shot-rate, a major limitation of FMCW LiDAR when compared to ToF LiDAR. ToF LiDAR works by sending out pulses in all directions and receiving reflections. Since ToF does not target a specific direction, it's able to pulse at a faster rate. FMCW on the other hand sends pulses in a specific field of view, limiting the rate of data it's able to receive. Most LiDAR technology out there uses ToF and has shot rates of about 2,000,000 shots/second, while FMCW only has a shot rate of about 100,000 shots/second. Voyant is able to achieve an above-average shot rate at 144,000 shots/second. Along with size reductions, dozens of Voyant LiDAR can be implemented into a single system at still a smaller size than one ToF system to match ToF shot rates.

2. Price

Since Voyant uses off-the-shelf semiconductor subcomponents and already established semiconductor manufacturing processes, it's able to drastically reduce the cost of production. Traditional LiDAR solutions in the world today costs anywhere from $7,000 to $70,000 per unit. This is part of the reason why LiDAR has been limited in high-end luxury cars - it simply does not work unit-economically for other consumer products. This high cost mostly comes from manufacturing processes, which relates to the fact that most LiDAR technology out there uses "Edge-Emitter Diode Lasers" instead of "Vertical Cavity Surface Emitting Lasers" (VCSEL). Edge-Emitter Diode Lasers require scrutinous manufacturing because the laser is shot out of the edge of the wafer, so each wafer needs to be cut open during manufacturing. Another reason for the high cost is due to the fact that traditional LiDAR uses moving parts, which increases maintenance costs. Since Voyant is able to fit all the subcomponents onto a single chip, it is able to take advantage of semiconductor manufacturing processes that have been refined over decades and enjoy economies of scale of production from the beginning. Voyant's estimated $350 unit production cost opens up commercial applications in a variety of consumer-facing products.

3. Functionality

Past attempts at reducing the size and cost of LiDAR systems led to a reduction in functionality. One example of this is Apple's use of LiDAR in its iPad Pro, iPhone 12 Pro, 12 Pro Max, and 13 Pro Max models sourced from Ouster for its AR capabilities. Apple's use of LiDAR technology is a type of solid-state LiDAR system called Digital Flash LiDAR. Unlike traditional LiDAR that uses a rotating mirror to scan regions point by point, Digital Flash LiDAR simply emits a light wall without any mechanical rotation for object detection (see Figure 2).

Ouster designed this product for Apple using VCSELs and Single Photon Avalanche Diodes (SPADs) in order to achieve low costs and compact size, and its performance is quite well relative to its intended use. However, this technology is nowhere near Vehicle Grade in terms of detection range, precision, and shot rate. Voyant's LoC is indeed Vehicle Grade with a 90% reflective target range up to 70m, less than 1cm range precision, and 144,000 shots/second in its Lark Rev A product. Beyond these capabilities, Voyant has made innovations in its 5D LiDAR ability. Most ToF LiDAR systems are limited to 3 dimensions - x, y, and z positions of objects. All FMCW LiDAR systems are able to capture a 4th dimension: doppler velocity. Doppler Velocity basically reveals how fast objects are moving. It is based on the Doppler Effect where waves move at different frequencies when the source is nonstationary (see Figure 3). ToF LiDAR can also calculate this by measuring marginal movements between different pulses, but it requires more data points which can lead to latency (decision lag from processing large amounts of data). Voyant's Lark Rev B will be 5D - it will include x, y, z, doppler velocity, and a highly accurate fifth dimension based on reflectance and polarization. This fifth dimension will be able to tell what material the objects in the field of view are by analyzing the waves of its reflection (a furry surface reflects light differently from a metal stop sign surface). This will enable object identification with fewer data and higher efficiency, as material recognition coupled with object geometry will allow for an educated guess on what the object is.

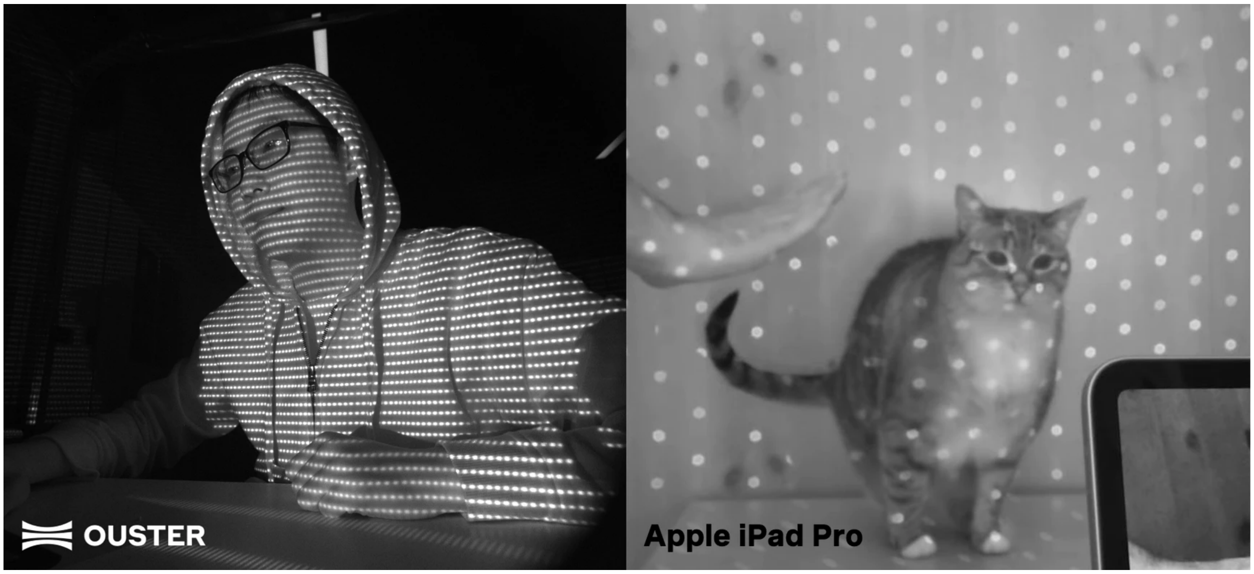

Figure 2: Resolution comparison commercial lidar and consumer lidar, taken by infrared camera

(Image source for iPad is https://www.youtube.com/watch?v=xz6CExnGw9w)

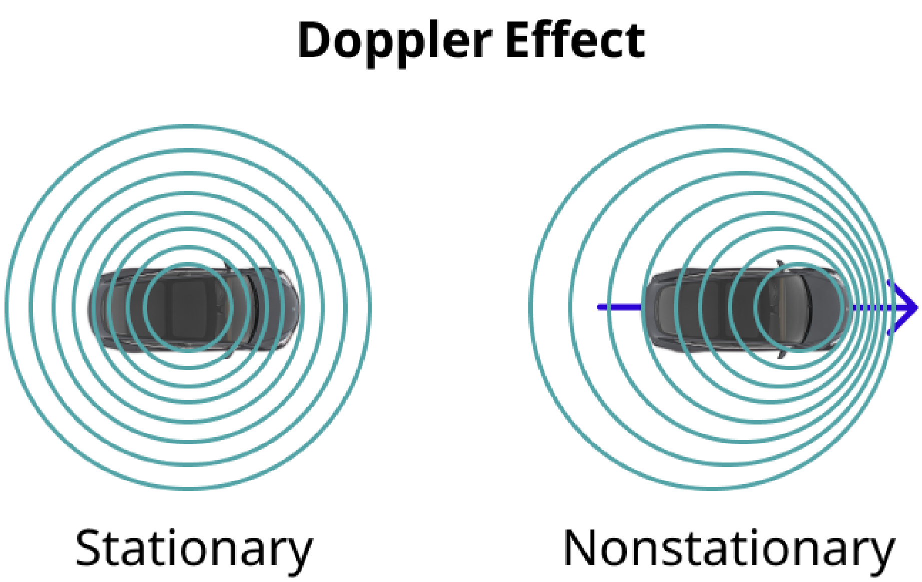

Figure 3: Doppler Effect, by Koko Xu

ICP

Given Voyant Photonics' technological advancements, any industry that currently uses LiDAR technology is a potential customer. However, in Voyant's first go-to-market strategy it should target industries with high user painpoint, high WTP, and low peripheral competition. I believe Voyant's best go-to-market approach should be in the following order:

1. Consumer Products that are Size/Price Sensitive with Proven Value Prop

Since Voyant's main differentiator is its size and price, industries where these factors play a big role in the decision-making process in the solution map are ideal first customers. These customers have a medium to high demand for machine perception capabilities because they've had market validation, and were able to get by with subpar solutions in the past. One example of this is smartphone applications in LiDAR - Apple has found success in Digital Flash LiDAR and tested end-user feature-market-fit to determine that iPhone owners do indeed want LiDAR associated services. This creates incentive for Apple to keep its LiDAR features and drives demand for better solutions on the market. With Voyant's improved FMCW LiDAR solution, Apple iPhones will be able to implement a lot more features such as robust object outlining and improved AR experience. Samsung, Huawei, and other smartphone makers have similar user personas.

2. Consumer Products that are Size/Price Sensitive with Unproven Value Prop

Industries associated with IoT can benefit greatly from having LiDAR features, but they were not able to test out value proposition in the past because no robust solutions existed. An example of this is smart home systems like Google Home and Amazon Alexa, both of which don't currently have LiDAR systems built-in. These products could benefit from LiDAR with features such as automatic 3D reconstruction of an indoor environment or person identification and locational tracking to offer specific services. Think turning lights on and off in different rooms automatically as an Alexa owner walks around the house. Implementations of LiDAR in PCs can also provide useful features such as motion sensing to automatically sleep or turn on the PC for preserving power, although this specific use case can be done with other simpler LiDAR approaches.

3. Enterprise Products that are Size/Weight Sensitive

For enterprise Hitech and Deeptech applications, consumers care less about unit economics and more about functionality and engineering friction. Although price is still a factor, it comes second to the viability of the product. Customers in this category have a high demand for improved systems used for machine perception. For example, robotics require machine perception capabilities that are small enough in size and weight to match their engineering specs. With Voyant's LoC technology, they are able to increase product performance and create more product features from engineering/design space saved with LoC. Although they are likely to be high-paying customers, onboarding friction is also expected to be higher because enterprise customers will likely demand customization which demands more engineering resources from Voyant. Other customers that fall under this persona include drone developers, eVTOL developers, and developers of payload-sensitive CubeSats with docking capabilities.

Case Studies

I would like to explore two specific use cases for Voyant's technology that are outliers to the above ICPs but can potentially prove to be massively successful when executed correctly.

1. Meta

With Meta's focus on the Metaverse and its rollout of the Oculus product lines, Voyant can exploit Meta's heavy investment in onboarding end-users to the Metaverse to achieve economies of scale faster. Oculus currently uses an in-house software/hardware stack called Insight. Insight is a primarily camera-based positional tracking and object/depth perception system powering Oculus headsets. Although mostly used for VR, in July 2021, then Facebook introduced the Passthrough API Experimental that allows Quest 2 owners to experience AR as well. Insight's hardware stack currently does not include LiDAR sensors but uses multiple Inertial Measurement Units (IMUs), four cameras, and infrared LEDs in the controllers. Insight uses Computer Vision alongside visual-inertial Simultaneous Localization and Mapping (SLAM) to track user location and movements. This approach uses visual-inertial mapping to calculate distances of objects from the user, which requires frames of the object from multiple angles. Voyant's LoC technology will be able to massively reduce the workload of this with a lot fewer data points, thus reducing the processing power needed in Insight. This solves Oculus' painpoints of jitter, latency, and swimminess, all of which stem from delays in data processing. It will also greatly improve Oculus' AR capabilities since AR requires higher resolution real-world data points than VR.

2. Tesla

It’s impossible to discuss LiDAR technology without bringing up AVs. Tesla is a unique case because of CEO Elon Musk’s public dismissal of LiDAR technology, but Voyant’s LoC might have other uses with Tesla than autonomous driving. Tesla famously takes pride in its ANN-based Autopilot system, which is based on its core technology called Vision. Vision is a neural network that depends on eight cameras around the vehicle and trains on an enormous dataset collected from Tesla’s fleet around the world. Due to the nature of ANNs, Vision requires a large amount of data to improve itself in object detection and depth perception - two key capabilities of AVs. While Tesla has developed gimmicks to help with Vision training such as Fleet Learning and Shadow Mode, one barrier persists: data labeling. Data labeling is important because Vision needs to make predictions and know if it was right or wrong in order to improve. But it is expensive and laborious to manually label frames/videos taken from the fleet, this is where Voyant’s LoC comes in. With Voyant’s unique 5D LiDAR technology, the implementation of a few Voyant chips into Tesla vehicles will be very valuable for training Vision. This is because Voyant chips will be able to “grade” Vision on its performance by accurately identifying distances, velocities, and object types. This will serve as an automatic data labeling method for raw data collected from the Tesla fleet, taking away an expensive process. Note that this doesn’t undermine Tesla and Elon’s vision in ANN-based Autopilot, but instead aids that product mission. Voyant’s LoC can also prove beneficial in solving Vision’s latency issues, which Musk identified as a major painpoint for Tesla’s engineering team in a December 2021 interview with Lex Fridman.

Conclusion

Voyant Photonics has clear competitive advantages in its core technology with applications in a large variety of industries. However, it must be wary of scaling too fast and delivering subprime products. Voyant must hire engineers strategically yet aggressively, provide consistently great customer service, and most importantly, pursue customers in a systematic way. In this paper, I identified the top three customer personas ranked by a mix of user value proposition and product rollout friction. This is in an effort to achieve high scalability and establish recurring revenue early on. With a proper go-to-market strategy that doesn't overstrain Voyant's team and product, I believe Voyant will be able to capture the majority of the LiDAR market and revolutionize LiDAR adoption much like the CCD vs. CMOS camera revolution decades ago.

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