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MOTIVE TECHNOLOGIES, INC.

UNITED STATES DISTRICT COURT

NORTHERN DISTRICT OF CALIFORNIA

MOTIVE TECHNOLOGIES, INC., a Delaware Corporation Plaintiff, v. SAMSARA INC., a Delaware corporation. Defendant.	CASE NO. **COMPLAINT** **DEMAND FOR JURY TRIAL**

COMPLAINT

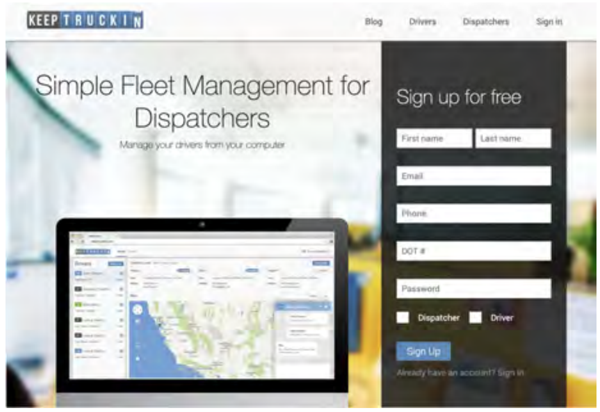
Plaintiff Motive Technologies, Inc. ("Motive"), for its Complaint against Defendant Samsara, Inc. ("Samsara"), brings claims for patent infringement, fraud, false advertising under the Lanham Act, unfair competition through deceit and fraud, defamation, and theft of Motive's trade secrets, among other things, and states and alleges as follows:

NATURE OF THE ACTION

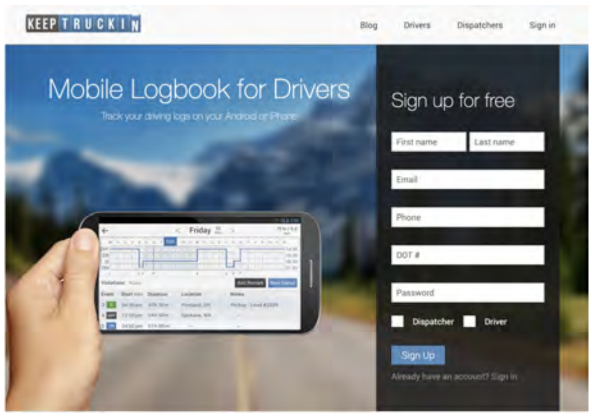
1. Motive was founded in early 2013 (as KeepTruckin), with a vision to build technology that would improve the safety and efficiency of America's transportation industry. Motive's singular focus on its customers' most pressing operational needs has led to the release of the only AI-powered platform to combine driver safety, fleet management, equipment monitoring, and spend management in one solution. Today, Motive serves over 120,000 customers across North America (including America's largest fleets), with more than 1 million vehicles and assets managed on its platform.

2. Motive brings this suit against Samsara, a company that attempts to compete with Motive for customers in the marketplace, but has done so using unethical, improper, and unlawful tactics. Samara has engaged in these tactics because it continues to lag behind Motive in its technology.

3. In December 2013, over a year before Samsara incorporated, Motive pioneered the first Android and iPhone based fleet management and electronic logging platform in the industry, depicted below:



Fleet Management



Electronic Logging

4. In January 2015, Motive began designing a proprietary Vehicle Gateway (LBB-1), the first vehicle telematics device to contain an advanced processor, 4 GB of storage, WiFi and Bluetooth radios, multiple USB interfaces, and running the Linux operating system instead of the real-time operating systems used by traditional telematics devices. Motive created a Vehicle Gateway with more capabilities than traditional telematics devices because Motive intended to add more software applications, and attach additional devices to the Vehicle Gateway over time. Most importantly, Motive envisioned a connected dashboard camera ("Dashcam") using the USB interface so that customers could combine driver safety and fleet management in one integrated platform.

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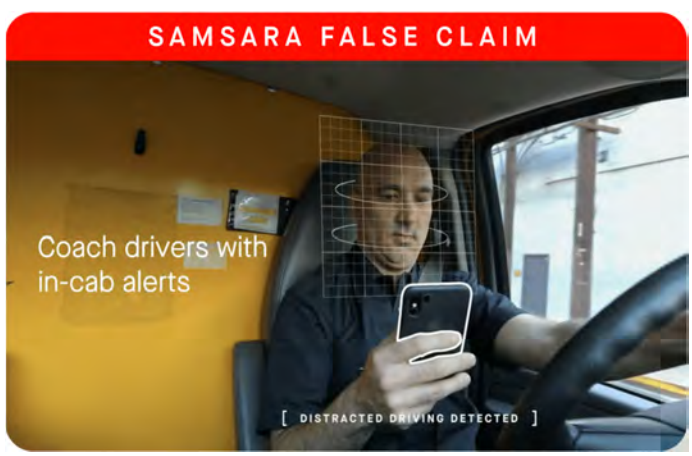
Picture of Motive's first Vehicle Gateway, dated August 21, 2015:

5. Before Samsara ever began operating as an industrial sensor start-up in 2015, thousands of fleets were already using Motive to improve the safety and efficiency of their operations. Contrary to Samsara's false claims in the marketplace that it was the innovator of this technology, Samsara released its first Vehicle Gateway in 2016, well after Motive, as depicted here:

6. In April 2017, Motive acquired Ingrain, an AI startup that was developing cutting-edge computer vision technology, and tasked the Ingrain team with building AI models to detect unsafe driving behavior for the Motive Dashcam. A Motive team of 25 engineers and 35 data annotators invested over three years of effort to build the first AI models to accurately detect driver cell phone use and tailgating. Motive first released a road-facing dashcam in 2018, allowing customers to obtain video of safety events captured by the Vehicle Gateway. Motive released its AI Dashcam in August 2021, after it confirmed that the AI models performed to the highest degree of accuracy.

7. Samsara chose a different path. In February 2019, Samsara rushed to market its so-called AI dashcam, claiming the product used AI to detect tailgating, cell phone use, and driver distraction to "prevent accidents before they happen." This is the same AI dashcam Samsara sells today. As discussed below, two independent, third-party studies that Motive commissioned in 2021 and 2023 show that Samsara's dashcam is unable to consistently and reliably detect the unsafe driving behaviors Samsara advertises it can, and

Samsara's dashcams lack the AI capabilities that it claims they have had since 2019. Samsara's false claims include the ones noted below:



8. While all of the above events were unfolding, Samsara, fearful it continued to lag behind Motive, hatched a plot to use a series of unlawful, deceitful, and fraudulent tactics, in an effort to try to catch up with Motive and copy Motive's technology.

9. The scope of Samsara's fraud and unfair competition is staggering. Among other things, Motive has documented proof of a years-long campaign of Samsara's deceit, including that:

a. for almost six years, beginning in at least 2016 and running through at least June 2022, multiple Samsara design engineers and employees falsely posed as Motive customers, set up accounts on Motive's platform, often using phony user ID names such as "Flanders Foundation," "Indus Enviro," and "PNP Transportation," and accessed Motive's platform in an effort to steal Motive's technology. Motive is currently aware of at least 30 accounts that Samsara employees created and accessed repeatedly during Samsara's six-year scheme;

b. among the Samsara personnel who set up these phony accounts and repeatedly accessed Motive's platform are senior Samsara executives Kiren Sekar, *Samsara's Chief Product Officer and Chief Strategy Officer*—the person who leads Samsara's global product organization and oversees Samsara's entire product strategy—Sean McGee, *Samsara's Vice-President of Product Platform Infrastructure*, Nirav Patel, *Samsara's Vice President of Business Operations,* Rushil Goel, *Samsara's (now former) VP of Products*, and several named inventors on Samsara's patents who accessed Motive's platform before filing their patent applications. The chart below shows only some examples of Samsara's multi-year fraudulent scheme of accessing Motive's platform:

Fake Company/Name	**Samsara Employees Associated with the Account**	**Created At**
N/A	Billy Waldman[1] *Director of Product Management*	2016-04-10 05:09:34 UTC
N/A	Michael Ulrich *Account Executive*	2016-11-20 01:17:38 UTC
Pat Sorn	Patrick Sornsin *Account Executive*	2017-06-24 01:45:04 UTC
Lo Kri Transport	Lauren Roberts *AVP Sales*	2017-08-02 18:14:38 UTC
N/A	Jonte Craighead[2] *Product Manager*	2017-08-31 20:13:59 UTC
PNP Transportation	Ian Solomon *Senior Sales Manager*	2017-10-25
N/A	Nirav Patel *Vice President, Business Operations*	2017-11-10 21:13:47 UTC
Nirvana Test Account	Rushil Goel[3] *VP, Product*	2018-01-19 02:18:02 UTC
N/A	Corbin Muraro[4] *Product Designer*	2018-02-07 02:35:48 UTC
self	Kiren Sekar[5] *Chief Product Officer*	2018-02-28 15:12:30 UTC 2018-07-23 15:42:14 UTC

[1] Mr. Waldman is a named inventor on at least one patent Samsara has sought to assert against Motive—a patent Samsara filed after Mr. Waldman's first access to Motive's platform.
[2] Mr. Craighead is a named inventor on at least one Samsara patent filed after Mr. Craighead's first access of Motive's platform.
[3] Mr. Goel is a named inventor on at least one Samsara patent filed after Mr. Goel's first access of Motive's platform.
[4] Mr. Muraro is a named inventor on at least one Samsara patent filed after Mr. Muraro's first access to Motive's platform.
[5] Mr. Sekar is a named inventor on at least one Samsara patent filed after Mr. Sekar's first access to Motive's platform.

Flanders Foundation	Michael Ross[6] *Director, Product Management* Sean McGee[7] *VP, Product - Platform & Infrastructure*	2018-03-09 02:29:04 UTC 2018-03-11 06:37:33 UTC
Indus Enviro	Ishaan Kansal[8] *Product Designer*	2018-09-27 22:18:36 UTC
Donald Karel	Donald Donkers *Product Manager*	2018-10-24 03:08:26 UTC
N/A	Matt Basham[9] *Senior Product Designer*	2019-08-22 14:03:11 UTC
N/A	Emily White *Product Design Manager*	2019-10-10 17:39:07 UTC
dnol inc	Dave Nolan *Product Manager*	2020-02-06 23:05:23 UTC
Frank Jon	Jeff Angius *Tech Support*	2020-03-06 06:07:24 UTC
N/A	Alan Liu[10] *Senior Product Designer*	2020-03-12 00:09:36 UTC
Test Rest	Semur Nabiev *Full Stack Engineer*	2020-08-19 02:57:25 UTC
N/A	Faiz Abbasi[11] *Engineering Manager*	2020-08-27 23:27:47 UTC
Uncle Bob	Ishan Tikku *Product Manager*	2021-06-23 03:30:31 UTC

[6] Mr. Ross is a named inventor on several Samsara patents filed after Mr. Ross' first access to Motive's platform.
[7] Mr. McGee is a named inventor on at least one Samsara patent filed after Mr. McGee's first access to Motive's platform.
[8] Mr. Kansal is a named inventor on several Samsara patents filed after Mr. Kansal's first access to Motive's platform.
[9] Mr. Basham is a named inventor on at least one Samsara patent filed after Mr. Basham's first access to Motive's platform.
[10] Mr. Liu is a named inventor on at least one Samsara patent filed after Mr. Liu's first access to Motive's platform.
[11] Mr. Abbasi is a named inventor on at least one Samsara patent filed after Mr. Abassi's first access to Motive's platform.

c. in setting up these fake customer accounts on Motive's platform, on at least one occasion Samsara identified the phony company by using the official identification number that the U.S. Department of Transportation ("DOT") issues to actual commercial carriers[12], to make it appear as if the company was legitimate—such false use of a federally-issued DOT ID number can be prosecuted under federal fraud and identity theft statutes;

d. Samsara sales representatives provided Motive customers and prospective customers with a chart (reproduced in paragraph 89 below) purporting to compare Samsara's and Motive's products, including their dashcam technologies, falsely claiming that Samsara's products could do things Samsara knew they could not, and that Motive's products could not do things that they could, all in an effort to steal customers from Motive under false pretenses;

e. at least one Samsara employee called a Motive customer, claiming that she was a *Motive* sales representative, in an effort to steal that customer from Motive, which indicates that Samsara had a copy of Motive's detailed customer lists and was training its employees to misrepresent themselves to Motive's customers;

f. in late 2019, Samsara began a campaign to hire key members of the Motive engineering team to steal trade secrets and intellectual property. Samsara hired Olivier Boireau, Motive's former VP of Hardware Engineering, in 2019, and in 2021 hired Pearl Lai, Motive's former Engineering Manager for its Vehicle Gateway, AI Dashcam and Asset Gateway products in Taiwan; and

g. Samsara hired former Motive sales representatives who downloaded Motive customer lists and brought them to Samsara in an effort to steal customers from Motive.

[12] For example, "Nirvana Test Account" used a DOT number associated with an actual trucking company based in Kentucky.

10. All of the above conduct violates Samsara's own Code of Conduct, which is posted on its website and states (falsely) that Samsara "does not seek competitive advantages through illegal and unethical business practices."

11. Samsara is a public company, which requires it to file annual and quarterly reports with the U.S. Securities and Exchange Commission (SEC) disclosing, among other things, material facts about the operation of and risks to its business. Knowing about all of the above conduct by its employees–because Motive informed them of it–Samsara's CEO (Sanjit Biswas) and CFO (Dominic Phillips) signed and submitted false SEC filings, including Samsara's 2023 Form 10-K that claimed "What Sets Us Apart" is "our differentiated company culture," which focuses on the company's "values," "operat[ing] with trust and respect," and "keeping our standards high through every part of our organization." Samsara's SEC filings did not (and do not) disclose that it knew its employees had engaged in all of the above fraudulent conduct against Motive and had repeatedly violated the company's own Code of Conduct, which renders multiple statements in the company's SEC filings false and misleading. Samsara has purposefully concealed all of its own fraudulent conduct from its public shareholders.

12. Samsara paired its fraudulent conduct with infringement of Motive's patents. For example, Samsara's dashcams (including its CM31 and CM32 dash cams) use precisely the same calibration techniques as Motive's AI Dashcam to determine the height of the cameras, a critical aspect to ensure proper machine-learning operations. Samsara's pattern of misconduct had the ultimate goal of misappropriating and imitating Motive's superior technology.

13. In 2021, in order to combat Samsara's false statements in the market about the capabilities (or lack thereof) of its products and false disparagement of Motive's products, Motive commissioned an independent, third-party study by a respected product testing firm, Strategy Analytics, Inc., to compare Motive's AI Dashcam with Samsara's dashcam. The results were clear: Motive's AI Dashcam far

outperformed Samsara's in every respect, including in detecting lack of seat-belt use, close following, and cellphone use. In April 2022, Motive posted Strategy Analytics' 25-page report, which contains supporting data, video, and test results, on Motive's website, so that all customers in the industry could see the truth about the superiority of Motive's AI Dashcam.

14. Samsara, of course, did not like the Strategy Analytics results, because they exposed the basic functional gaps in the Samsara product and the lies Samsara had been spreading in the market about its dashcam's capabilities. Most importantly, the test results exposed that use of Samsara's dashcam was posing safety risks to drivers and the public.

15. Samsara immediately began falsely claiming to customers that the Strategy Analytics test results were designed to favor Motive and that Samsara's dashcam was better than the results indicated. Samsara's complaints centered on confessions about its product's limitations–for example, its dashcam is not able to detect close following events until they happen for 30 seconds or more, a time period in which a vehicle operating at 60 miles per hour would have traveled a full half mile. Samsara also attempted to pressure Motive to remove the report from Motive's website, because Samsara didn't want customers to see it or confess to these obvious limitations.

16. Motive explained to Samsara in great detail why the Strategy Analytics testing produced reliable, valid results. Further, Motive invited Samsara to jointly engage another independent third-party, to be mutually agreed by the parties, to again test the two companies' dashcams head-to-head—which Motive was confident would confirm the Strategy Analytics results and prove once again that Motive's product was superior. Samsara refused.

17. In 2023, Motive therefore commissioned another independent, third-party study comparing the Motive and Samsara dashcams, this time by the Virginia Tech Transportation Institute ("VTTI"), one of the most prestigious research institutes in the transportation field, and part of Virginia Tech, one of the

premier engineering colleges in the United States. The VTTI study and testing found the same thing Strategy Analytics had: Motive was more likely to issue a successful in-cab alert compared to Samsara for phone calls, lap texting, 45-degree texting, close following, and rolling stop trials across all lighting conditions. Samsara has falsely claimed that this study, too, was somehow not fair.

18. Two independent third party studies have now confirmed what Motive already knew: simply put, Motive's products are better than Samsara's. Samsara—knowing its products are inferior to Motive's—decided to resort to the above fraudulent and underhanded practices in an effort to deceive customers and prevent them from learning the truth about Motive's superior technology.

19. Despite Samsara's unethical, improper, and unlawful efforts to compete in the marketplace, Motive was content to let its products and services do the talking: customers continue to favor Motive's technology over Samsara's; Motive continues to beat Samsara in the fleet management and driver safety market; and Samsara continues to refuse to sponsor and make publicly available any head-to-head testing of the two companies' dashcams.

20. However, because Samsara cannot successfully compete against Motive based on the merits of the two companies' products, Samsara recently decided to try to silence Motive, cast doubt on Motive's ability to operate, and stifle competition by resorting to litigation, filing a lawsuit against Motive in Delaware (not California, where both companies are located), complete with a splashy marketing campaign touting its false litigation claims, and a second complaint with the U.S. International Trade Commission regarding certain of its patents—patents that Motive obviously does not infringe, if they are even directed to patentable subject matter in the first place. Samsara is acting with malice in an attempt to cast doubt on fair competition in a technology industry where products often have the same basic functionality, are easily accessible, and can be compared on a daily basis by their users. Samsara's goal is to cost Motive millions

of dollars in litigation fees, hundreds of millions of dollars in lost revenue, and billions of dollars in lost brand value.

21. Faced with an onslaught of tactical and bad faith litigation, Motive—the actual injured party here—now brings its own claims against Samsara, in the jurisdiction where the companies are located, to show the truth about Motive's industry-leading products, Samsara's inferior copies, and Samsara's lies and deception; to recover damages caused by Samsara's fraudulent behavior; and to stop Samsara from continuing to compete unfairly in the marketplace.

PARTIES

22. Motive is a corporation organized and existing under the laws of the State of Delaware with its principal place of business at 55 Hawthorne Street, Suite #400, San Francisco, CA 94105.

23. Samsara is a corporation organized and existing under the laws of the State of Delaware with its principal place of business at 1 De Haro Street, San Francisco, CA 94107.

JURISDICTION AND VENUE

24. This Court has subject matter jurisdiction over this action pursuant to 28 U.S.C. §§ 1331, 1338, and 1367.

25. This Court has personal jurisdiction over Samsara because Samsara is a citizen of California.

26. Venue is proper in this judicial district under 28 U.S.C. §§ 1391 (b) and 1400 (b) because defendant Samsara is based in and hence resides in San Francisco, and because a substantial portion of the acts giving rise to liability both took place in San Francisco and were directed at Motive in San Francisco.

DIVISIONAL ASSIGNMENT [Civ. L.R. 3-5(b)]

27. Under General Order No. 44(D)(3), claims involving intellectual property rights such as patent rights are assigned district-wide and may properly be heard in any venue in this District.

28. However, Motive's non-intellectual property claims arise in the City and County of San Francisco and shall be assigned to the San Francisco Division or the Oakland Division. Civil Local Rule 3-2(d).

FACTS

MOTIVE IS AN INDUSTRY PIONEER

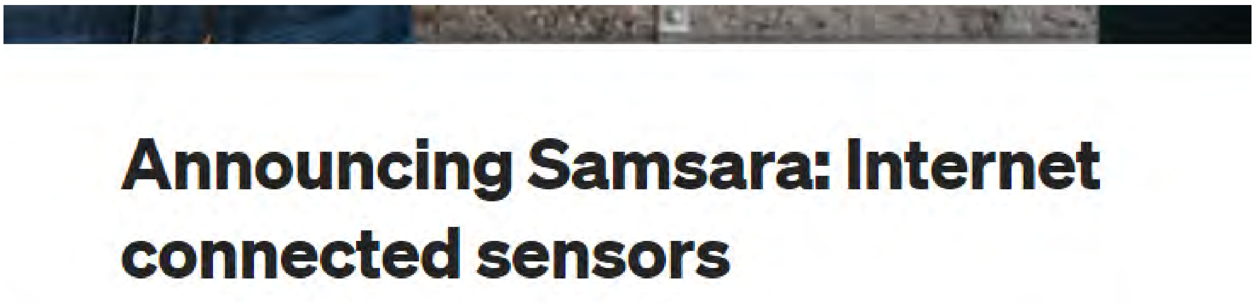
29. Motive—not Samsara—is the true innovator and pioneer in the fleet management and physical operations market. Samsara followed Motive, and has struggled to keep up with Motive's superior product offerings and more satisfied customer base and users. Because of its struggles, Samsara has resorted to unethical, improper, and unlawful tactics to try to compete against Motive's technology.

30. Motive was founded in 2013, and was at the time known as "KeepTruckin." Motive began with the vision to build technology that would improve the safety and efficiency of America's transportation industry. Motive sought, and still seeks, to save lives and solve its customers' most pressing operational needs.

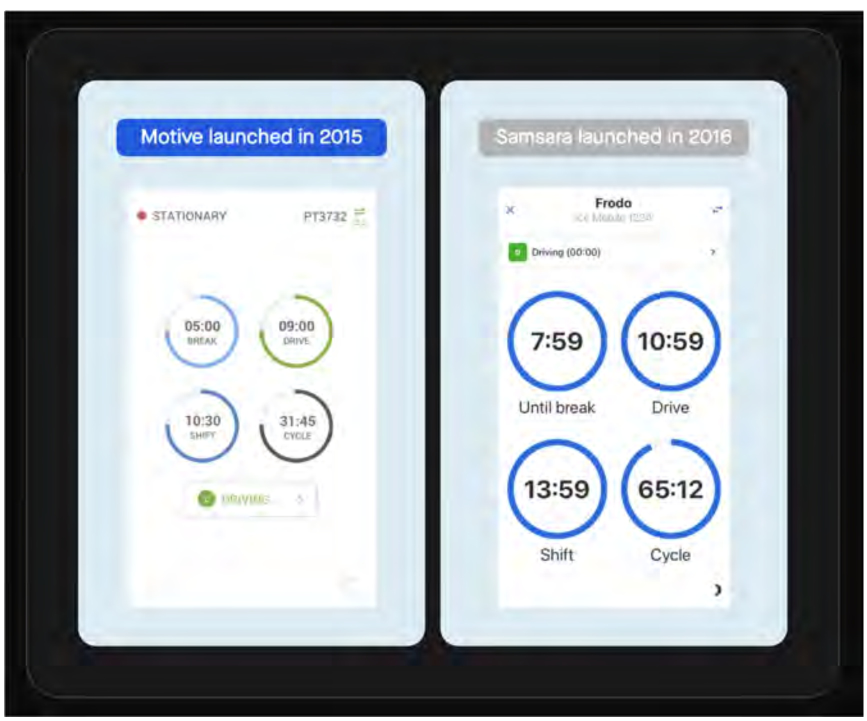
31. The initial step in achieving this vision, in December 2013, was Motive's launch of the first Android and iOS based fleet management and electronic logging platform in the industry. But this was only the beginning; in 2015 Motive soon followed with its first hardware product, a proprietary Vehicle Network Gateway (LBB-1).

32. Motive's Vehicle Gateway, the LBB-1, was the first vehicle telematics device to contain an advanced processor, 4 GB of storage, WiFi and Bluetooth radios, multiple USB interfaces, and running the Linux operating system instead of the real-time operating systems used by traditional telematics devices. Motive ultimately envisioned offering customers a connected dashcam using the USB interface so that customers could combine driver safety and fleet management in one integrated platform.

33. By contrast, Samsara incorporated two years after Motive, in 2015, and initially sold only temperature sensors, as is described online when the company launched: https://medium.com/@biswas/announcing-samsara-internet-connected-sensors-24484e7c33c6.



34. In other words, Samsara entered the fleet management, telematics, and compliance space long after Motive. Samsara's products with which it entered into this space were copied from Motive's. For example, Motive launched a redesigned Driver App in July 2015; Samsara's first Driver App was released in July 2016 and used an identical interface, as shown below:



35. As time moved forward, Samsara's ability to build and debut products was based in substantial part on Samsara employees surreptitiously accessing Motive's platform in an effort to copy Motive's technology.

36. By the time Samsara followed Motive into the fleet management and electronic logging market, Motive was well ahead, particularly in the trucking industry, a lead that Samsara sought to take from Motive.

37. In early 2017, Motive acquired Ingrain, an AI startup, and began working on cutting-edge new technology that could detect unsafe driving behavior. Motive invested over three years of effort and resources to build its first accurate AI Dashcam models. Motive understood that inaccurate AI models would not make drivers safer—it would only train them to ignore false alarms or rely on alarms that never sounded. In 2018 Motive first released a road-facing dash cam that allowed fleets to quickly retrieve video of harsh driving events. But Motive waited until 2021 to release its AI Dashcam, after Motive was able to confirm the accuracy and safety of the AI models. In other words, Motive was focused on building the best and safest product for its users, which meant it was unwilling to rush an inferior product to market.

38. Samsara did the opposite, rushing to market a flawed and low-performance AI dashcam product in 2019. Samsara claimed it used AI to detect tailgating, cell phone use, and driver distraction to "prevent accidents before they happen."

39. This is the same AI dashcam that Samsara still sells today, even though—as confirmed by two independent, third-party studies—Samsara's dash cam is unable to detect the unsafe driving behaviors Samsara advertises it can, and Samsara's dash cams lack the AI capabilities that it claims they have had since 2019.

40. Motive has continued to innovate in technologies that power the physical economy, and offers a number of unique product features, including fuel cards for expense management, machine learning

models for safety and fuel usage, and an AI Omnicam to provide 360-degree visibility around a vehicle. Motive also offers its own versions of industry-standard products.

41. Motive's offerings include its AI Dashcam, which Motive released after years of development on a platform that is entirely different from Samsara's low-performance product. Motive also has meaningfully improved its Dashcam since the initial release by leveraging AI to automate coaching and offer real time alerts for harsh events and high-risk behavior detection, including close following, cell phone use, failure to use seat belt, and distracted driving.

42. Motive's superior product offerings have helped Motive surpass Samsara in the market. Samsara has responded with the unlawful and underhanded business practices described herein.

FOR AT LEAST SIX YEARS, SAMSARA EMPLOYEES ACCESSED MOTIVE'S PLATFORM TO ATTEMPT TO COPY MOTIVE'S TECHNOLOGY

43. When Motive customers purchase Motive's products, they create accounts to connect to the Motive Fleet Dashboard, which allows them to manage their drivers and vehicles from a single cloud-based platform. On initial login, the customer creates a secure password and inputs its company (or individual) name, email address, and other identifying information.

44. Beginning in at least 2016, just a year after Samsara was founded and while it was still developing its initial products, Samara began a scheme to access Motive's Driver App and Fleet Dashboard under false pretenses and attempt to copy Motive's technology. For example, on April 10, 2016, Samsara employee Billy Waldman (Director of Product Management) created an account on Motive's platform and accessed it multiple times over at least the next year. On August 2, 2017, Lauren Roberts, then Samsara's Vice President of Sales, created an account on Motive's platform using her personal email address and the fake company name "Lo Kri Transport." She too accessed the account for over a year.

45. For at least the next six years, through at least June 2022, Samsara employees created and accessed at least 30 customer accounts on Motive's platform, with multiple accounts opened most years.

The Samsara employees who did so were not lower-level personnel, but rather included multiple senior executives at the company. They also included multiple Samsara employees who were listed as inventors on patent applications Samsara filed *after* these employees first fraudulently accessed Motive's platform.

46. For example, Kiren Sekar is both the Chief Product Officer and Chief Strategy Officer of Samsara—one of the most senior executives in the entire company, who was one of the original employees at the company's founding. Samsara's website states that Mr. Sekar is "responsible for company strategy," "leads Samsara's global product organization … overseeing the company's product strategy, roadmap, and development activities," and "previously led the Product organization from founding through Samsara's IPO, and also led Marketing at Samsara from founding until 2021."

47. On at least two occasions, Mr. Sekar created phony customer accounts on Motive's platform. On February 28, 2018, he created an account under the username "Kevin Smith," using a personal email address to register the account, and on July 23, 2018 he created a second account under the username "test test" and the company name "self," using a different personal email address. He accessed these accounts multiple times.

48. Similarly, Sean McGee is Samsara's Vice-President of Product - Platform & Infrastructure, in which he leads product development and strategy, especially relating to platforms. On March 9, 2018, Mr. McGee and his Samsara colleague Michael Ross (Director, Product Management) created a customer account on Motive's platform using the fake company name "Flanders Foundation" and a personal email address. Mr. Ross purchased a Vehicle Gateway from Motive on March 8, 2018. Three months later, on June 10, 2018, Mr. McGee also created a separate account under his own name, using a different personal email address. These accounts were repeatedly accessed by Mr. McGee and Mr. Ross multiple times over at least the next three years.

49. Based on Motive's investigation to date, the chart at paragraph 9 above gives examples of the fake customer accounts registered by Samsara employees on Motive's platform and the scope of the scheme Samsara hatched to steal and/or copy Motive's technology.

50. In a market with free and open competition, competitors in the technology sector often access and use each other's products, test them to determine their capabilities and limitations, and compare their products to their competitors' products, in an effort to provide consumers with the best possible products and truthful information about the available options. Motive has no issue with competing with Samsara (or any other company) in that fashion. But that is not what Samsara has done.

51. On information and belief, Samsara employees accessed Motive's platform under the false pretenses described above with the specific intent to steal and/or copy Motive's fleet management technology, platform capabilities and features, and business and marketing strategy, including to attempt to reverse-engineer the source code or underlying algorithms of the technology. These efforts were carried out by and/or approved by Samsara's senior executives and employees; these employees knew they were acting improperly and unlawfully, but did so because Samsara's technology was inferior to Motive's, and they hoped to incorporate Motive's technology into Samsara's products.

52. In June and July 2022, Motive discovered the years-long Samsara fraudulent scheme to access Motive's platform. In late July 2022, Motive informed Samsara's management, legal department, and Board of Directors (through Samsara's outside counsel) of the above facts about Samsara's conduct, and demanded that Samsara immediately cease and desist. Samsara waited almost two months to respond, then admitted that its employees had surreptitiously accessed Motive's platform under false pretenses, but claimed that Samsara "has never condoned" such conduct (even though, as described above, the employees who accessed the platform were senior executives at the company, including its Chief Product Officer) and

that the misconduct occurred "years ago" (even though the access continued into June 2022, just before Motive notified Samsara).

MOTIVE'S PATENT AND SAMSARA'S INFRINGING PRODUCTS

53. Samsara's scheme extended to infringing Motive's patents on Motive's dashcam technology. On January 16, 2024, the United States Patent and Trademark Office duly and lawfully issued to Motive U.S. Patent No. 11,875,580 (the "'580 Patent"), entitled "Camera Initialization for Lane Detection and Distance Estimation Using Single-View Geometry," a true and correct copy of which is attached as **Exhibit A**. The '580 Patent is valid and enforceable. The '580 Patent discloses and claims various novel, non-obvious, and useful features relating to the calibration of dashcam sensor (e.g., camera) parameters for use in, *inter alia,* on-device machine learning and/or artificial intelligence applications relating to automotive monitoring functions.

54. The inventors of the '580 Patent faced, and solved, several technical problems facing in-vehicle dashcam devices. Previous systems required a "predefined or preset" positioning of the camera, which is prone to human error. Ex. A at 1:10–17. Alternatively, previous systems required the use of radar or Lidar to aid in object detection, a technically complex and computationally expensive approach. *See id.*

55. Motive's inventors realized that the ability to use a monocular and adjustable camera would solve these technical problems resulting from the use of multiple cameras or non-image sensors (e.g., radar or Lidar). *See id.* at 1:6–25. However, Motive's approach would require innovations in how to determine the position of a single outward-facing camera, regardless of how the camera is positioned on a vehicle, a problem previously unsolved in the industry.

56. To solve this problem, claim 1 of the '580 Patent describes a system that can receive video (e.g., image frames) from such an adjustable camera. The system then first uses a predictive model to identify various reference lines in the video (e.g., a horizon line) automatically and without human

intervention. Using this automatically determined horizon line, the system can determine a camera parameter (e.g., the height of the camera) based on the lines and can then generate a digital video (e.g., image frames) that overlay the horizon on the images captured by the dashcam. To aid in confirmation, the system can then transfer the predicted horizon line (and other lines) to an annotator for confirmation before automatically adjusting the dashcam parameters based on the automatically determined parameter.

57. The recited system was unconventional and not well understood at the time of the invention of the ’580 Patent, as outlined above. Further, such a system implements a solution that utilizes predictive modeling, camera parameter estimation, and a confirmation workflow. Such a system cannot be implemented in the human mind, as it requires implementation with computers and electronic equipment, e.g., to use a predictive model to identify the horizon line, to estimate a camera parameter based on the horizon, generating overlaid images, and communicating with network devices to confirm the horizon.

58. Samsara makes, uses, sells, and offers to sell in-vehicle dashcam devices including its CM31 and CM32 dashcams (the “Infringing Dashcams”).

59. Samsara makes, uses, sells access to, and offers to sell access to a software-as-a-service platform referred to as its “Connected Operations Cloud” or “Samsara Cloud” (and similarly named services) that receives data from dashcams and provides analytics and control interfaces for customers that install the Infringing Dashcams (the “Infringing Platform”).

60. The Infringing Dashcams and Infringing Platform (collectively, the “Infringing Products”) operate in synchrony to provide fleet management services to Samsara’s customers. The Infringing Products infringe Motive’s ’580 Patent.

SAMSARA SOLICITS MOTIVE’S EMPLOYEES AND STEALS MOTIVE’S CONFIDENTIAL INFORMATION

61. As part of its scheme to unlawfully compete with Motive, Samsara has also actively solicited Motive’s employees to join Samsara in order to acquire Motive’s confidential and proprietary information

relating to current and future product plans, sales, and prospective and existing customers. Samsara's efforts to poach Motive employees has occurred over the course of years, as Samsara otherwise struggles to fairly compete with Motive's superior business and product offerings.

62. Samsara has poached and attempted to poach multiple high-level employees, including high-level individuals—vice presidents, managers, and directors—from Motive's hardware engineering and software programming departments.

63. On information and belief, Samsara encourages employees it has successfully poached from Motive to obtain and keep—in other words, steal—confidential information from Motive before their departure. This includes confidential and proprietary information on Motive's products, customers, sales, and business strategies, among other areas of competitive interest.

64. Motive has made extensive efforts to maintain the secrecy of its proprietary information. These efforts include training employees in the protection of corporate secrecy, requiring employees to sign confidentiality agreements, limiting electronic access to proprietary information, requiring employees to use company-provided computers, requiring employees to sign a Separation and Release agreement upon termination of their employment that reminds them of their confidentiality obligations, and performing exit interviews with employees who voluntarily depart. Motive has informed any recipient of its proprietary information that the information is proprietary and has required any recipient of such information to maintain its confidentiality.

65. On information and belief, Samsara hired former Motive employees who then provided confidential Motive information to Samsara, which unlawfully uses such information in Samsara's efforts to compete with Motive in the marketplace.

66. Samsara's tactics have become increasingly aggressive over time, and now go beyond just stealing Motive's employees and confidential information. Once Samsara has successfully convinced a

Motive employee to defect with that confidential information, Samsara actively shields those employees from Motive's efforts to lawfully reclaim its confidential information.

67. As part of its campaign to assist former Motive employees in not returning confidential and proprietary information to Motive, Samsara's internal legal department has interfered with Motive's lawful attempts to retrieve its information. This includes intercepting communications by Motive to its former employees and threats to Motive to cease trying to retrieve its information from those individuals.

68. For example, in or around July 2022, Samsara hired a former Motive account executive ("Former Employee 1"). Shortly after Former Employee 1's departure from Motive, Motive's IT department determined that Former Employee 1 had downloaded a large number of files. The download was highly suspicious because it included multiple files containing confidential and proprietary information about Motive's customers, pricing, sales, and business strategies, among other things. Former Employee 1 had no valid work purpose for accessing and downloading these files.

69. The files downloaded by Former Employee 1 include, among other things, Motive's proprietary method for setting its pricing and structuring its deals, and account lists that contain not only the names of current and potential customers, but also each customer's address, telephone number, contact person, private email address, prior order history, and pricing information. Motive has gathered this customer information over the entire history of its operations, which span not only many years but thousands of hours of research, including prior order/pricing information. Many of those on the list have been Motive's customers for years.

70. When Motive attempted to explore the issue with Former Employee 1, Motive was quickly stonewalled. Former Employee 1 refused to acknowledge the suspicious download of the files, and refused to answer any questions pertaining to them. Former Employee 1 further refused to provide a declaration

or affidavit, as is customary in these circumstances, confirming Former Employee 1 did not intend to break the law by taking Motive's confidential and proprietary information.

71. Upon further attempts by Motive to retrieve the stolen information from Former Employee 1, Samsara's internal legal department intervened, shielding Former Employee 1 from communications with Motive and demanding Motive provide additional information in support of its request. When Motive provided a list of over 130 files it identified that Former Employee 1 had downloaded shortly before the employee left Motive, Samsara stopped responding.

72. On information and belief, Samsara has also obtained from Motive employees confidential Motive information with respect to Motive's Dashcam; Samsara has used such information to help develop the latest version of Samsara's dashcam, which Samsara is in the process of launching. Specifically, Samsara took Motive's confidential and proprietary information regarding the Ambarella platform that Motive uses in its dashcams.

73. Motive began developing its AI Dashcam platform on an Ambarella chip in 2019. Motive ultimately launched its Dashcam in 2021 using the Ambarella CV22 CVflow edge AI vision system on chip (SoC). Motive's AI Dashcam was manufactured by Quanta Shanghai Manufacturing City ("QSMC"), a Taiwan-based company. On information and belief, at the time, Motive was the only major fleet management dashcam provider using the Ambarella chip and, to this day, remains the only major fleet management dashcam provider using an Ambarella chip. Samsara, along with some of Motive's other dashcam competitors, have used Qualcomm or other chip platforms for their dashcams.

74. Although the fact that Motive was using an Ambarella chip for its AI Dashcam was publicly disclosed in 2021, certain technical specifications and designs are not generally known or readily ascertainable. An Ambarella chip uses an entirely different architecture than the Qualcomm chip that Samsara and others in the industry use. Motive thus spent considerable resources and time developing

proprietary specifications and designs to efficiently use, for example, the vector processor on the Ambarella chip, and effectively run the neural networks and AI models necessary for a superior dashcam product.

75. On or around October 28, 2019, Samsara hired Olivier Boireau, Motive's former Vice President of Hardware Engineering—the individual responsible for all hardware at Motive. Mr. Boireau, as head of hardware, was aware of Motive's plans to develop an Ambarella-based AI Dashcam, and was involved in fostering Motive's relationship with QSMC. On information and belief, Mr. Boireau left Motive with confidential and proprietary information regarding Motive's plans to use the Ambarella platform in its AI Dashcam, and shared that information with Samsara.

76. On or around August 6, 2021, Samsara also hired Pearl Lai, Motive's former Engineering Manager in Taiwan—the individual responsible for hardware at Motive's Taiwan office. Ms. Lai had directly worked with QSMC on Motive's AI Dashcam product that uses the Ambarella chip. On information and belief, Ms. Lai left Motive with confidential and proprietary information regarding Motive's specifications and designs for the Ambarella platform used on its AI Dashcam, and shared that information with Samsara. Motive launched its AI Dashcam only weeks after Ms. Lai began at Samsara, on August 12, 2021. On information and belief, Ms. Lai thus provided Samsara with knowledge of the inner workings of Motive's near-finished product.

77. As independent studies and Motive's growing market share have proven since then, Motive's AI Dashcam and its unique Ambarella-based design has achieved superior performance compared to its competitors' dashcams.

78. On information and belief, Samsara began developing a dashcam using the confidential and proprietary information taken from Motive and provided to Samsara by Mr. Boireau and Ms. Lai. On information and belief, Samsara's new dashcam is in the process of being launched and features use of an Ambarella chip, and will be manufactured by QSMC—directly copying Motive's hardware design.

79. On information and belief, Mr. Boireau and Ms. Lai also shared Motive's confidential and proprietary information regarding other Motive products that they worked on or had knowledge of, including Motive's Vehicle Gateway and Asset Gateway, with Samsara.

80. Samsara's inducement of Motive employees to defect from Motive with confidential information is an attempt by Samsara to gain an unfair and unlawful advantage in the marketplace.

81. This unfair and unlawful conduct harms Motive in multiple ways. Motive loses valuable employees and confidential information to Samsara's unethical recruiting practices. Motive must then expend time, money, and other resources in its attempts to retain employees. Motive must further expend resources in attempts to lawfully retrieve its stolen information.

82. Motive is further harmed in its ability to fairly compete in the marketplace by this conduct, because it results in Samsara's unlawful possession and use of Motive's confidential and proprietary information.

SAMSARA UNLAWFULLY IMPERSONATES MOTIVE EMPLOYEES

83. Samsara's deceptive practices extend to having its employees impersonate Motive employees in interactions with Motive's customers. This illicit practice is designed to mislead and steal Motive customers.

84. For example, on May 20, 2022, a sales representative from Samsara, who said her name was "Natalie," left a voicemail for a current Motive customer. In an effort to have the customer call her back, she falsely identified herself as an employee of Motive, left her phone number, and asked for a return call. The customer called the number, and "Natalie" admitted she actually was an employee of Samsara.

85. Samsara's deception upsets Motive's customers, who are satisfied with Motive's superior product offerings. In fact, Motive customers have voiced their displeasure with such conduct directly to Motive, and their unhappiness with being exposed to Samsara's fraudulent and misleading conduct.

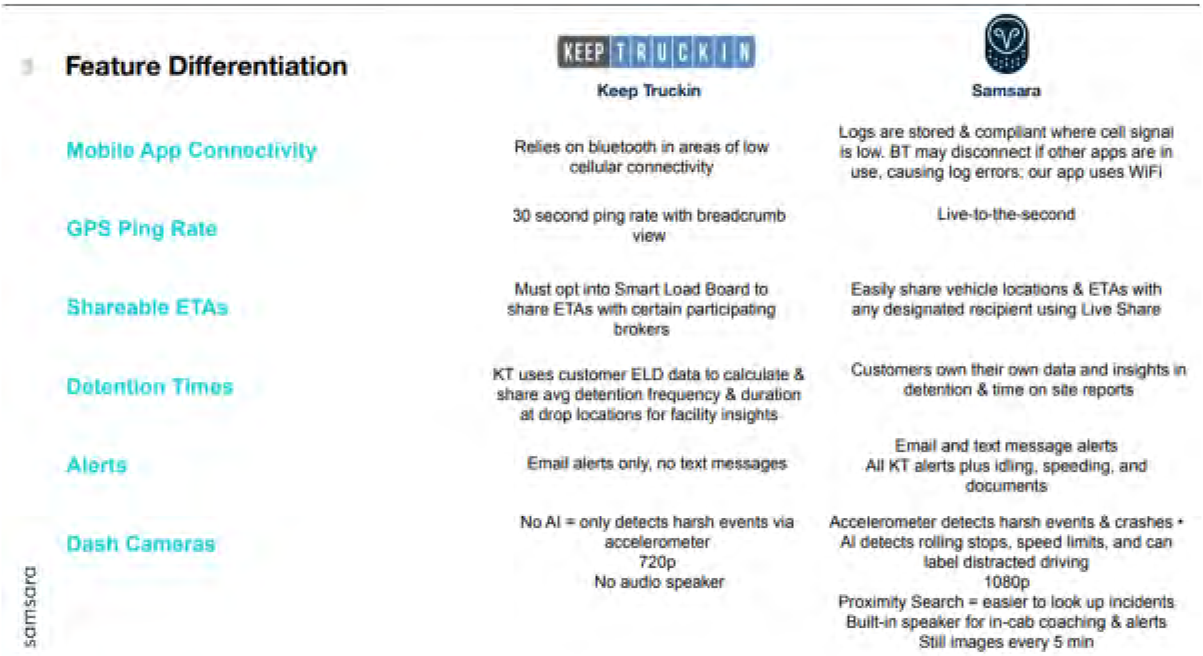
86. Samsara's deceptive practices force Motive to expend valuable time, money, and resources in responding to them. For example, because of Samsara's deception, Motive employees must work to maintain customer relationships, reassure current customers of their status, and continue to monitor further attempts by Samsara's representatives to impersonate Motive. Impersonation of a competitor has no place in a free and fair marketplace.

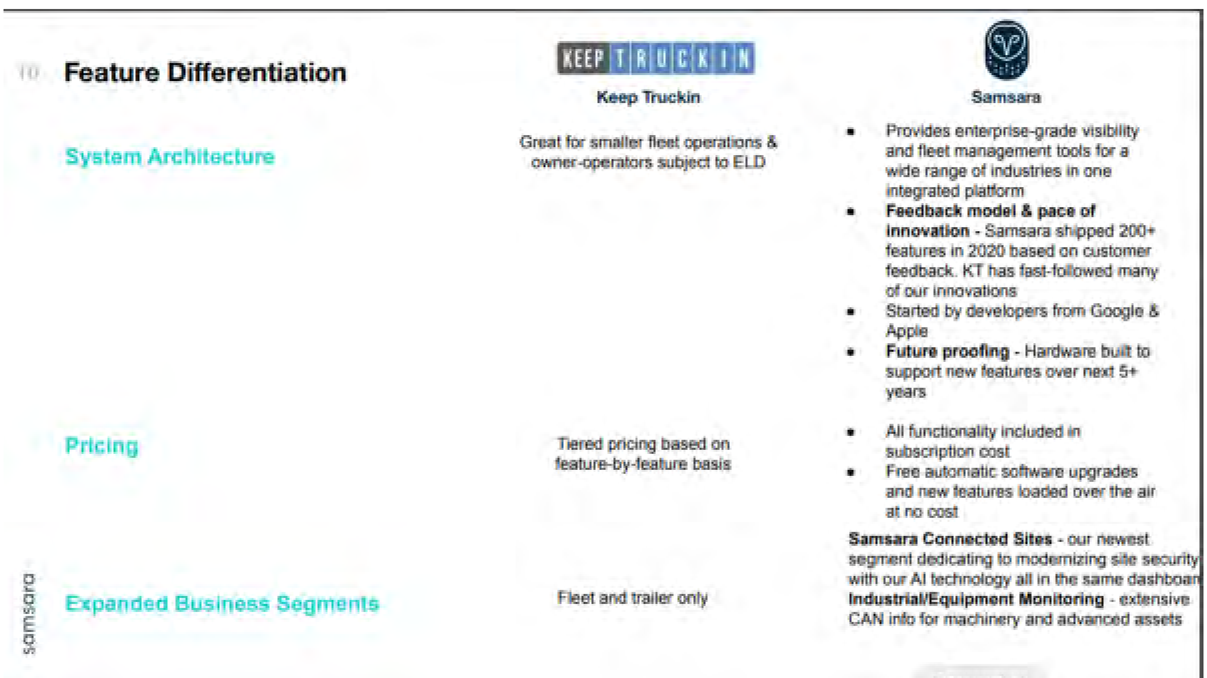
SAMSARA'S FALSE AND/OR MISLEADING ADVERTISING AND STATEMENTS ABOUT SAMSARA'S AND MOTIVE'S PRODUCTS AND TECHNOLOGY

87. Samsara has also sought to unlawfully compete with Motive through advertisements and marketing materials that contain false and/or misleading claims about the functionality and efficacy of Motive's AI video-based safety applications (falsely claiming that Motive's products lack certain capabilities that they in fact have) and Samsara's own products (falsely claiming that Samsara's products have certain capabilities that they don't).

88. Motive has notified Samsara on multiple occasions that Samsara employees are using false and misleading advertising to try to deceive customers about the relative capabilities of Motive's and Samsara's products, writing directly to Samsara's CEO and General Counsel about these issues. Samsara initially promised it would put a stop to this unethical and unlawful business practice, but it continued unabated.

89. For example, in December 2021, a Motive customer provided Motive with the below "Feature Differentiation" chart that Samsara sent to the customer in an effort to convince the customer to switch from Motive (then KeepTruckin) to Samsara:





90. Multiple statements within this advertisement are false and/or misleading, including the following:

91. *First*, Samsara claimed that Motive's Vehicle Gateway has a 30-second GPS ping rate, while Samsara's product has a to-the-second ping rate. That is false. Motive's product provides a real-time, to-the-second ping rate that updates continuously while a vehicle is in motion.

92. *Second*, Samsara claimed that Motive's dashcams have "no AI" and can only detect harsh events through an accelerometer. That is false. Motive's dashcams are driven by AI and can detect unsafe driving other than accelerometer-based harsh events. For instance, Motive's dashcams can use AI and computer vision to detect close following, cell-phone use, seat-belt use (or lack thereof), and much more, even when harsh events are not detected.

93. *Third*, Samsara claimed that Motive's products are suitable only for smaller fleet and trailer operations. To the contrary, Motive's technology is designed for any company that operates commercial vehicles, from the nation's largest enterprise fleet companies to companies in construction, oil and gas, passenger transport, utilities, and field services. Any suggestion otherwise is false.

94. *Fourth*, Samsara claimed that Motive offers only tiered pricing on a feature-by-feature basis. This is false. Motive offers multiple different pricing packages based on its customers' unique and/or differentiated needs.

95. Motive confronted Samsara with this false advertisement in December 2021, and explained why it was false, but Samsara refused to stop using it.

96. In another instance, in April 2020, Samsara sought to take advantage of the COVID-19 pandemic to distribute additional false claims regarding the capabilities of its own products. Under the guise of helping "essential businesses" during those "pressing times," Samsara sent potential customers misleading video footage that appeared to show Samsara's dashcam detecting instances of distracted driving in ways and within time intervals that independent testing has shown Samsara's dashcam cannot

detect. Samsara sent these advertising emails and communications even though Samara knew its dashcam was not capable of such performance.

97. Samsara has also promoted, and continues to promote, false and misleading statements about its own products. For example, Samsara has posted multiple videos online, including on the company's website and on YouTube, which overstate the abilities of Samsara's dashcam.

98. One such video, posted in February 2019, claimed that Samsara's product "contained artificial intelligence" that could be used to "prevent accidents before they happen" and detect certain instances of distracted driving. These claims were false and misleading; Samsara's dashcam was unable to perform the tasks claimed. Indeed, the video is still available online—and considering the poor performance of Samsara's dashcam in independent third-party testing, these statements regarding Samsara's dashcam's alleged capabilities remain untruthful and misleading.

99. Samsara made these false and misleading statements, among other misrepresentations to customers and prospective customers, to gain an unfair competitive advantage. These false and misleading statements impacted Motive's performance and standing in the marketplace.

SAMSARA MISREPRESENTS INDEPENDENT THIRD-PARTY STUDIES THAT CONSISTENTLY CONFIRM THAT MOTIVE'S DASHCAM IS BETTER

100. Samsara's deceptive and unfair business practices extend to falsely maligning independent third-party studies of dashcam products. These studies, conducted by market leaders and trusted organizations, consistently demonstrate the superiority of Motive's AI Dashcam.

101. In 2021, Motive commissioned Strategy Analytics, Inc.—now known as TechInsights—to perform an independent, objective, third-party comparison of the dashcams sold by Motive, Samsara, and another competitor in the market. Strategy Analytics was and still is a respected product testing firm, and Motive had no prior relationship with the company.

102. The commission of such independent third-party studies is a common practice in the industry, and a way of helping to demonstrate to current and prospective customers the merits and value of competing products.

103. Strategy Analytics' testing occurred over the course of a year. Motive did not interfere with the testing and analysis; did not provide Strategy Analytics with any misleading parameters; and did not alter the results or findings of the testing. Instead, Motive asked Strategy Analytics to test key features that each company claimed its dashcam offered, including the ability to correctly and timely detect lack of seatbelt use, close following, and cell phone use. The Introduction to Strategy Analytics' Report is below:

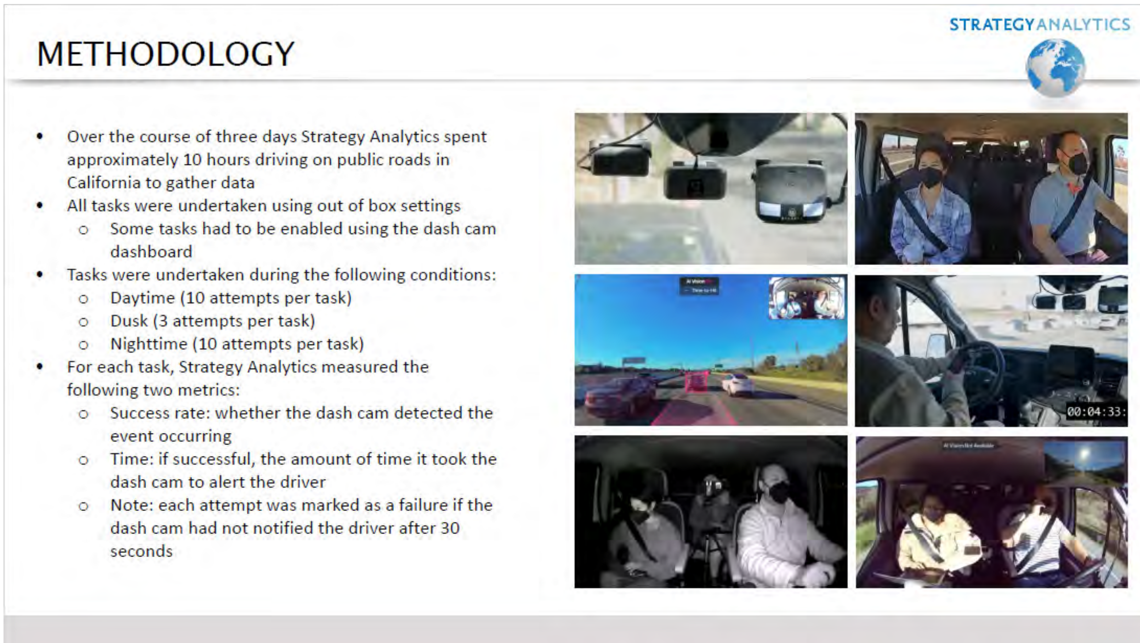
STRATEGY ANALYTICS

INTRODUCTION

- AI dash cams help prevent accidents by reducing distracted driving and other risky road behaviors. The cameras are mounted on the windshield and use artificial intelligence to detect unsafe driving behaviors and road conditions. Once detected, the cameras notify drivers with in-cab audio and visual alerts to help drivers modify their behaviors.
- Strategy Analytics undertook an independent evaluation of three leading AI dash cam providers (Motive, Lytx, and Samsara) on behalf of Motive. Strategy Analytics benchmarked performance across the following four criteria, which Motive has identified as essential when considering which AI dash cam to purchase:
  - Accuracy and speed of alerts
  - Image/video quality
  - Alerting style
  - Hardware design
- Strategy Analytics, Inc. is a global leader in supporting companies across their planning lifecycle through a range of syndicated and customized consumer and market research solutions. Strategy Analytics' multi-discipline capabilities include industry research advisory services, consumer insights, user experience design and innovation expertise, mobile consumer on-device tracking and business-to-business consulting competencies. Strategy Analytics has domain expertise in smart devices, connected cars, intelligent home, service providers, IoT, strategic components and media.
- This report covers the following:
  - AI Performance Evaluation and Methodology
  - Image and Hardware Quality Comparison and Methodology

104. In short, Motive sought to prove what it always believed, that its AI Dashcam performed better than two of its competitors, including Samsara. Motive was right. Strategy Analytics conducted 342 separate tests comparing Motive's product, the Motive DC-54, against Samsara's product, the Samsara HW-CM32, and the other competitor's product, as follows:

105. The dashcams were tested under varying driving conditions, such as the product's performance while driving during the dusk or evening. The products were compared across: accuracy and speed of alerts; image/video quality; alerting style; and hardware design. All dashcams were tested with their out-of-box settings, just as a customer would receive them; neither Strategy Analytics nor Motive altered or tampered with the products being tested. Strategy Analytics' methodology was clearly stated in its Report:



106. Motive's dashcam performed better than Samsara's in each category and was better-liked by users in the majority of categories. Indeed, Strategy Analytics' tests supported the claims that Motive's AI Dashcam was the "best performing," "most accurate," and "fastest" as compared to its competitors. As to Samsara's dashcam in particular, the testing showed that Samsara's claims in the marketplace about the capabilities of its product were false and grossly overstated, and that Samsara's dashcam was actually dangerous for users because it did not and could not detect a range of unsafe driver behaviors.

107. Specifically, Strategy Analytics' overall test results demonstrated that Motive's AI Dashcam successfully detected unsafe driving behavior 89% of the time, as opposed to Samsara's dashcam, which detected unsafe driving only 15% of the time.

STRATEGYANALYTICS

SUMMARY RESULTS

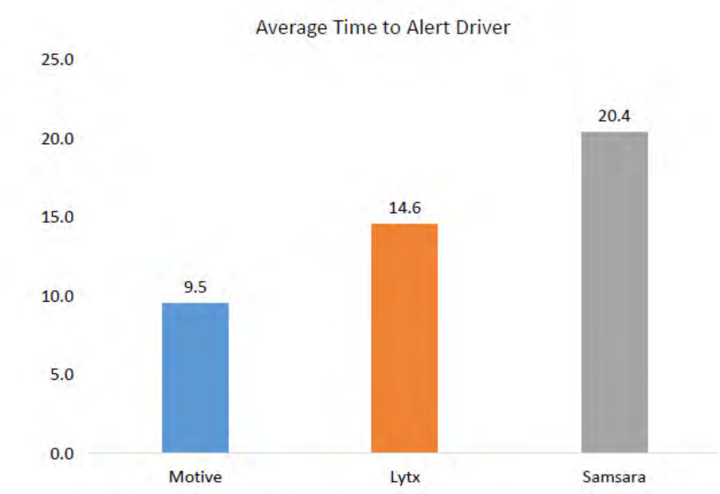
The chart below shows the alert success rate and average time for alerts to trigger:

	# of Tests	Motive	Lytx	Samsara
Overall	**342**	**89% (9.5 sec)**	**61% (14.6 sec)**	**15% (20.4 sec)**
Texting	69	100% (7.1 sec)	100% (12.8 sec)	14% (12.6 sec)
Phone call	69	94% (11.0 sec)	54% (14.0 sec)	0% (n/a)
Phone in lap	69	78% (10.5 sec)	42% (18.0 sec)	16% (13.8 sec)
Close following	69	72% (11.8 sec)	42% (7.2 sec)	42% (26.0 sec)
Seat belt use	66	98% (8.2 sec)	68% (20.2 sec)	5% (15.9 sec)

108. Motive's AI Dashcam also alerted drivers to modify their behavior much more quickly, on average, than Samsara's—thus preventing potentially dangerous accidents on the road.

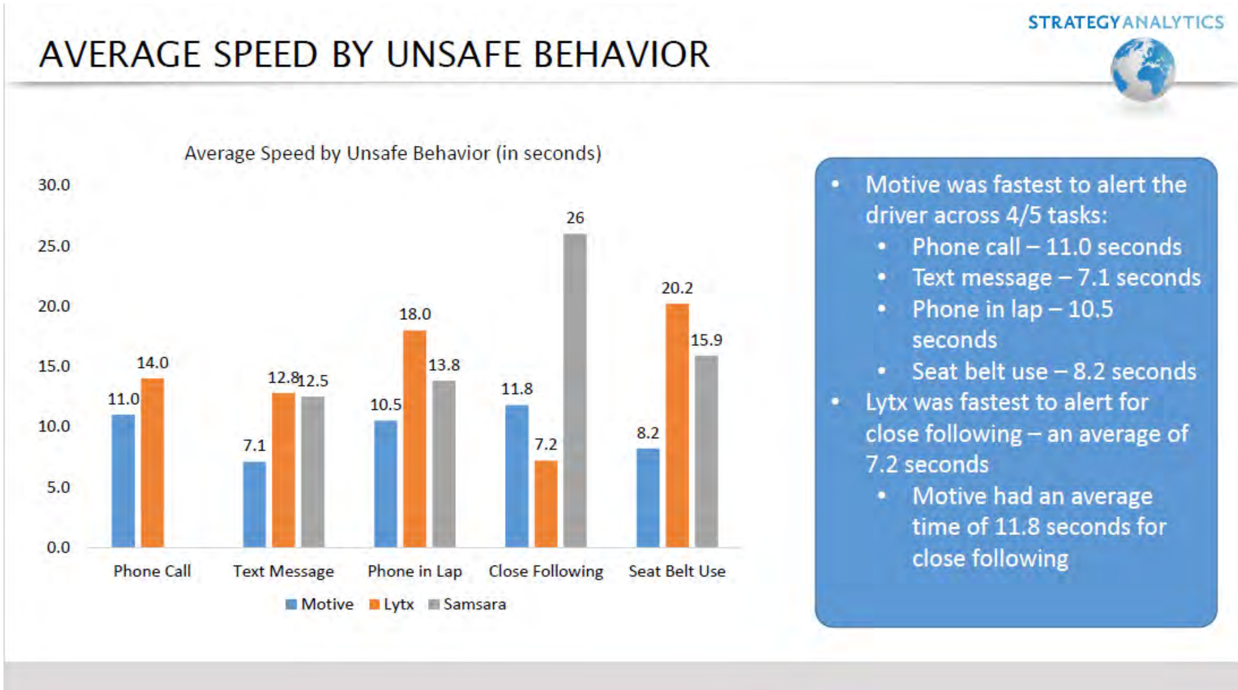
STRATEGYANALYTICS

OVERALL SPEED



- Motive alerted the driver faster than Lytx and Samsara on average across all successful tasks
  - Motive took an average of 9.5 seconds to provide an alert
  - Lytx took an average of 14.6 seconds to provide an alert
  - Samsara took an average of 20.4 seconds to provide an alert

Average time to alert driver across all successful tasks combined



109. Motive posted the Strategy Analytics Report on its website in April 2022, so that consumers could see the truth about the capabilities of Motive's AI Dashcam, contrary to what Samsara had been falsely representing in the marketplace.

110. Only after the Strategy Analytics Report became public did Samsara make a host of false allegations about Motive supposedly infringing Samsara's patents and competing unfairly, in an effort to extort Motive into withdrawing the Report and keeping the results from consumers. Samsara falsely claimed that Strategy Analytics' test results were not reliable and were "rigged" to favor Motive. Motive demonstrated to Samsara that the results were the result of rigorous, objective, independent analysis and that Samsara's criticisms were wrong—but also invited Samsara to jointly engage another respected third-party consultant to likewise test the companies' dashcams and see what the results were. Samsara—knowing that its dashcam is inferior—refused.

111. To confirm the validity of Strategy Analytics' test results, in 2023 Motive engaged the Virginia Tech Transportation Institute ("VTTI") to perform another independent, third-party study

comparing the Motive DC-54; Samsara HW-CM32; and Lytx DriveCam SF400. VTTI is one of Virginia Tech's centers of excellence and one of the nation's leading transportation research institutes. Just as with the Strategy Analytics study, Motive did not interfere or tamper with the methodology or results of the study.

112. VTTI's testing once again found that Motive's AI Dashcam was superior to Samsara's across multiple metrics.

113. The study utilized both a first phase—the technical performance phase—and a second phase—the user performance phase.

114. The first phase gauged how frequently each system issued an alert to the six driving behaviors using a controlled test-track experiment. Those six different "driving events" were: 1) making an outgoing phone call, 2) texting mid-air on a cellphone (45-degree angle), 3) texting in the lap on a cellphone, 4) close following, 5) not wearing a seatbelt, and 6) rolling through a stop sign.

115. The second phase involved recruiting 188 commercial vehicle drivers to provide ratings in an online survey about various qualities of the systems.

116. At the end of this rigorous study, VTTI's results confirmed that Motive's AI Dashcam was the overall superior product:

> The following conclusions highlight significant results from the two-phase study that pertain to the Motive system.
>
> - Motive was more likely to issue a successful in-cab alert compared to Lytx and Samsara for phone call, lap texting, 45-degree texting, close following, and rolling stop trials across all lighting conditions.
> - For Motive, *In-Cab Alert or Dashboard Alert* was the most frequent result for all tasks (phone calls, lap texting, 45-degree texting, close following, rolling stops, and no seatbelt).
> - Motive had significantly shorter time to alert compared to Lytx for phone call tasks, 45-degree texting, and no seatbelt trials and significantly shorter time to alert for close following trials compared to Samsara.
> - Motive was more likely to be ranked number one for daytime and nighttime video quality when compared to Lytx and Samsara.
> - Motive was more likely to be ranked number one for nighttime image quality when compared to Samsara.
> - Motive was more likely to be ranked number one for cell phone alert quality when compared to Lytx and more likely to be ranked first for close following alert quality when compared to both Lytx and Samsara.
> - Motive had a significantly higher rating for hardware design when compared to Samsara.

117. Samsara, not surprisingly, also refuses to accept the clear findings of the VTTI study, making a number of false and misleading statements about the study's methodology and results. Yet Samsara still refuses Motive's challenge to conduct a joint study, or even to commission its own third-party study and publish the results.

118. Motive is harmed by Samsara's false and misleading statements about these objective, independent reports. On information and belief, such statements impeded Motive's ability to fairly compete in the marketplace and reduced Motive's sales to customers. Motive must expend additional time, money, and resources in order to correct the public record, accurately inform the market, and fight back against Samsara's false and misleading statements.

SAMSARA DEFAMES MOTIVE

119. Samsara has extended its unethical, unlawful business practices into false public allegations about Motive and its senior executives. Samsara has done so in order to try and prop up its own business

in the face of Motive's recent successes and the results of the independent Strategy Analytics and VTTI studies.

120. On January 24, 2024, Samsara filed a lawsuit against Motive in federal court in Delaware containing numerous false allegations. Motive, of course, denies these allegations and will respond to them at the appropriate time. However, Samsara then used the filing of its suit to launch a public smear campaign against Motive, defaming Motive to customers and the market in general.

121. Samsara created an entire new website devoted to spreading these false, misleading, and defamatory statements, which it launched on the day the lawsuit was filed.

122. Among other things, Samsara's website states that Motive has committed "BRAZEN THEFT OF INTELLECTUAL PROPERTY" and engaged in "PERVASIVE FRAUD WITHIN LEADERSHIP TEAM," "A CULTURE BASED ON COPYING" and a "PATTERN OF THEFT." All of these statements are false, and Samsara knew or should have known they were false. They also extend far beyond the allegations made in Samsara's pleadings, and hence are not protected by any litigation privilege.

123. In fact, it is Samsara that has engaged in these activities, as shown by the facts described above. In other words, Samsara is trying to distract from its own unethical and unlawful business practices by accusing Motive of engaging in the same or similar conduct.

124. Samsara's defamatory statements—stating as fact on its website that Motive engaged in criminal conduct and other misconduct—cause Motive harm in the eyes of at least some customers or potential customers in the marketplace.

SAMSARA TORTIOUSLY INTERFERES WITH MOTIVE'S CURRENT AND PROSPECTIVE CUSTOMER RELATIONSHIPS

125. Samsara also has used its false allegations in its lawsuit as a way to improperly interfere with Motive's current and potential customer relationships. Samsara is of course free to file a lawsuit containing whatever allegations it chooses, which Motive will vigorously defend. But what Samsara cannot do,

consistent with the law, is communicate those (false) allegations to companies whose business Motive is in the process of attempting to secure through open and honest competition.

126. Before Samsara filed its Complaint, with the assistance of a large public relations firm (Edelman), it spent months creating a media smear campaign that it launched the day the lawsuit was filed. Part of the campaign was to create the defamatory website described above; another part was to send unsolicited communications to actual and potential Motive customers, urging them to access the new website and to read Samsara's false allegations.

127. The purpose of Samsara's smear campaign was, among other things, to convince companies that were in the midst of considering purchasing Motive's products and services, based on the superiority of Motive's technology, to change their minds and not do business with Motive.

128. One such company, Company 1, has a fleet of approximately 70 vehicles. Company 1 contacted Motive in January 2024 to seek information about Motive's products and services. Company 1 was also evaluating Samsara's products. After learning of Samsara's false allegations, Company 1 cut off contact with Motive and refused to engage further. On information and belief, Company 1 was informed by Samsara of Samsara's lawsuit and saw the Samsara website and the false and defamatory materials published on it, and that caused or substantially contributed to Company 1 not awarding a contract to Motive when it otherwise would have.

129. Another such company, Company 2, has a fleet of approximately 1000 vehicles. When a Motive sales rep recently contacted a representative of Company 2, the representative stated Company 2 wanted nothing to do with Motive, did not trust Motive, and was signing a contract with Samsara. On information and belief, Company 2 was informed by Samsara of Samsara's lawsuit and saw the Samsara website and the false and defamatory materials published on it, and that caused or substantially contributed to Company 2 not considering Motive for a contract when it otherwise would have.

SAMSARA FRAUDULENTLY CONCEALS ITS DECEIT

130. As described above, Samsara took steps to fraudulently conceal its access to, and copying of, Motive's technology and products.

131. As detailed in paragraphs 1–21 and 43–52, Samsara's employees accessed Motive's platform on at least 30 occasions over at least six years. This surreptitious access began in at least 2016, and the employees included some of the highest-ranking individuals at Samsara, such as its Vice President of Sales and Chief Product and Chief Strategy Officer.

132. When creating accounts to access Motive's platform, users must provide their identifying information, such as their individual or company name, email address, and other identifying information.

133. When Samsara's employees accessed Motive's platform, however, they either did not provide their actual names, or used phony company names, their personal email addresses, and/or other inaccurate identifying information.

134. On information and belief, Samsara employees used this illicit and fraudulent access to Motive's platform to steal and/or copy Motive's fleet management technology, platform capabilities and features, and business and marketing strategy, including to attempt to reverse-engineer the source code or underlying algorithms of the technology.

135. Samsara took affirmative steps to conceal this unlawful scheme; it did so in part by providing the false identifying information to access Motive's platform, and on at least one occasion using a real company's DOT ID number. By providing fake company names and other identifying information to Motive, Samsara concealed its illicit access to Motive's platform, and prevented Motive from identifying and halting this conduct.

136. Because of the steps Samsara took to fraudulently conceal its unlawful access to Motive's platform, Motive was unable to uncover the ongoing fraud by Samsara for many years.

137. Indeed, as described above, it was not until June and July of 2022 that Motive finally began to uncover and unravel Samsara's fraudulently concealed scheme. Motive moved quickly to identify the fraudulently-concealed Samsara-employee accounts. To do so, among other things, Motive searched publicly-available sources (e.g., LinkedIn) to identify the names of Samsara employees whose names matched or were similar to usernames or email addresses that had been used to register accounts on Motive's platform, searched for any Samsara email addresses associated with an account, and searched for names of Samsara employees who had applied to Motive or who had left Motive for Samsara. Due to the Samsara employees' use of personal email addresses to conceal their connection to Samsara, the process was time consuming and required contributions from multiple Motive employees.

138. Motive's investigation into Samsara's fraudulently concealed scheme is ongoing. Because of the length of time for which Samsara was able to mask its access, Motive has had to expend substantial resources to review and analyze old records and data. Motive must review older logs that have been archived, which requires rehydrating the data. There is a cost to both rehydrate the data and to store it.

139. On information and belief, further instances of Samsara's fraudulent concealment of its accounts and access to Motive's platform are yet to be uncovered.

FIRST CAUSE OF ACTION
(Infringement of the '580 Patent)

140. Motive incorporates paragraphs 1–21 and 53–60 by reference as if fully set forth herein.

141. Motive is the owner of all right, title, and interest in the '580 Patent and it possesses all rights of recovery under the '580 Patent, including the rights to sue for infringement, seek damages, and request injunctive relief.

142. Samsara has infringed, and continues to infringe, one or more claims of the '580 Patent by making, using, selling, offering to sell, and/or importing in the United States products, including the

Infringing Products, that embody or otherwise practice one or more claims of the ’580 Patent, including at least claim 1, literally and/or pursuant to the doctrine of equivalents.

143. Claim 1 of the ’580 Patent recites as follows:

A method comprising:

> *receiving, over a network from a camera device, a video comprising a set of image frames;*
>
> *identifying one or more lines in the video using a predictive model, the one or more lines including a horizon line;*
>
> *computing at least one camera parameter based on the one or more lines;*
>
> *overlaying the one or more lines on the video to generate an overlaid video;*
>
> *transmitting the overlaid video to an annotator device for manual review;*
>
> *receiving a confirmation from the annotator device, the confirmation indicating that the one or more lines are accurate; and*
>
> *transmitting data representing at least one camera parameter to the camera device.*

144. The Infringing Products (including, without limitation, Samsara’s CM31, CM32, and similar dashcams as well as its software-as-a-service platform) receive image and video data from dashcams and perform calibration of the dashcams via predictive models and user-control of such dashcams via a web-based portal and/or mobile application.

145. By way of example, Samsara’s Infringing Products meet each and every limitation of claim 1 of the ’580 Patent as outlined in **Exhibit B**.

146. Samsara’s infringing activity took place in the United States, including, but not limited to, within this judicial district, in violation of 35 U.S.C. § 271.

147. Samsara has targeted, and continues to directly target, the Infringing Products to residents of this judicial district, as well as elsewhere in and throughout the United States.

148. Samsara has sold and offered for sale, and continues to sell and offer for sale, the Infringing Product to customers located in this judicial district, as well as elsewhere in and throughout the United States.

149. Samsara has not sought or obtained from Motive a license under the ’580 Patent, and it is not authorized or permitted to market, manufacture, use, offer for sale, sell, or import any products embodying the inventions disclosed and claimed in the ’580 Patent.

150. Samsara has caused Motive to suffer, and unless enjoined by this Court, will cause Motive to continue to suffer substantial injury, including lost profits, for which Motive is entitled to damages adequate to compensate it for Samsara’s infringement.

151. Samsara’s infringement will continue to cause Motive irreparable injury and loss of revenues unless and until enjoined by this Court.

152. Motive therefore seeks judgment as set forth in its Prayer for Relief for Samsara’s infringement of the ’580 Patent.

SECOND CAUSE OF ACTION
(Violation of Lanham Act, 15 U.S.C. § 1125(a))

153. Motive incorporates paragraphs 1–21 and 87–99 by reference as if fully set forth herein.

154. Motive and Samsara are direct competitors in the vehicle fleet management industry.

155. Samsara’s sales representatives provided Motive customers and prospective customers with the chart at paragraph 89, purporting to compare the Samsara and Motive product offerings, including their dashcams, and falsely claiming that Samsara’s products could do things Samsara knew they could not, and that Motive’s products could not do things that they could.

156. On information and belief, Samsara has made other statements in connection with the sale of its dashcam and related products and services that similarly imply that Samsara's products have functionalities they do not, and Motive's products do not have functionalities that they do.

157. Samsara's statements are each individually and collectively are literally false and are presumptively deceptive to customers. If not literally false, Samsara's statements are each individually and collectively misleading and have the tendency to deceive a substantial segment of its audience into believing that Samsara's products have functionalities they do not, and that Motive's products do not have functionalities that they do.

158. These false statements are each individually and collectively material, as they are likely to influence the purchasing decisions of customers in the vehicle fleet management market to purchase Samsara's products instead of Motive's because they are deceived into believing they will obtain certain functionalities through purchase of Samsara's products and will not obtain those functionalities through purchase of Motive's products.

159. Samsara placed these statements in interstate commerce by providing them to customers and prospective customers across state lines, and because the Motive products and services that are the subject of Samsara's misrepresentations are used, sold, shipped, or ordered in, or intended to be used, sold, shipped, or ordered in, interstate and foreign commerce.

160. Motive has faced and continues to face economic and reputational injury flowing directly from the deception wrought by Samsara's false advertising, including the direct diversion of customers and tarnishing Motive's industry reputation and goodwill.

161. Because as a direct and proximate result of Samsara's false and deceptive campaign, Motive has sustained and will continue to sustain irreparable injury for which it has no adequate remedy at law, Motive seeks injunctive relief to protect its legitimate business interests.

162. As a direct and proximate result of Samsara's statements, Motive has sustained and will continue to sustain significant harm and damages in an amount to be proven at trial.

163. Samsara's false advertising was knowing and willful.

164. This is an exceptional case within the meaning of Section 35 of the Lanham Act, 15 U.S.C. § 1117.

165. Motive has been damaged by all of the foregoing and is entitled to injunctive relief and recovery of all available damages, treble damages, attorneys' fees, costs, and Samsara's profits.

THIRD CAUSE OF ACTION
(Fraud)

166. Motive incorporates paragraphs 1–21 and 43–52 by reference as if fully set forth herein.

167. As set forth in the chart at paragraph 9 and described above, Samsara employees, including senior executives such as Kiren Sekar, Samsara's Chief Product Officer and Chief Strategy Officer, Sean McGee, Samsara's Vice-President of Product Platform Infrastructure, and Rushil Goel, Samsara's (now former) VP of Products, created accounts on Motive's platform using fictitious company names and/or personal email addresses to defraud Motive into believing that they were actual customers of Motive.

168. In at least one instance, Samsara employees used another company's DOT ID numbers, in furtherance of their efforts to defraud Motive into believing that these fictitious companies were actual companies that the Samsara employees were affiliated with.

169. Samsara's employees knew that their representations regarding their identities and corporate affiliations were false and/or they intentionally concealed their true identities and affiliation with Samsara.

170. Samsara's employees made these misrepresentations and/or concealed these facts at the direction of Samsara, and within the scope of their employment with Samsara, to induce Motive to rely on these misrepresentations and/or concealments such that Motive would grant them access to its platform and technology and divulge non-public, competitive information about Motive's products and business.

171. Samsara had exclusive knowledge of its employees' identities and corporate affiliations.

172. Samsara had a duty to disclose complete and accurate information about its employees' identities and corporate affiliations to Motive because Samsara actively concealed, or provided only partial and incomplete information, about their true identities by creating accounts using fictitious corporate affiliations, other companies' DOT ID numbers, and/or personal email addresses.

173. Motive did in fact rely on Samsara's misrepresentations and/or concealment to grant Samsara access to Motive's platform and provide Samsara with non-public, competitive information about Motive's products and business, and such reliance was justifiable. Had Motive known the true identities and corporate affiliations of the Samsara employees, Motive would not have granted them access to its platform or provided such information.

174. Motive's reliance on Samsara's misrepresentations was a substantial factor in causing harm to Motive including, among other things, the loss of competitive information, as well as the expenditure of substantial time and resources of employees who conducted internal investigations regarding the existence of fictitious accounts, the Samsara employees associated with those accounts, and Samsara's unauthorized access of these accounts, ultimately requiring Motive to deactivate the accounts and terminate access.

175. Motive is entitled to compensatory damages arising from Samsara's fraudulent conduct pursuant to Cal. Civ. Code § 1709 et seq. and common law.

176. Because Motive did not discover the facts constituting the fraud due to Samsara's active concealment until June-July 2022, Motive may recover damages for conduct beyond three years before the filing of this Complaint.

FOURTH CAUSE OF ACTION
(Violation of California Unfair Competition Law, Cal. Civ. Code § 17200)

177. Motive incorporates paragraphs 1–21, 43–52, 83–99, and 119–129 by reference as if fully set forth herein.

178. Samsara engaged in unlawful, unfair, and fraudulent business acts and practices, as well as unfair, deceptive, untrue, or misleading advertising. Such wrongful conduct includes without limitation Samsara's fraudulent access to Motive's Fleet Dashboard, use of false and misleading advertising in violation of the Lanham Act, defamation, and interference with prospective economic relations, as set forth above.

179. In addition, such wrongful conduct includes Samsara's employees' impersonation of Motive employees in interactions with Motive's customers, as described in paragraphs 83–86. On information and belief, such conduct is likely to deceive members of the public into believing that they are interacting with Motive employees when they are in fact interacting with Samsara's employees. Indeed, on information and belief, such conduct in fact deceived a Motive customer into believing that a voicemail was from a Motive employee, only to learn upon calling back that the customer was actually interacting with a Samsara employee.

180. This wrongful conduct constitutes Samsara's business practices, as such conduct was performed in connection with the sale of dashcams and related products and services.

181. Motive has been injured and has lost money and property as a result of Samsara's false advertising, fraud, defamation, interference with prospective economic relations, and impersonation of Motive employees, including, but not limited to: lost current and prospective customers; loss of industry reputation and goodwill; lost profits; legal fees; and costs expended to mitigate the impact of Samsara's false statements.

182. As a direct and proximate result of Samsara's wrongful conduct, Motive has sustained and will continue to sustain significant harm. Motive is therefore entitled to (1) recover restitution, including without limitation all benefits that Samsara received as a result of its wrongful conduct, and (2) an injunction restraining Samsara from engaging in additional wrongful conduct.

183. Because Motive did not discover the facts constituting certain of Samsara's unfair and fraudulent business practices due to Samsara's concealment until on or after June-July 2022, Motive may recover damages for conduct beyond four years before the filing of this Complaint.

FIFTH CAUSE OF ACTION
(Violation of California's Uniform Trade Secrets Act,
Cal. Civ. Code §§ 3426 to 3426.11)

184. Motive incorporates paragraphs 1–21 and 61–82 by reference as if fully set forth herein.

185. Motive owns and possesses certain confidential, proprietary, and trade secret information, as alleged above. This information includes specifications, designs, and customer lists that are essential to manufacture and sale of Motive's fleet management solutions and other products.

186. These specifications, designs, and customer lists constitute trade secrets as defined by California's Uniform Trade Secret Act because they derive economic value from not being generally known to the public or other persons who could obtain economic value from their disclosure or use.

187. Motive has made reasonable efforts to maintain the confidentiality and secrecy of its proprietary information. These efforts include training employees in the protection of corporate secrecy, requiring employees to sign confidentiality agreements, limiting electronic access to proprietary information, requiring employees to use company-provided computers, requiring employees to sign a Separation and Release agreement upon termination of their employment that reminds them of their confidentiality obligations, and performing exit interviews with employees who voluntarily depart.

188. In violation of Motive's rights, Samsara misappropriated Motive's confidential, proprietary, and trade secret information through the improper and unlawful means alleged herein, including (1) the recruitment of Motive employees with detailed knowledge of proprietary information to re-create Motive's dashcam, fleet management solutions, and other products, and (2) the recruitment of Motive employees with detailed knowledge of proprietary customer information.

189. Samsara's conduct constitutes a misappropriation and misuse because Samsara knew or had reason to know that Motive's former employees disclosed the information without Motive's consent and while under a duty to maintain its secrecy, and induced them to do so.

190. Samsara's misappropriation of Motive's trade secret information was intentional, knowing, willful, malicious, fraudulent, and oppressive. Samsara has attempted, and continues to attempt, to conceal its misappropriation.

191. Samsara has not returned the information taken from Motive. Upon information and belief, Samsara is retaining and using Motive's trade secrets and confidential information.

192. As a direct and proximate result of Samsara's conduct, Motive has sustained and will continue to sustain significant harm and damages in an amount to be proven at trial.

193. In addition, because Motive has sustained and will continue to sustain irreparable injury for which it has no adequate remedy at law, Motive seeks injunctive relief to protect its confidential, proprietary, and trade secret information and to protect other legitimate business interests. Absent such relief, Motive will continue to suffer irreparable injury, including in connection with Samsara's launch of its new dashcam.

194. Motive has been damaged by all of the foregoing and is entitled to an award of exemplary damages and attorneys' fees and costs.

SIXTH CAUSE OF ACTION
(Violation of Defend Trade Secrets Act,
18 U.S.C. §§ 1836 *et seq.*)

195. Motive incorporates paragraphs 1–21 and 61–82 by reference as if fully set forth herein.

196. Motive owns and possesses certain confidential, proprietary, and trade secret information, as alleged above. This information includes specifications, designs, and customer lists that are essential to manufacture and sale of Motive's dashcam, fleet management solutions, and other products.

197. These specifications, designs, and customer lists relate to products and services, including Motive's dashcam and fleet management solutions, that are used, sold, shipped, or ordered in, or intended to be used, sold, shipped, or ordered in interstate or foreign commerce.

198. Motive's confidential, proprietary, and trade secret information derives economic value from not being generally known to, and not being readily ascertainable through proper means by, the public or other persons who could obtain economic value from the disclosure or use of the information.

199. Motive has made reasonable efforts to maintain the confidentiality and secrecy of its proprietary information. These efforts include training employees in the protection of corporate secrecy, requiring employees to sign confidentiality agreements, limiting electronic access to proprietary information, requiring employees to use company-provided computers, requiring employees to sign a Separation and Release agreement upon termination of their employment that reminds them of their confidentiality obligations, and performing exit interviews with employees who voluntarily depart.

200. In violation of Motive's rights, Samsara misappropriated Motive's confidential, proprietary, and trade secret information through the improper and unlawful means alleged herein, including (1) the recruitment of Motive employees with detailed knowledge of proprietary information to re-create Motive's dashcam, fleet management solutions, and other products, and (2) the recruitment of Motive employees with detailed knowledge of proprietary customer information.

201. Samsara's conduct constitutes a misappropriation and misuse because Samsara knew or had reason to know that Motive's former employees disclosed the information without Motive's consent and while under a duty to maintain its secrecy, and induced them to do so.

202. Samsara's misappropriation of Motive's trade secret information was intentional, knowing, willful, malicious, fraudulent, and oppressive. Samsara has attempted, and continues to attempt, to conceal its misappropriation.

203. Samsara has not returned the information taken from Motive. Upon information and belief, Samsara is retaining and using Motive's trade secrets and confidential information.

204. As a direct and proximate result of Samsara's conduct, Motive has sustained and will continue to sustain significant harm and damages in an amount to be proven at trial.

205. In addition, because Motive has sustained and will continue to sustain irreparable injury for which it has no adequate remedy at law, Motive seeks injunctive relief to protect its confidential, proprietary, and trade secret information and to protect other legitimate business interests. Absent such relief, Motive will continue to suffer irreparable injury, including in connection with Samsara's launch of its new dashcam.

206. Motive has been damaged by all of the foregoing and is entitled to an award of exemplary damages and attorneys' fees and costs.

SEVENTH CAUSE OF ACTION
(Defamation)

207. Motive incorporates paragraphs 1–21 and 119–124 by reference as if fully set forth herein.

208. Since January 24, 2024, Samsara has intentionally published and intentionally continues to publish defamatory statements about Motive on Samsara's website.

209. Those statements are false and carry false implications. Among other things, they falsely state and imply that Motive engaged in "brazen theft"; that there is a culture of "pervasive fraud" or "culture based on copying" within Motive; and that Motive engages in "deceptive marketing."

210. By posting these statements on its website, Samsara communicated them to third parties including, among others, Motive's current and prospective customers, shareholders, and the general public. On information and belief, those third parties reasonably understood that these false statements concerned Motive, and such third parties further reasonably understood these false statements to mean that Motive had committed criminal, unethical, and/or immoral conduct in fact, and not merely as a matter of Samsara's opinion.

211. Publication of these statements are not protected by any legal privilege.

212. Motive is not a public figure.

213. On information and belief, Samsara knows these statements are false and carry false implications. At minimum, Samsara has acted without using reasonable care to determine its truth or falsity or with reckless disregard as to the falsity of these statements.

214. On information and belief, Samsara intended that these false statements would have the effect of injuring Motive's reputation, preventing others from doing business with Motive, and interfering with Motive's existing business relationships.

215. Samsara's false statements have directly harmed Motive's business, property, and reputation in numerous ways, including, but not limited to: lost current or prospective customers; loss of industry reputation and goodwill; lost profits; legal fees; and costs expended to mitigate the impact of Samsara's malicious campaign.

216. Samsara's publication of the false and defamatory statements cited herein have proximately caused Motive to suffer monetary damages in an amount to be determined at trial.

217. Samsara's actions show willful misconduct, malice, fraud, wantonness, oppression or that entire want of care which would raise the presumption of conscious indifference to consequences.

218. Because Samsara has engaged in conduct of a fraudulent and malicious nature, Motive is entitled to reputational and punitive damages.

219. In addition, because as a direct and proximate result of Samsara's false statements, Motive has sustained and will continue to sustain irreparable injury for which it has no adequate remedy at law, Motive seeks injunctive relief to protect its legitimate business interests.

220. Motive has been damaged by all of the foregoing and is entitled to injunctive relief and recovery of all available damages, including presumed, general, specific, and punitive damages.

EIGHTH CAUSE OF ACTION
(Intentional Interference with Prospective Economic Relations)

221. Motive incorporates paragraphs 1–21 and 125–129 by reference as if fully set forth herein.

222. Samsara knowingly interfered with Motive's relationships with its current and prospective customers.

223. For example, Samsara used its false and defamatory statements to undermine Motive's prospective economic relationship with Company 1 and Company 2.

224. Upon information and belief, there was a high probability of future economic benefit to Motive in the form of a contractual relationship with Company 1 and Company 2.

225. Samsara was aware of the prospective business relationship between Motive and Company 1 because it was directly competing for Company 1's business. Samsara was aware of the prospective business relationship between Motive and Company 2 because it was directly competing for Company 2's business.

226. Although Samsara was aware of these prospective economic relationships, Samsara published its defamatory statements with the intent to disrupt such relationships.

227. This misconduct was independently wrongful as a violation of California common law.

228. Samsara knew that this misconduct would result in a disruption in the prospective economic relationship between Motive and Company 1, and Motive and Company 2.

229. Samsara's intentional misconduct has disrupted the prospective economic relationship between Motive and Company 1, and Motive and Company 2.

230. As a direct and proximate result of Samsara's conduct, Motive has sustained and will continue to sustain significant harm and damages in an amount to be proven at trial.

231. In addition, because Motive has sustained and will continue to sustain irreparable injury for which it has no adequate remedy at law, Motive seeks injunctive relief to restrain Samsara from engaging in additional intentional interference. Absent such relief, Motive will continue to suffer irreparable injury.

PRAYER FOR RELIEF

WHEREFORE, Motive respectfully requests the following relief:

a. Judgment in Motive's favor and against Samsara on all causes of action alleged herein;

b. Judgment that Samsara has infringed the '580 Patent;

c. An injunction against Samsara, its subsidiaries, affiliates, parents, successors, assignees, officers, agents, servants, employees, and all persons acting in concert or in participation with them, or any of them, permanently enjoining each of them from infringing the '580 Patent;

d. Judgment awarding Motive lost profit damages adequate to compensate for Samsaras' infringement of the '580 Patent, but in no event less than a reasonable royalty on Samsara's use of Motive's inventions;

e. For damages in an amount to be further proven at trial, including trebling of all damages awarded with respect to the Second Cause of Action;

f. For presumed, general, and special damages for Samsara's defamation;

g. For disgorgement of profits for Samsara's false advertising;

h. For permanent injunctive relief;

i. For judgment that this is an exceptional case under the Lanham Act;

j. For exemplary or punitive damages;

k. For costs of suit incurred herein;

l. For pre-judgment and post-judgment interest;

m. For attorneys' fees and costs; and

n. For such other and further relief as the Court may deem to be just and proper.

DATED: February 15, 2024

GREENBERG TRAURIG, LLP
WILLIAMS & CONNOLLY LLP

By */s/ David S. Bloch*
David S. Bloch

Attorneys for Plaintiff
MOTIVE TECHNOLOGIES, INC.

DEMAND FOR JURY TRIAL

Pursuant to Civil Local Rule 3-6 and Federal Rule of Civil Procedure 38(b), Motive Technologies hereby demands a trial by jury on all issues and claims triable by jury.

DATED: February 15, 2024

GREENBERG TRAURIG, LLP

WILLIAMS & CONNOLLY LLP

By */s/ David S. Bloch*
David S. Bloch

Attorneys for Plaintiff
MOTIVE TECHNOLOGIES, INC.

EXHIBIT A

US011875580B2

(12) **United States Patent**
Hassan et al.

(10) **Patent No.: US 11,875,580 B2**
(45) **Date of Patent: Jan. 16, 2024**

(54) **CAMERA INITIALIZATION FOR LANE DETECTION AND DISTANCE ESTIMATION USING SINGLE-VIEW GEOMETRY**

(71) Applicant: **MOTIVE TECHNOLOGIES, INC.**, San Francisco, CA (US)

(72) Inventors: **Ali Hassan**, Lahore (PK); **Ahmed Ali**, Lahore (PK); **Syed Wajahat Ali Shah Kazmi**, Lahore (PK)

(73) Assignee: **MOTIVE TECHNOLOGIES, INC.**, San Francisco, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 291 days.

(21) Appl. No.: **17/493,011**

(22) Filed: **Oct. 4, 2021**

(65) **Prior Publication Data**

US 2023/0106961 A1 Apr. 6, 2023

(51) **Int. Cl.**

G06T 7/80	(2017.01)
G06V 20/56	(2022.01)
G06T 7/73	(2017.01)
G06T 7/50	(2017.01)
G06F 18/214	(2023.01)
G06N 3/044	(2023.01)

(52) **U.S. Cl.**

CPC ***G06V 20/588*** (2022.01); ***G06F 18/214*** (2023.01); ***G06N 3/044*** (2023.01); ***G06T 7/50*** (2017.01); ***G06T 7/75*** (2017.01); *G06T 2207/30256* (2013.01)

(58) **Field of Classification Search**

CPC G06V 20/588; G06V 10/82; G06F 18/214; G06N 3/044; G06N 3/0442; G06N 3/045; G06N 3/0464; G06N 3/084; G06N 3/09; G06T 7/50; G06T 7/75; G06T 2207/30256

See application file for complete search history.

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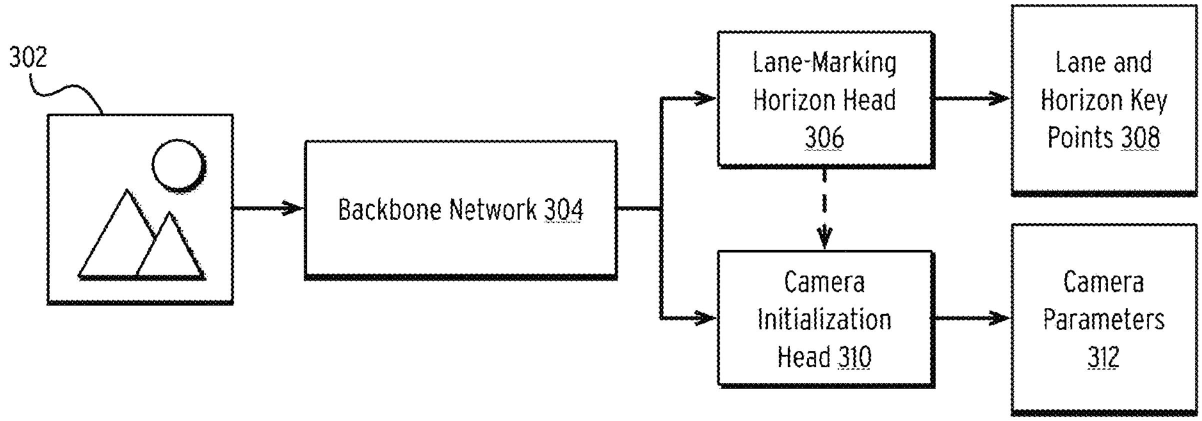
Primary Examiner — Howard D Brown, Jr.
(74) *Attorney, Agent, or Firm* — George David Zalepa; Greenberg Traurig, LLP

(57) **ABSTRACT**

Disclosed are methods, devices, and computer-readable media for detecting lanes and objects in image frames of a monocular camera. In one embodiment, a method is disclosed comprising receiving a plurality of images; identifying a horizon in the plurality of images by inputting the plurality of images into a deep learning (DL) model (either stored on a local device or via a network call); determining one or more camera parameters based on the horizon; and storing or using the camera parameters to initialize a camera.

20 Claims, 10 Drawing Sheets



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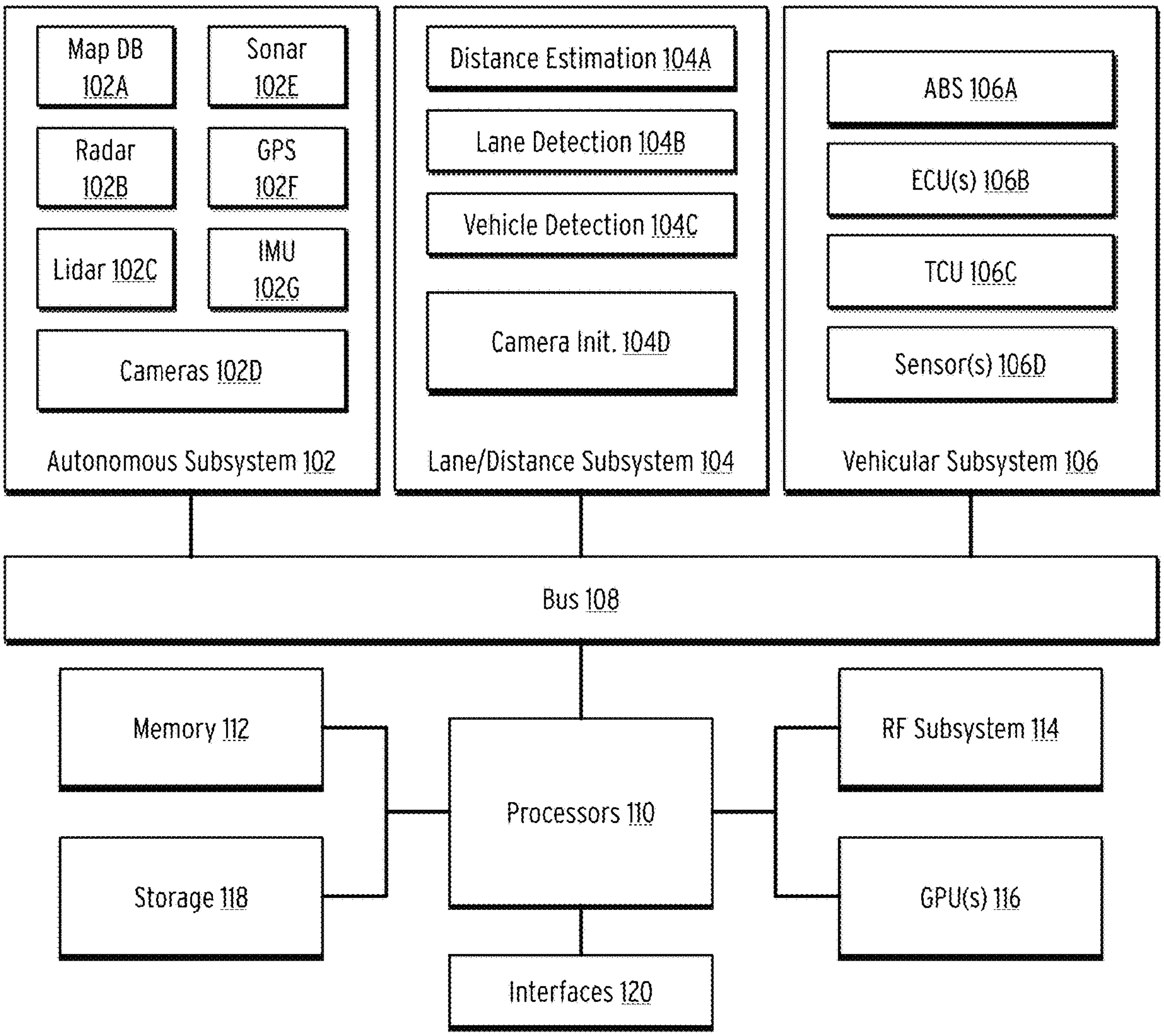
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FIG. 1

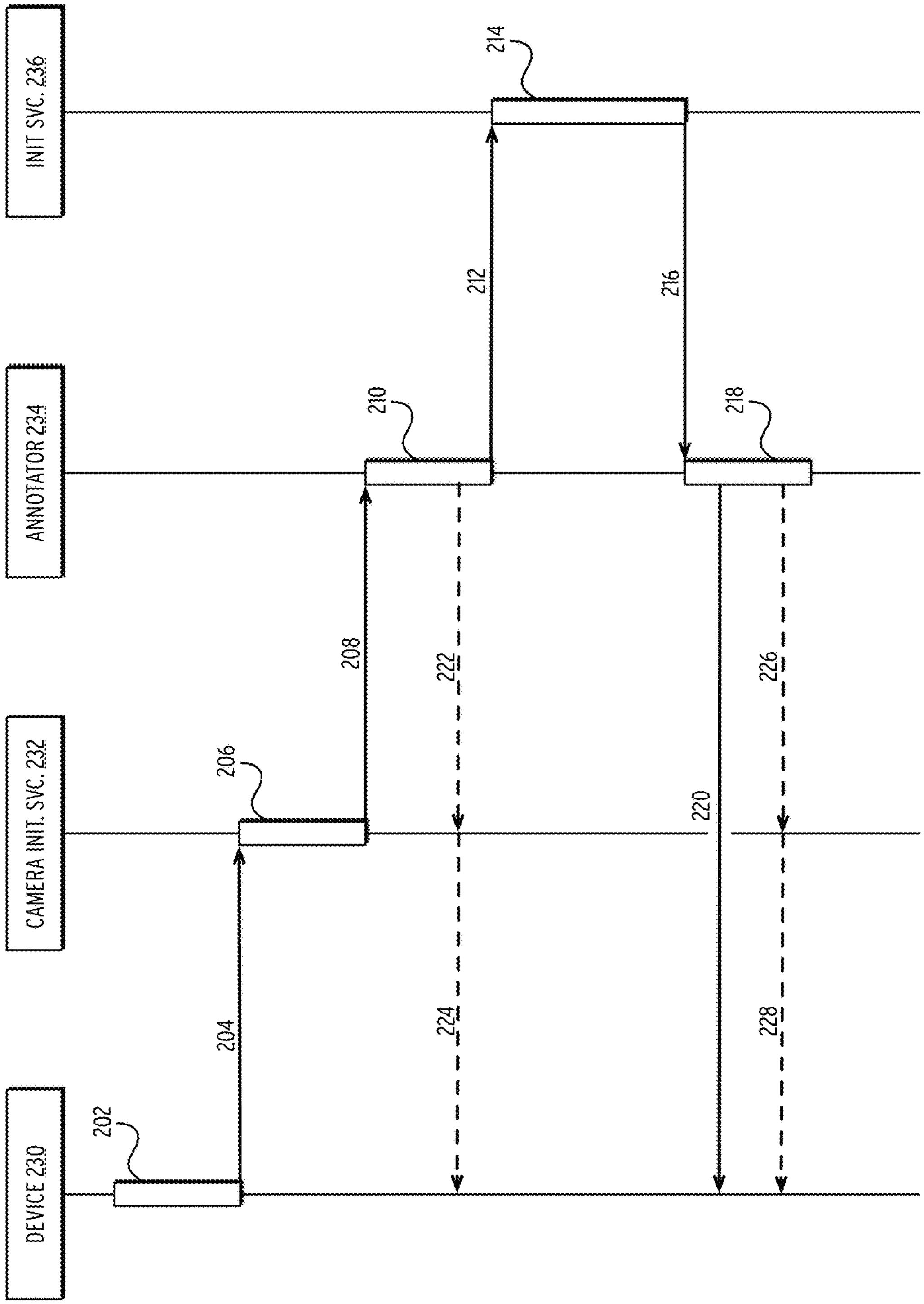
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FIG. 2

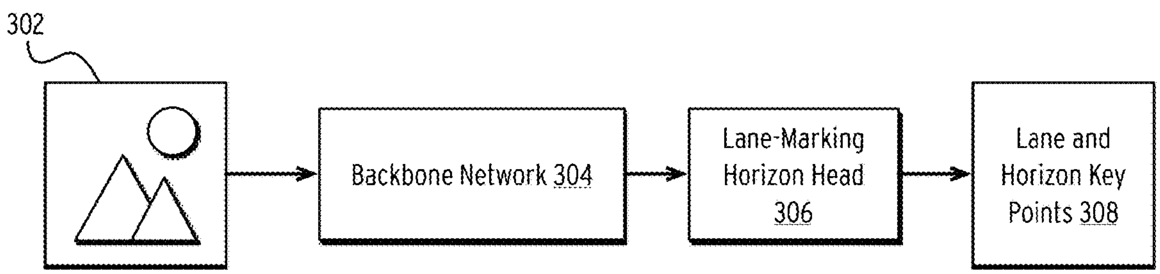


FIG. 3A

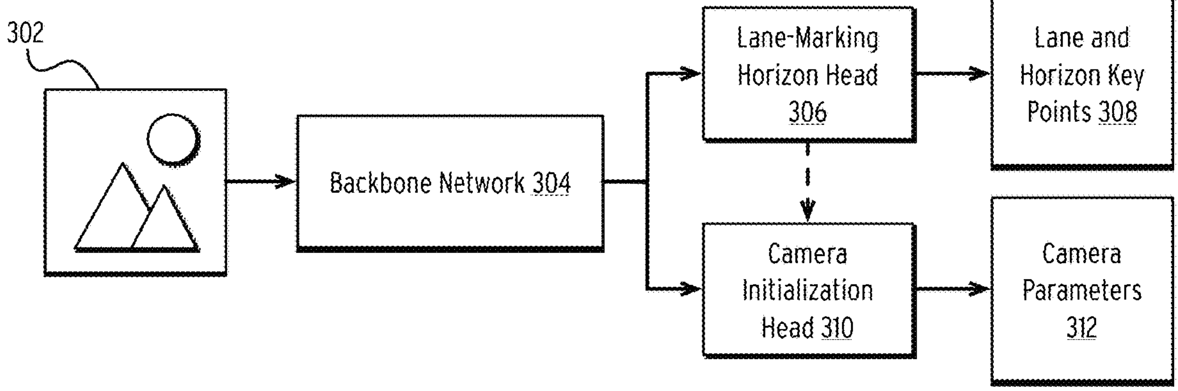


FIG. 3B

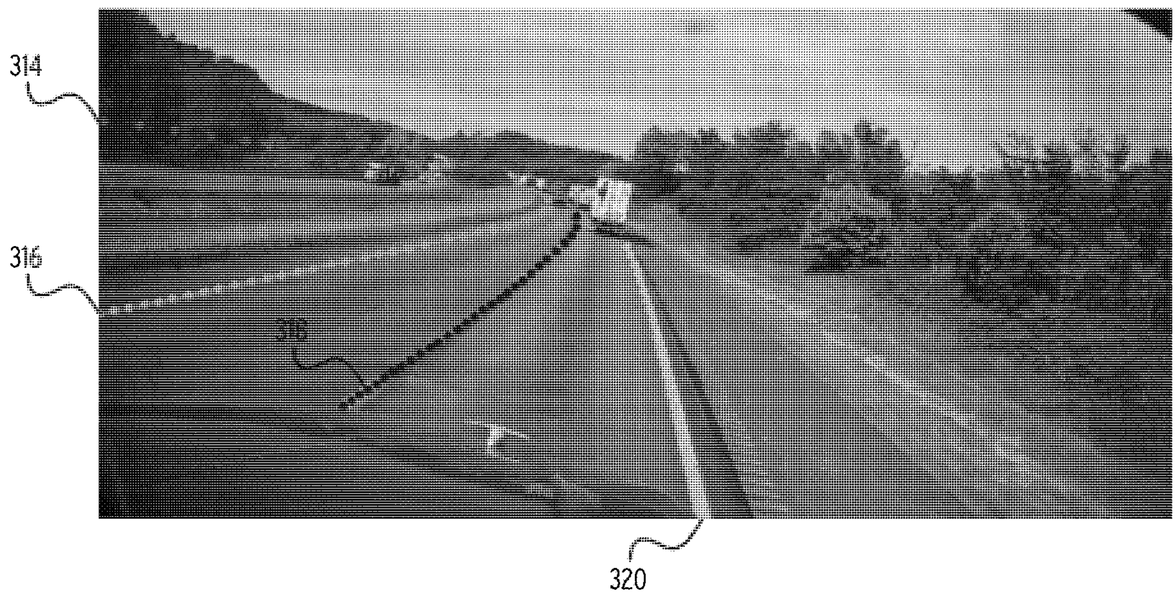
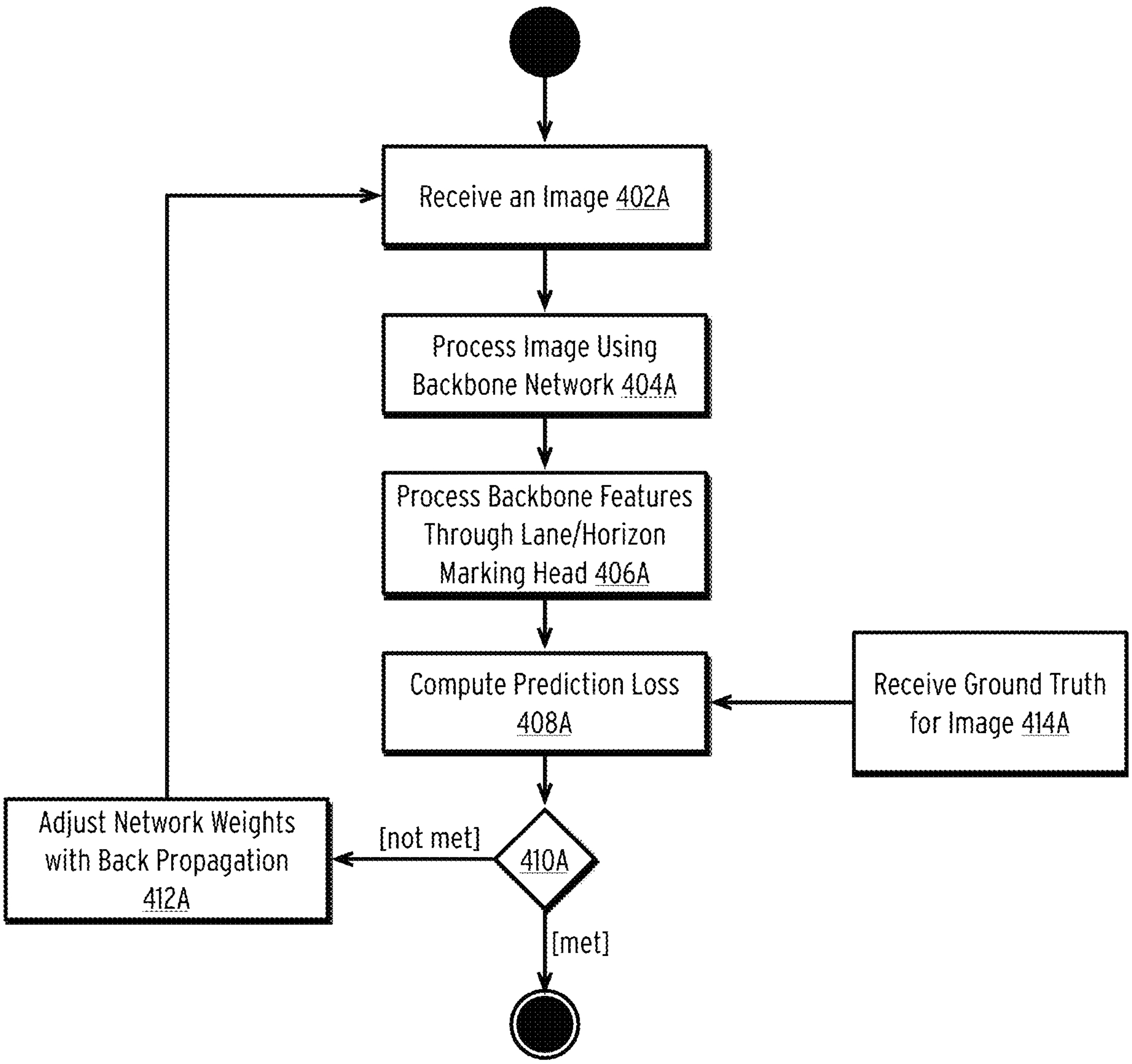


FIG. 3C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Adjust Network Weights with Back Propagation 412A

FIG. 4A

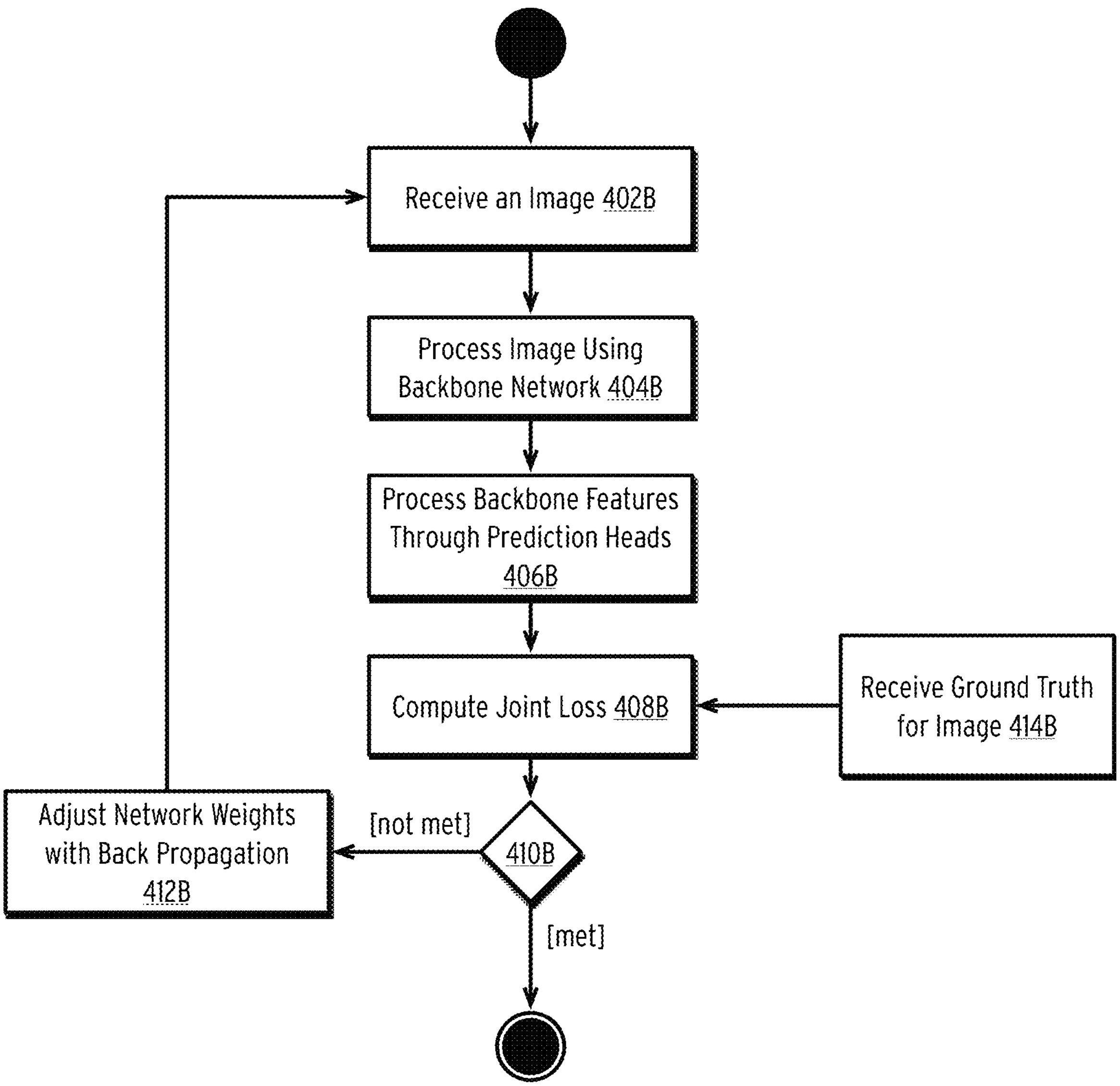
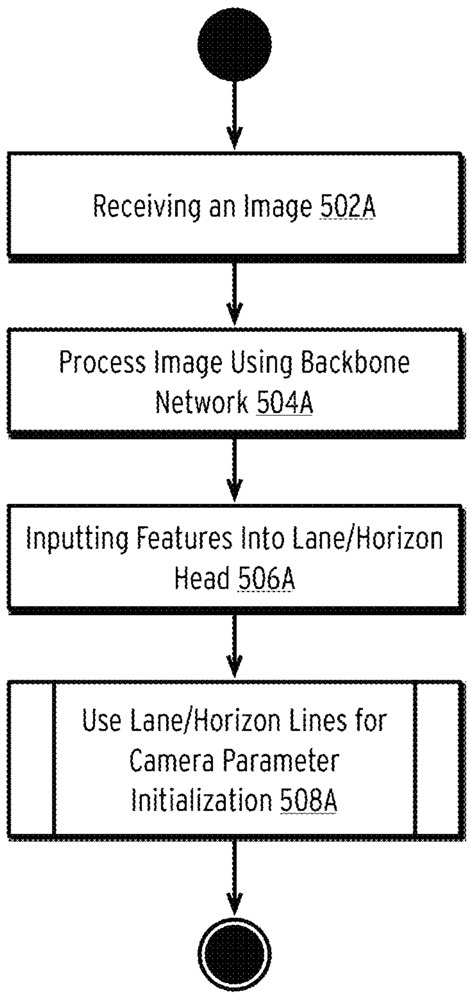

Receive an Image 402B
Process Image Using Backbone Network 404B
Process Backbone Features Through Prediction Heads 406B
Compute Joint Loss 408B
Receive Ground Truth for Image 414B
[not met]
410B
Adjust Network Weights with Back Propagation 412B
[met]

FIG. 4B



Receiving an Image 502A
Process Image Using Backbone Network 504A
Inputting Features Into Lane/Horizon Head 506A
Use Lane/Horizon Lines for Camera Parameter Initialization 508A

FIG. 5A

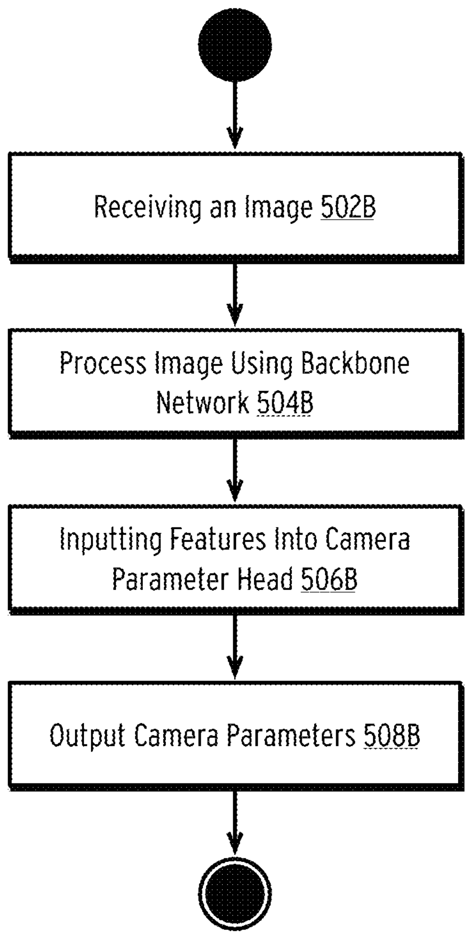
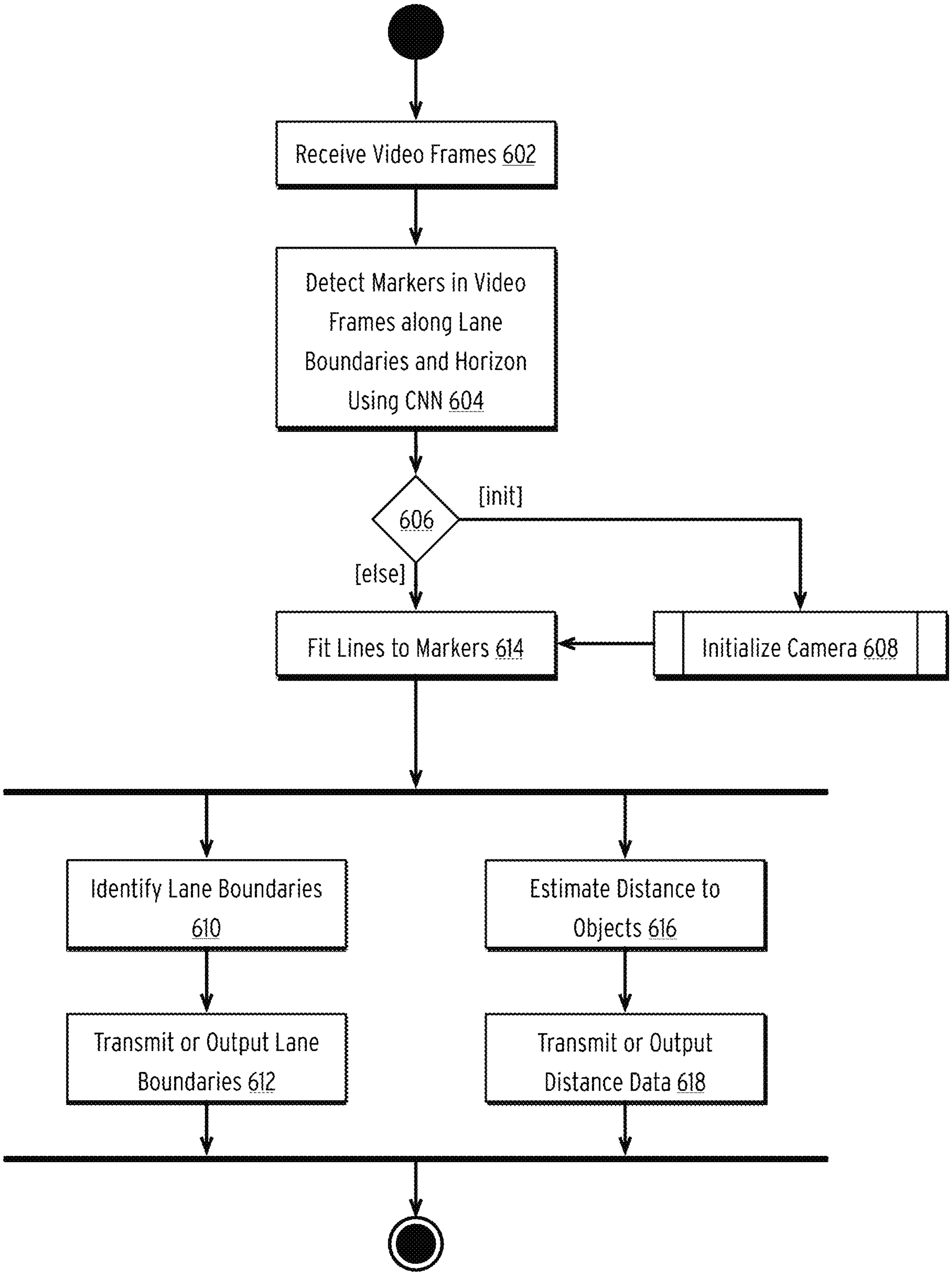

Receiving an Image 502B
Process Image Using Backbone Network 504B
Inputting Features Into Camera Parameter Head 506B
Output Camera Parameters 508B

FIG. 5B



Receive Video Frames 602
Detect Markers in Video Frames along Lane Boundaries and Horizon Using CNN 604
606
[init]
[else]
Fit Lines to Markers 614
Initialize Camera 608
Identify Lane Boundaries 610
Estimate Distance to Objects 616
Transmit or Output Lane Boundaries 612
Transmit or Output Distance Data 618

FIG. 6

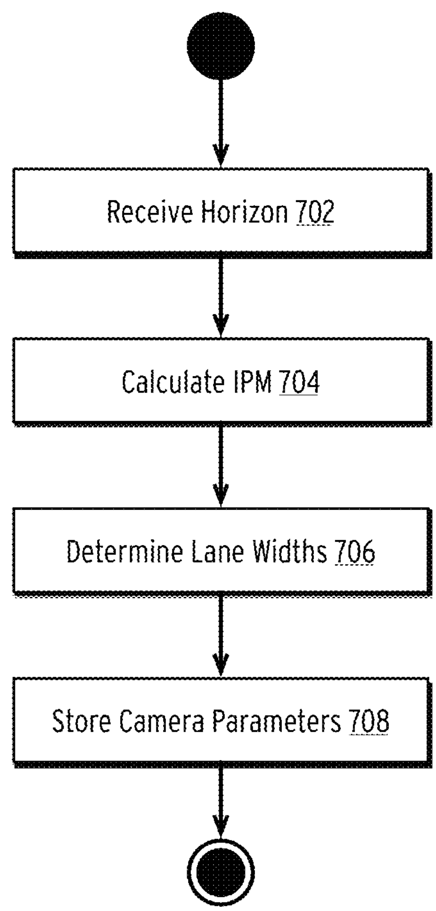

Receive Horizon 702
Calculate IPM 704
Determine Lane Widths 706
Store Camera Parameters 708

FIG. 7

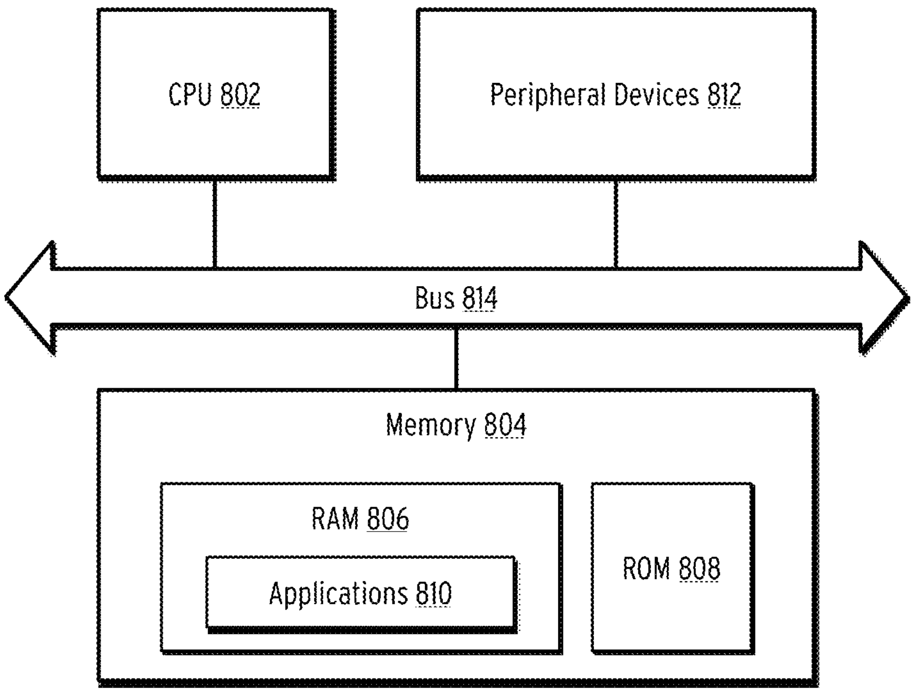

CPU 802
Peripheral Devices 812
Bus 814
Memory 804
RAM 806
Applications 810
ROM 808

FIG. 8

CAMERA INITIALIZATION FOR LANE DETECTION AND DISTANCE ESTIMATION USING SINGLE-VIEW GEOMETRY

BACKGROUND

The disclosed embodiments relate to automotive systems and to machine learning systems for analyzing sensor data in such systems.

Multiple cameras or sensors may be installed in a vehicle to detect objects. However, the use of multiple cameras may be expensive. Sensors such as Radar and Lidar may also be used as proximity sensors, but such sensors may also be costly. In addition, a built-in monocular camera may be used to detect the relative distance to proximate objects; however, this may require the location of the camera to be predefined or preset.

BRIEF SUMMARY

The present disclosure relates to using a monocular camera (e.g., an image sensor) that may be retrofitted and adjustable within the vehicle such as, the vehicle's dashboard. Upon driving, the camera initializes itself to determine its height with respect to the ground as well as a road plane normal. Thus, the camera may be installed in various positions and later re-initialized or recalibrated as needed.

The example embodiments are directed towards initializing such a camera onboard a vehicle. In the various embodiments, parameters can include the height of the camera, the viewing angle of the camera relative to the roadway, and a ground or road plane normal vector. Various embodiments are illustrated for performing this initialization which can then be used by downstream processes such as distance estimation or lane boundary detection.

In a first embodiment, a network-based initialization system is disclosed. In this embodiment, a server-side system receives a video comprising a set of image frames and identifies one or more lines in the video using a predictive model (e.g., a convolutional neural network). In one embodiment, the lines can include a horizon line. After identifying the horizon line, the system computes some camera parameters (e.g., height, viewing angle, road plane normal, etc.) based on the horizon line. The system then overlays the computed horizon line on the video and transmits it to an annotator device for manual review. In response, the annotator device can transmit a confirmation indicating the horizon line was accurate. In some embodiments, the annotator device can reject the horizon line and manually add the horizon line. Once the horizon line is confirmed, the system returns the camera parameters to the calling party (e.g., a camera onboard a vehicle).

In a second embodiment, an on-vehicle neural network is disclosed. In this embodiment, a camera records a video comprising one or more image frames. A backbone network generates a set of intermediate features representing the video. The intermediate features are then input into a lane or horizon prediction head (e.g., a neural network). The lane or horizon prediction head can then predict a horizon line using the lane or horizon prediction head, the horizon line comprising a set of horizon markers. Finally, the on-vehicle device can compute a camera parameter (e.g., height, viewing angle, road plane normal, etc.) based on the horizon line and lane key points.

In a third embodiment, an on-vehicle neural network is disclosed. In this embodiment, a camera records a video comprising one or more image frames. A backbone network generates a set of intermediate features representing the video. The intermediate features are then input into a camera parameter estimation head (e.g., a neural network). The on-vehicle device can then predict camera parameters using the output of the camera parameter estimation head, the camera parameter estimation head trained using an output of the backbone network, and an output of a lane and horizon line prediction head.

Various further embodiments are disclosed in the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a vehicle according to some embodiments of the disclosure.

FIG. **2** is an interaction diagram illustrating a method for initializing a camera according to some embodiments.

FIG. **3**A is a block diagram illustrating a neural network for predicting lane and horizon lines according to some embodiments.

FIG. **3**B is a block diagram illustrating a neural network for predicting lane and horizon lines and camera parameters according to some embodiments.

FIG. **3**C is an illustration of the output of the neural networks of FIGS. **3**A and **3**B, according to some embodiments.

FIG. **4**A is a flow diagram illustrating a method for training the neural network of FIG. **3**A according to some embodiments.

FIG. **4**B is a flow diagram illustrating a method for training the neural network of FIG. **3**B according to some embodiments.

FIG. **5**A is a flow diagram illustrating a method for predicting lane and horizon lines using the neural network of FIG. **3**A according to some embodiments.

FIG. **5**B is a flow diagram illustrating a method for predicting lane and horizon lines and camera parameters using the neural network of FIG. **3**B according to some embodiments.

FIG. **6** is a flow diagram illustrating a method for detecting lane markers on a roadway and determining distances to objects according to some embodiments.

FIG. **7** is a flow diagram illustrating a method for initializing a camera installed in a vehicle according to some embodiments.

FIG. **8** is a block diagram illustrating a computing device showing an example embodiment of a computing device used in the various embodiments.

DETAILED DESCRIPTION

FIG. **1** is a block diagram of a vehicle according to some embodiments of the disclosure.

The system illustrated in FIG. **1** may be installed entirely within a vehicle. In some embodiments, some components may comprise existing autonomous vehicle subsystems, although, in some embodiments, autonomous vehicle subsystems are optional. Thus, the vehicle in FIG. **1** may comprise either an autonomous, semi-autonomous, or non-autonomous vehicle. Descriptions made herein are primarily described with respect to autonomous vehicles; however, this is not intended to be limiting.

In the illustrated embodiment, the system includes an autonomous vehicle subsystem **102** or Advanced Driver Assistance System (ADAS). In an embodiment, autonomous vehicle subsystem **102** includes map database **102**A, radar devices **102**B, Lidar devices **102**C, digital cameras **102**D, sonar devices **102**E, global positioning system (GPS) receivers **102**F, and inertial measurement unit (IMU) devices **102**G. Each of the components of autonomous vehicle subsystem **102** comprises standard components provided in most current autonomous vehicles or ADAS. In an embodiment, map database **102**A stores a plurality of high-definition three-dimensional maps used for routing and navigation. Radar devices **102**B, Lidar devices **102**C, digital cameras **102**D, sonar devices **102**E, GPS receivers **102**F, and IMU devices **102**G may comprise various respective devices installed at various positions throughout the autonomous vehicle as known in the art. For example, these devices may be installed along the perimeter of an autonomous vehicle to provide location awareness, collision avoidance, and another standard autonomous vehicle or ADAS functionality. As discussed, in some embodiments, the autonomous vehicle subsystem **102** may be optional or limited such as any form of an ADAS. For example, a non-autonomous vehicle may only include one camera device, such as a dash-mounted camera device. In this embodiment, the camera may be included in the sensors **106**D.

Vehicular subsystem **106** is additionally included within the system. Vehicular subsystem **106** includes various anti-lock braking system (ABS) devices **106**A, engine control unit (ECU) devices **106**B, transmission control unit (TCU) devices **106**C, and various other sensors **106**D such as heat/humidity sensors, emissions sensors, etc. These components may be utilized to control the operation of the vehicle. In some embodiments, these components perform operations in response to the streaming data generated by autonomous vehicle subsystem **102**. The standard autonomous vehicle interactions between autonomous vehicle subsystem **102** and vehicular subsystem **106** are generally known in the art and are not described in detail herein.

The processing side of the system includes one or more processors **110**, short-term memory **112**, a radio frequency (RF) system **114**, graphics processing units (GPUs) **116**, long-term storage **118**, and one or more interfaces **120**.

One or more processors **110** may comprise central processing units, field-programmable gate array (FPGA) devices, or any range of processing devices needed to support the operations of the autonomous vehicle. Memory **112** comprises dynamic random-access memory (DRAM) or other suitable volatile memory for the temporary storage of data required by processors **110**. RF system **114** may comprise a cellular transceiver and/or satellite transceiver. Long-term storage **118** may comprise one or more high-capacity solid-state drives (SSDs). In general, long-term storage **118** may be utilized to store, for example, high-definition maps, routing data, and any other data requiring permanent or semi-permanent storage. GPUs **116** may comprise one or more high throughput GPU, vector processing unit (VPU), and/or tensor processing unit (TPU) devices for processing data received from autonomous vehicle subsystem **102**. Finally, interfaces **120** may comprise various display units positioned within the autonomous vehicle (e.g., an in-dash screen).

Each of the devices is connected via a bus **108**. In an embodiment, bus **108** may comprise a controller area network (CAN) bus. In some embodiments, other bus types may be used (e.g., a FlexRay or Media Oriented Systems Transport, MOST, bus). Additionally, each subsystem may include one or more additional busses to handle internal subsystem communications (e.g., Local Interconnect Network, LIN, busses for lower bandwidth communications).

The system additionally includes a lane and distance subsystem **104**, which performs the operations required by the methods illustrated in the following figures. The lane and distance subsystem **104** includes a distance estimation subunit **104**A that can determine the distance between the system and other objects. The lane and distance subsystem **104** additionally includes a lane detection subunit **104**B that can detect lanes (including unmarked lanes) on a roadway the vehicle is operating on. The lane and distance subsystem **104** additionally includes a vehicle detection subunit **104**C that can detect vehicles within image frames of a roadway the vehicle is operating on, as described in more detail herein.

In some embodiments, the lane and distance subsystem **104** may be an after-market device installed in a non-autonomous vehicle system. In other embodiments, the lane and distance subsystem **104** can be integrated into an autonomous vehicle's or ADAS processing units. Details of distance estimation subunit **104**A, lane detection subunit **104**B, and vehicle detection subunit **104**C (and their operations) are further described herein. The lane and distance subsystem **104** additionally includes a camera initialization subunit **104**D. In an embodiment, camera initialization subunit **104**D can initialize a camera upon startup or upon detecting a movement or repositioning of the camera. In some embodiments, the camera initialization subunit **104**D can communicate with a remote system (illustrated in FIG. **2**) to initialize a camera with one or more camera parameters (e.g., camera height, camera viewing angle, and road plane normal). In other embodiments, the camera initialization subunit **104**D can store one or more predictive models (e.g., as depicted in FIGS. **3**A and **3**B) to generate camera parameters locally. In some embodiments, a combination of approaches can be employed. For example, the camera initialization subunit **104**D can locally predict camera parameters and then confirm these parameters with a remote system. Alternatively, in an embodiment, the camera initialization subunit **104**D can predict a horizon line and transmit the horizon line along with lane key points to a remote system to determine camera parameters.

As will be discussed in more detail, some embodiments of the disclosure are related to lane detection in the above vehicular system. The disclosed embodiments generalize lane boundary (line or curve) detection on a rather small dataset as compared to lane region analysis which requires larger data sets. The disclosed embodiments utilize a convolutional neural network (CNN) to predict lane boundary and horizon markers directly instead of sampling them from segmentation maps. The CNN output is then passed through a post-processing pipeline to fit lines to the predicted markers generated by the CNN and to initialize lane width. At inference, if the disclosed embodiments fit two lane boundaries (e.g., lines or curves) to the detected markers jointly using the initialized lane width within a reasonable tolerance (e.g., 30%) and parallelism, the disclosed embodiments may then predict any missing lane boundaries and handle multiple predictions through weighted averaging. The disclosed embodiments greatly improve the lane detection accuracy when compared to existing systems.

FIG. **2** is a swim lane diagram illustrating a method for initializing a camera according to some embodiments.

In process **202**, a device **230** (e.g., a camera and processor installed in a vehicle) captures a video, represented as, for example, a set of one or more images. In an embodiment, process **202** can include capturing a sequence of frames. In an embodiment, the device **230** can trigger process **202** when a vehicle equipped with the device **230** is in a preferred location, such as traveling on a highway. In such an embodiment, process **202** can comprise determining the location of a vehicle and confirming that the location is near a highway or other predefined location type. In an embodiment, the device **230** can implement process **202** as a state machine executing on the device **230** that continuously monitors for a special event. Examples of special events include driving over a preset speed (e.g., **35** miles per hour) for a preset duration (e.g., sixty seconds). Once this special event is detected, process **202** can then begin capturing images for a preset duration (e.g., thirty or sixty seconds). In an embodiment, process **202** can additionally confirm a road type (e.g., determining if the vehicle is on a highway or two-lane road) before recording images.

Once process **202** records a video of the preset duration, it transmits a camera initialization event to a camera initialization service **232** in transmission **204**. In the illustrated embodiment, the camera initialization service **232** can comprise a remote computing device executing the camera initialization service **232**. For example, the camera initialization service **232** can comprise an application running on a remote server.

In process **206**, the camera initialization service **232** receives the video transmitted in transmission **204**. In an embodiment, the camera initialization service **232** can comprise a remote endpoint configured to receive network requests and process the request body (i.e., the video). In an embodiment, the camera initialization service **232** detects lane and horizon lines in the video using a predictive model, such as a deep learning or other AI model. In an embodiment, process **206** can comprise inputting the video into a predictive model, such as a CNN or other type of deep learning model to identify lane and horizon markers in a given video file automatically. Details of this type of predictive model are provided in the description of FIG. **6** and are not repeated herein. Additionally, examples of such models are provided in FIGS. **3**A and **3**B. In general, the model can output a set of lane and horizon lines identified by key points or markers.

In one embodiment, if process **206** can detect at least two lanes (e.g., identified by three independent lane lines), process **206** can further include computing camera parameters for the device **230** that recorded the video. Further detail on computing camera properties based on detected lane lines is provided in commonly-owned application Ser. No. 17/173,950, filed Feb. 11, 2021, and incorporated by reference in its entirety. As one example, process **206** can predict the camera height, viewing angle, and road plane normal.

In an embodiment, process **206** overlays the computed lane and horizon lines on the original video file, generating an overlaid video file. An example of such an overlaid video file is provided in FIG. **3**C. In some embodiments, the overlaying of lane lines can be optional. In another embodiment, process **206** can only overlay a horizon on the original video file as part of generating an overlaid video file. Process **206** can then transmit this overlaid video file to an annotator device **234** in transmission **208**.

In an embodiment, if the camera initialization service **232** fails to estimate lane or horizon lines and thus does not compute camera parameters, the camera initialization service **232** can bypass generating an overlaid video file. In such a scenario, the camera initialization service **232** can transmit the original video file in transmission **208** to enable the annotator device **234** so that the annotator device **234** can add lane markings manually, as will be discussed.

In an embodiment, the annotator device **234** can comprise a workstation or web-based application allowing for human review of automatically detected horizon and lane lines.

When the annotator device **234** receives an overlaid video file, process **210** presents the overlaid video file to the human annotator. The process **210** then requests that the human annotator confirm the lane lines (if present) and horizon in the overlaid video file. If the annotator confirms the overlaid lines, the annotator can accept the lines and transmit its acceptance back to the camera initialization service **232** in transmission **222**. In response, the camera initialization service **232** can then transmit the generated camera parameters back to the device **230** in transmission **224**. As described in, for example, FIG. **6**, the device **230** can then use these parameters to perform lane detection and distance estimation, respectively, while a camera is in motion.

As discussed, if the annotator device **234** receives the original video file and not an overlaid video file, the annotator device **234** may manually mark lane markers and thus lane lines using an annotation interface allowing for graphical entry of lane markers and (optionally) horizons on the images in the original video file. For example, the annotator interface may allow for manual drawing of lines (e.g., via straight lines or Bezier curves) overlaid on an image in a video file. These manual entries can then be converted into lane lines of the same format output by the deep learning model of the camera initialization service **232**. In an embodiment, if the annotator device **234** received an overlaid video file but determines that the overlaid lane lines or horizon is not accurate, the human annotator can manually annotate the lane lines and bypass the transmission **222**. Thus, if the annotator device **234** receives an original video or receives an incorrectly labeled overlaid video file, the human annotator will manually add a horizon line and/or lane lines in process **210**.

In the illustrated embodiment, if process **210** transmits an acceptance in transmission **222**, the method ends after transmission **224**. However, if process **210** determines that no lane lines were added by process **206** or that the added lane lines were inaccurate, the human annotator manually adds such lines, generating a second, manually overlaid video file, and transmits the manually overlaid video file to the initialization service **236** in transmission **212**.

In the illustrated embodiment, the initialization service **236** executes a process **214** in response to a video file and lane line markers. In an embodiment, process **214** can comprise a deep learning or AI model that predicts camera parameters (e.g., height, IPM, etc.) based on such input data. Certainly, in some embodiments, camera initialization service **232** may employ dual models: one predicting lane lines and one predicting camera parameters based on lane lines. In such an embodiment, the initialization service **236** can reuse the model for predicting camera parameters. In some embodiments, these two models may comprise heads of a multi-headed model sharing a common backbone neural network. Details of such models are provided in FIGS. **3**A and **3**B.

After processing, process **214** returns a computed horizon line and camera parameters to the annotator device **234** in transmission **216**. In one embodiment, the data in transmission **216** can comprise an overlaid video similar or identical to that transmitted in transmission **208**. In response, the annotator device **234** performs process **218**, which can be similar or identical to that of process **210**. Specifically, the manually overlaid video file is reviewed by human reviewers to confirm the horizon line and/or camera parameters. If the annotator rejects the predicted horizon line and/or camera parameters, the annotator device **234** can request a new video capture by the device **230** by requesting one in transmission **220**. Alternatively, if the annotator confirms that the horizon and/or camera parameters are accurate, the annotator device **234** can transmit the camera parameters to the camera initialization service **232** in transmission **226**. The camera initialization service **232** can receive the camera parameters and, in some embodiments, can store the camera parameters as training data to improve the deep learning model. Further, the camera initialization service **232** can return the accepted camera parameters to the device **230** in transmission **228**.

FIG. **3**A is a block diagram illustrating a neural network for predicting lane and horizon lines according to some embodiments.

Systems can use the illustrated neural network in some embodiments instead of a geometric process to determine lane and horizon lines. Specifically, given an input image **302** (e.g., a video frame), a backbone network **304** can convolve the input image **302** to generate a set of intermediate features (not illustrated). The backbone network **304** feeds these intermediate features into a lane-horizon marking head **306**, which outputs a plurality of key points **308** representing both the lane lines in the input image **302** as well as a horizon line in the input image **302**.

In an embodiment, the lane-horizon marking head **306** can comprise a CNN configured to process images and output a sequence of points representing the horizon and/or lane lines. For example, in some embodiments, lane-horizon marking head **306** can be a fully convolutional network (FCN) that includes a plurality of convolutional blocks where each block can include one or more convolution, batch normalization, activation and up-sampling layers. In some embodiments, FCN can also be a network comprising, or based on, Unet, DeepLab, PSPNet, SCNN or EnetSAD architectures. In some embodiments, FCN can include a neck module that further processes backbone features to detect markers on fine-grain scale. The neck module can have one or more feature pyramid network (FPN), spatial pyramid pooling (SPP), recurrent neural network (RNN) or long short-term memory (LSTM) layers to take advantage of contextual information. In an embodiment, the lane-horizon marking head **306** can be a transformer network. In some embodiment, the lane-horizon marking head **306** can further include a plurality of fully connected layers (e.g., dense layers) with optional dropout layers that output predicted lane or horizon markers.

In some embodiments, the lane-horizon marking head **306** can comprise a combined deep learning network that predicts both horizon and lane lines. In another embodiment, lane-horizon marking head **306** can comprise two separate prediction heads (e.g., deep learning models). In such an embodiment, the losses of the two separate prediction heads can be combined as a joint loss function when backpropagating.

FIG. **3**C illustrates the predicted lane/horizon lines overlaid on top of an input image. As illustrated, the neural network predicts both horizon line **314** and multiple lane lines (e.g., lane line **316**, lane line **318**, and lane line **320**).

In some embodiments, the backbone network **304** can comprise an EfficientNet backbone network. For example, in some embodiments, the backbone network **304** can comprise an EfficientNet or EfficientNet-lite backbone. In an embodiment, the backbone network **304** can further comprise a plurality of convolutional layers followed by one or more LSTM layers. In some embodiments, a max-pooling layer can be inserted between the convolutional layers and the LSTM layers. In some embodiments, a fully connected layer can be placed after the LSTM layers to process the outputs of the LSTM layers. Alternatively, or in conjunction with the foregoing, the intermediate network can comprise an RNN. In other embodiments, the intermediate network can be implemented using Gated Recurrent Unit (GRU), bidirectional GRU, or transformer layers (versus LSTM or RNN layers).

In an embodiment, the neural network is trained to predict lane and horizon key points **308**. During testing, image frames are fitted with lane lines and horizon lanes based on estimated key points. As described, in some embodiments, human annotators can be used to perform this fitting, as described in the description of FIG. **2**. In other embodiments, a geometric process can be performed to identify lane and horizon lines. As discussed in previous figures, once the horizon line is determined, downstream processes can use the horizon line to determine the height of a camera and its viewing angle (i.e., road plane normal) with respect to the ground. Further, from these, downstream processes can determine the road-plane normal vector.

In some embodiments, by using a neural network, a camera device equipped with the neural network can more rapidly estimate a horizon line using a lightweight model locally installed on the camera device. As such, if the camera device is moved (either intentionally or unintentionally), the camera can automatically re-estimate the horizon lines and re-compute the camera parameters. In some embodiments, Kalman filtering can be employed to temporally smooth image and/or horizon/lane key points over time.

In some embodiments, the neural network can be employed in combination with the process depicted in FIG. **2**. Specifically, the processing in FIG. **2** utilizes a remote computing system to annotate horizon and lane lines, and in some cases, manually adding lane markers. In some embodiments, a vehicular system can use the system of FIG. **3**A and “fallback” to the procedure described in FIG. **2** in the event that the key points **308** cannot be accurately predicted using the system of FIG. **3**A. In some embodiments, the model of FIG. **3**A can provide advantages over the offline process of FIG. **2**. For example, the use of the neural network can relax constraints that the vehicle needs to be driving on a highway having three or more lane lines. Indeed, just two lane-lines with a known lane-width would be sufficient for camera initialization. That is, since the model is capable of predicting the horizon line directly, previous requirements of having three lane lines in frame (e.g., to geometrically calculate a horizon line) can be relaxed. Additionally, the neural network can be configured to run directly on in-vehicle devices and does not require a cloud-based service initiation or annotator review. Further, since the camera itself can detect (or be informed of) movements, recalibration can be done on an as-needed basis.

FIG. **3**B is a block diagram illustrating a neural network for predicting lane and horizon lines and camera parameters according to some embodiments.

In the illustrated embodiment, various elements have previously been discussed, such as input image **302**, backbone network **304**, lane-horizon marking head **306**, and key points **308**. The discussion of these components is not repeated herein but is incorporated by reference in its entirety.

In the illustrated embodiment, in addition to the component of the model of FIG. **3**A, a separate camera parameter prediction head **310** that outputs camera parameters **312** is coupled to backbone network **304**. Thus, the backbone network **304** feeds intermediate representations of input image **302** into the separate camera parameter prediction head **310**, and the separate camera parameter prediction head

310 outputs corresponding camera parameters **312**. In an embodiment, the camera parameters **312** can comprise a camera height and viewing angle with respect to the ground plane and the road-plane normal vector. In some embodiments, when the neural network of FIG. **3**B is used, the lane-horizon marking head **306** can be modified to only predict lane lines and not a horizon line.

As with lane-horizon marking head **306**, in some embodiments, the camera parameter prediction head **310** can include a plurality of convolutional blocks used to compute relationships among different objects in the scene. Each convolutional block can include, in some embodiments, one or more convolutional, batch normalization, activation or up-sampling layers. In an embodiment, the camera parameter prediction head **310** can further include a plurality of fully connected layers (e.g., dense layers) with optional dropouts to predict camera parameters. The specific arrangement of layers in the camera parameter prediction head **310** is not limiting, and other configurations may be used.

In the illustrated embodiment, the separate camera parameter prediction head **310** can predict camera parameters **312** without relying on the key points **308**. Specifically, while the two heads are trained simultaneously (using a joint loss function), the individual heads can be separated and used independently. Thus, backpropagation based on the joint loss can utilize relevant features of backbone network **304** and lane-horizon marking head **306** to optimize the layers of the separate camera parameter prediction head **310**. Then, in production, the input image **302** can be fed through the backbone network **304** and separate camera parameter prediction head **310** to predict camera parameters such as camera height and viewing angle.

In an embodiment, the output of the lane-horizon marking head **306** can further be used as an input to separate camera parameter prediction head **310**. In such an embodiment, the key points **308** can be used as an additional feature (along with image representations) to predict the camera parameters. In some embodiments, this additional input may be optional.

In some embodiments, a joint loss is minimized, which comprises the aggregate of the loss of the lane-horizon marking head **306** ($loss_{lane\text{-}horizon}$) that evaluates the distance between the estimated and ground-truth lane/horizon key points and the loss of the separate camera parameter prediction head **310** ($loss_{own\text{-}init}$) that comprises the loss between the estimated and ground-truth camera parameters. Thus, the joint loss minimized is equal to $loss_{joint} = loss_{lane\text{-}horizon} + loss_{cam\text{-}init}$.

In some embodiments, the neural network of FIG. **3**B can provide additional advantages over current systems. For example, the neural network can directly estimate camera parameters and partially or completely eliminate the need for accurate lane and horizon detection. In addition, the illustrated neural network does not require the lane width of the road the vehicle is running on. In some embodiments, the estimation of an auxiliary horizon can also be used in formulating a fusion strategy among different methods of camera initialization (manual, geometry-based and model-based).

FIG. **4**A is a flow diagram illustrating a method for training the neural network of FIG. **3**A according to some embodiments.

In step **402**A, the method receives an image or set of images. In one embodiment, the image in the method comprises an image captured by a camera device installed within a vehicle. Such images were discussed previously in connection with FIG. **3**A, the disclosure of which is incorporated in its entirety. In some embodiments, a set of images can be received as a batch of images. In some embodiments, the image or set of images can comprise a video or video frames.

In step **404**A, the method processes the image(s) using a backbone network. In an embodiment, the backbone network can comprise a backbone network such as backbone network **304**, the disclosure of which is incorporated in its entirety. In some embodiments, the backbone network can include an intermediate network as discussed in the description of FIG. **3**A.

In step **406**A, the method inputs the features of the backbone network (and, if implemented, an intermediate network) into a lane/horizon marking head. As described in FIG. **3**A, the lane/horizon marking head can comprise a neural network configured to predict lane and/or horizon markers for a given image or set of images. In some embodiments, the lane/horizon marking head can include an RNN or LSTM layer (or layers) to refine predictions based on a sequence of images.

In step **408**A, the method takes input, from step **414**A, the ground truth image labels corresponding to the processed image along with all the classification prediction head's output to compute a prediction loss. Details of prediction loss and backpropagation are described in the previous FIG. **3**A and are not repeated herein but are incorporated in their entirety herein. In general, the ground truth can comprise a set of expected markers or lines (e.g., horizon and/or lane markers or lines). In step **408**A, the method computes the loss for each of the lane and/or horizon markers as compared to the predicted lane and/or horizon markers to determine a prediction loss.

In step **410**A, the method determines if a stopping criterion is met. If so, the method ends. In one embodiment, the stopping criterion can comprise a configurable parameter set during the training of the machine learning (ML) model. In one embodiment, the stopping criterion can comprise a monitored performance metric such as the output of the loss function. Other types of stopping criteria can be utilized alone or in combination with the foregoing. For example, one stopping criterion may comprise the lack of a change in the loss function output across a configured number of epochs, a decrease in performance of the ML model, or a cap on the maximum number of allowed epochs or iterations.

In step **412**A, if the method determines that the stopping criterion is not met, the method will compute partial derivatives against all trainable network parameters and back-propagates them to adjust each layer parameter, as described previously.

In brief, in steps **402**A-**412**A, the method can repeatedly adjust the parameters in the network so as to minimize a measure of the difference (e.g., cost function) between the predicted output of the ML model and the ground truth until the stopping criterion is met. In the illustrated embodiment, if the method returns to step **402**A after step **412**A, the method will utilize the weights updated in step **412**A. Alternatively, when the method determines that a stopping criterion is met, the method may end.

FIG. **4**B is a flow diagram illustrating a method for training the neural network of FIG. **3**B according to some embodiments.

In step **402**B, the method receives an image. In one embodiment, the image in the method comprises an image captured by a camera device installed within a vehicle. Such images were discussed previously in connection with FIG. **3**B, the disclosure of which is incorporated in its entirety. In some embodiments, a set of images can be received as a batch of images. In some embodiments, the image or set of images can comprise a video or video frames.

In step **404**B, the method processes the image using a backbone network. In an embodiment, the backbone network can comprise a backbone network such as backbone network **304**, the disclosure of which is incorporated in its entirety.

In step **406**B, the method feeds backbone features into a plurality of prediction heads. In various embodiments, the prediction heads can include multiple prediction heads as depicted in FIG. **3**B. Specifically, in an embodiment, the prediction heads include a first prediction head configured to predict lane and/or horizon lines/markers and a second prediction head configured to predict camera parameters (e.g., a height, angle with respect to a roadway, and road plane normal). In some embodiments, the method can optionally process the backbone features using an intermediate head (e.g., an intermediate network such a CNN, RNN, LSTM, GRU, etc.) prior to inputting data into the prediction heads. The specific processing of each of the prediction heads has been described previously in the descriptions of FIG. **3**B and is not repeated herein but is incorporated herein in its entirety.

In step **408**B, the method takes as input, from step **414**B, the ground truth image labels corresponding to the processed image along with all the prediction heads' outputs to compute a single joint loss aggregating the individual losses of the plurality of prediction heads. Details of joint loss function and backpropagation are described in the previous FIG. **3**B and are not repeated herein but are incorporated in their entirety herein. In general, the ground truth can comprise a set of expected markers or lines (e.g., horizon and/or lane markers or lines) as well as expected camera parameters. In step **408**B, the method computes the loss for each of the expected features as compared to the predicted features and aggregates these losses to determine a joint loss.

In step **410**B, the method determines if a stopping criterion is met. In one embodiment, the stopping criterion can comprise a configurable parameter set during the training of the ML model. In one embodiment, the stopping criterion can comprise a monitored performance metric such as the output of the loss function. Other types of stopping criteria can be utilized alone or in combination with the foregoing. For example, one stopping criterion may comprise the lack of a change in the loss function output across a configured number of epochs, a decrease in performance of the ML model, or a cap on the maximum number of allowed epochs or iterations.

In step **412**B, if the method determines that the stopping criterion is not met, the method computes partial derivatives against all trainable network parameters and back-propagates them to adjust each layer parameter, as described previously.

In brief, in steps **402**B-**412**B, the method can repeatedly adjust the parameters in the network so as to minimize a measure of the difference (e.g., cost function) between the predicted output of the ML model and the ground truth until the stopping criterion is met. Alternatively, when the method determines that a stopping criterion is met, the method may end. In the illustrated embodiment, if the method returns to step **402**B after the decision in step **410**B, the method will utilize the weights updated in step **412**B.

FIG. **5**A is a flow diagram illustrating a method for predicting lane and horizon lines using the neural network of FIG. **3**A according to some embodiments. As will be discussed, in some embodiments, FIG. **5**A can be used as part of step **608**.

In step **502**A, the method receives an image or set of images. In one embodiment, the image in the method comprises an image captured by a camera device installed within a vehicle. Such images were discussed previously in connection with FIG. **3**A, the disclosure of which is incorporated in its entirety. In some embodiments, a set of images can be received as a batch of images. In some embodiments, the image or set of images can comprise a video or video frames.

In step **504**A, the method processes the image(s) using a backbone network. In an embodiment, the backbone network can comprise a backbone network such as backbone network **304**, the disclosure of which is incorporated in its entirety. In some embodiments, the backbone network can include an intermediate network.

In step **506**A, the method inputs the features of the backbone network (and, if implemented, an intermediate network) into a lane and/or horizon prediction head. In some embodiments, the lane and/or horizon prediction head can comprise lane-horizon marking head **306**, the disclosure of which is incorporated in its entirety.

In step **508**A, the method uses the predicted lane and/or horizon markers or lines to compute camera parameters. Details of this step are provided in more detail in the description of FIG. **7**, incorporated herein in its entirety.

FIG. **5**B is a flow diagram illustrating a method for predicting lane and horizon lines and camera parameters the neural network of FIG. **3**B according to some embodiments. As will be discussed, in some embodiments, FIG. **5**B can be used as part of step **608**.

In step **502**B, the method receives an image or set of images. In one embodiment, the image in the method comprises an image captured by a camera device installed within a vehicle. Such images were discussed previously in connection with FIG. **3**B, the disclosure of which is incorporated in its entirety. In some embodiments, a set of images can be received as a batch of images. In some embodiments, the image or set of images can comprise a video or video frames.

In step **504**B, the method processes the image(s) using a backbone network. In an embodiment, the backbone network can comprise a backbone network such as backbone network **304**, the disclosure of which is incorporated in its entirety. In some embodiments, the backbone network can include an intermediate network.

In step **506**B, the method inputs the features of the backbone network (and, if implemented, an intermediate network) into a camera parameter head. In an embodiment, the camera parameter head can comprise separate camera parameter prediction head **310**. In an optional embodiment, the method can further input the features of the backbone network into a lane and/or horizon prediction head. In some embodiments, the lane and/or horizon prediction head can comprise lane-horizon marking head **306**, the disclosure of which is incorporated in its entirety.

In step **508**B, the method outputs camera parameters. In some embodiments, the camera parameters can be stored for future use, such as during lane detection or distance estimation as described in FIG. **6**. If the method predicts lane or horizon markers/lines, step **508**B can further comprise outputting the predicted lane/horizon markers/lines.

FIG. **6** is a flow diagram illustrating a method for detecting lane markers on a roadway and determining distances to objects according to some embodiments of the disclosure.

In step **602**, the method receives video frames. In an embodiment, the video frames are captured by a camera installed in or on a vehicle. In an embodiment, the camera is mounted at a fixed location and direction with respect to the vehicle. For example, the camera may be a dash-mounted camera. In an embodiment, the camera continuously streams video frames while in operation.

In step **604**, the method detects markers (or key points) in video frames using a CNN. Reference is made to FIG. **7**, which depicts one embodiment of a CNN used in step **604**, according to some embodiments of the disclosure. In an alternative embodiment, the network of FIG. **3**A or **3**B can alternatively be used to predict lane lines. For example, key points **308** can be used to generate horizon line key points using lane-horizon marking head **306**. In such an embodiment, the lane-horizon marking head **306** can be utilized both for initialization (as will be discussed) but also during the prediction phase (e.g., to continuously identify a horizon line).

In step **606**, the method determines if the system is initializing a camera. If so, the method proceeds to step **608**. If not, the method proceeds to step **610**. Next, in step **614**, the method fits one or more lines to the markers. In some embodiments, step **614** can be optional. As illustrated, if the camera is already initialized, step **608** is bypassed, and the method proceeds directly toward step **614**. In an alternative embodiment, as exemplified in FIG. **2**, step **606** can be executed after step **602** and step **608** can include the network-based initialization procedure described in FIG. **2**.

In an embodiment, the method determines that the system is initializing if camera parameters have not been stored for the camera. In an embodiment, the estimation of camera parameters is a one-off calculation for a given camera which is done over a small set of initial frames. Thus, each camera can be associated with a set of camera parameters and these camera parameters need only be calculated once per camera. In some embodiments, the camera parameters may be recalculated as desired or in response to a change in camera position or other intrinsic value. For example, in an embodiment, the method can determine if an orientation measured by one or more leveling devices has changed from an orientation that was present when calculating the camera parameters. If so, the method can perform step **608** in response to detecting such a change. In one embodiment, the camera parameters can comprise a camera height and road normal vector associated with a given camera. In some embodiments, an inverse perspective mapping can then be computed based on the camera height and road normal vector.

In step **608**, the method initializes the camera using the frames recorded by the camera.

In an embodiment, camera initialization involves using the horizon output by a CNN (e.g., using the methods described in FIG. **2**, **5**A, or **5**B) and third-party data sources to calculate a camera height and road normal vector. In some embodiments, after identifying a camera height and road normal vector, the method can further comprise calculating an IPM that can be used to synthetically rotate the viewpoint of the video frames. In some embodiments, the method can then use a lane width determined from the rotated viewpoint to fit equidistant parallel lanes in rectified view after the initialization.

In an embodiment, the methods discussed in connection with FIG. **6** may utilize horizon detection directly from lane detection network as a fifth line (in addition to four lane lines). In some embodiments, a separate neural network for horizon detection may also be used. Details of this approach are described in connection with FIGS. **3**A and **3**B. As an alternative, a server-side approach can be used to determine the camera parameters. Details of this approach are described in connection with FIG. **2**.

FIG. **7** is a flow diagram illustrating a method for initializing a camera installed in a vehicle according to some embodiments of the disclosure. As described above, the method may only need be performed once per camera or can be performed on demand (e.g., in response to a change in camera orientation or angle) as part of a recalibration or reinitialization procedure.

In step **702**, the method receives a horizon line detected using a CNN or similar model. As discussed above, in some embodiments, the horizon line can be determined by a local neural network (as in FIGS. **3**A and **3**B) or via a remote data source (as in FIG. **2**).

In step **704**, the method computes the IPM for a camera and rectifies the sample images. In an embodiment, step **704** comprises computing a road plane normal vector ($\hat{n}$) using an intrinsic camera matrix (K) and the detected horizon (l_h) according to:

$$\hat{n}=K^T l_h \quad \text{(Equation 1)}$$

where K^T comprises the transpose of the intrinsic camera matrix. In an embodiment, the intrinsic camera matrix comprises the geometric properties of the camera. After computing the plane normal ($\hat{n}$), the method computes the IPM (H) using:

$$H=KRK^{-1} \quad \text{(Equation 2)}$$

where H is the rectification homography which will rotate the camera view to align its Z-axis with the road plane normal, and R is the rotation matrix defined by:

$$R=[l_h\times\hat{n};(l_h\times\hat{n})\times-\hat{n};-\hat{n}] \quad \text{(Equation 3)}$$

Further detail on computing an IPM is provided in commonly-owned application Ser. No. 17/173,950, filed Feb. 11, 2021, and incorporated by reference in its entirety.

In some embodiments, the method may further include step **706** wherein lane widths (in pixels) of lanes in the video frames are determined.

In an embodiment, a current location is determined in step **706**. As used herein, a current location can refer to a latitude and longitude, Geohash value, or other identifying value. In an embodiment, this current location is used to retrieve lane width details from a third-party mapping service. In an embodiment, the method can transmit the current location to the third-party mapping service and receive a lane width associated with the current location or, more specifically, the roadway present at the current location. If the third-party mapping service returns such data, the method can set the value of the lane width in pixels (L_{w_p}) to the return value.

In other embodiments, the third-party mapping service may not return a lane width. In such an embodiment, the third-party mapping service may provide a bird's eye image of the roadway at the current location and a resolution. In an embodiment, the resolution can comprise a unit of measurement converting pixels to physical distances. Thus, as one example, one pixel may correspond to one foot. In such an embodiment, the method can automatically identify lane lines within the image (e.g., using a CNN or other machine learning approach) and then compute the number of pixels between each lane line. The method can then convert the lane width in pixels (L_{w_p}) to a real-world lane width distance (L_{w_r}) using the returned resolution.

In an alternative embodiment, the method can rely on user input to detect lane widths. In such an embodiment, the method can display the images returned from the third-party mapping service and display the image to a user. The user can then manually identify lane lines (e.g., by using a line drawing tool, touch screen, etc.). The method can then use the user markup to compute the distance between lane lines and compute the number of pixels between each lane line. The method can then convert the number of pixels to a real-world lane width distance (L_{w_r}) using the returned resolution.

In another embodiment, the method can attempt to automatically mark lane lines using, for example, a machine learning model. The method can then display the predicted lane lines to the user to allow the user to confirm, reject, and/or adjust the predicted markers. The method can then compute the number of pixels between each lane line. The method can then convert the number of pixels to a real-world lane width distance (L_{w_r}) using the returned resolution. Details of using a machine learning model to predict lane lines and/or horizon lines are described in the descriptions of FIGS. **2**, **3**A, **3**C, and **3**B.

In some embodiments, the result of the foregoing embodiments can be inconclusive. For example, image quality of the returned third-party service images may be unsuitable for annotation of lane lines and thus the lane widths are not able to be calculated. In such an embodiment, the method can revert to a geometric algorithm to determine a lane width, as detailed in commonly-owned application Ser. No. 17/173,950, filed Feb. 11, 2021.

In step **708**, the method stores the camera parameters. In one embodiment, step **708** comprises storing the camera height, horizon line, and road plane normal. In some embodiments, step **708** can optionally comprise storing the IPM (H) and the lane width (L_{w_p}). In an embodiment, the camera parameters are stored in a non-volatile storage device and are associated with a camera. Thus, the camera parameters may be reused during subsequent operations performed on images captured by a given camera, as discussed fully in step **610**. In some embodiments, the method may be executed directly on the camera and stored on the camera (such as on the edge hardware onboard the vehicle). In other embodiments, the value of H, lane width and camera height may be calculated off-camera and stored off-camera (such as in the cloud and stored in a cloud database).

Returning to FIG. **6**, if the method determines that the camera is initialized, the method proceeds to apply the IPM to line or curves represented by the CNN-predicted markers and horizon to identify lane lines in a given frame. As illustrated, in some embodiments, the method may execute step **610** on the sample frames used to initialize the camera in step **608** as well. Details of applying an IPM to a set of image frames to detect lane lines are provided in more detail in commonly-owned application Ser. No. 17/173,950, filed Feb. 11, 2021 In step **612**, the method transmits or outputs the perspective lane boundaries in step **612**. In an embodiment, the method may transmit the line/curve data to a downstream processing device for further processing. For example, the method may transmit the data to a lane warning system to enable the system to determine if the vehicle crosses a lane boundary. In other embodiments, the outputting of the line or curve comprises displaying the line or curve on an in-vehicle display (e.g., a dash-mounted display or mobile phone). In an embodiment, the lane boundaries may be overlaid on top of the capture video frames.

In step **616**, the method can additionally detect a distance to identified objects. As illustrated, steps **616** and **618** can be done in parallel with steps **610** and **612**. Further, in some embodiments, steps **610** and **616** can be triggered asynchronously.

As illustrated, in some embodiments, the method may execute step **616** on the sample frames used to initialize the camera in step **608** as well. In an embodiment, any type of object detection system may be used to identify objects (e.g., via bounding boxes) within an image including detecting objects using DL object detectors such as Faster-RCNN, MobileNet-SSD, EfficientDets, YoloV1, YoloV2, YoloV3, YoloV4, YoloV5, and similar such systems. Details of detecting object distances in step **608** were described in commonly-owned application Ser. No. 17/173,950, filed Feb. 11, 2021. Finally, in step **616**, the method transmits or outputs the distance data. In an embodiment, the distance data includes distances to detected objects. In some embodiments, the distance data includes bounding boxes for the detected objects. In some embodiments, the method may further detect lane boundary or lane lines/curves and may include these in the returned data. In an embodiment, the method may transmit the line/curve data to a downstream processing device for further processing. For example, the method may transmit the data to a collision detection system to enable the system to determine if the vehicle is too close to another object or vehicle.

FIG. **8** is a block diagram of a computing device according to some embodiments of the disclosure. In some embodiments, the computing device can be used to train and use the various ML models described previously.

As illustrated, the device includes a processor or central processing unit (CPU) such as CPU **802** in communication with a memory **804** via a bus **814**. The device also includes one or more input/output (I/O) or peripheral devices **812**. Examples of peripheral devices include, but are not limited to, network interfaces, audio interfaces, display devices, keypads, mice, keyboard, touch screens, illuminators, haptic interfaces, global positioning system (GPS) receivers, cameras, or other optical, thermal, or electromagnetic sensors.

In some embodiments, the CPU **802** may comprise a general-purpose CPU. The CPU **802** may comprise a single-core or multiple-core CPU. The CPU **802** may comprise a system-on-a-chip (SoC) or a similar embedded system. In some embodiments, a graphics processing unit (GPU) may be used in place of, or in combination with, a CPU **802**. Memory **804** may comprise a memory system including a dynamic random-access memory (DRAM), static random-access memory (SRAM), Flash (e.g., NAND Flash), or combinations thereof. In one embodiment, the bus **814** may comprise a Peripheral Component Interconnect Express (PCIe) bus. In some embodiments, the bus **814** may comprise multiple busses instead of a single bus.

Memory **804** illustrates an example of computer storage media for the storage of information such as computer-readable instructions, data structures, program modules, or other data. Memory **804** can store a basic input/output system (BIOS) in read-only memory (ROM), such as ROM **808** for controlling the low-level operation of the device. The memory can also store an operating system in random-access memory (RAM) for controlling the operation of the device

Applications **810** may include computer-executable instructions which, when executed by the device, perform any of the methods (or portions of the methods) described previously in the description of the preceding Figures. In some embodiments, the software or programs implementing the method embodiments can be read from a hard disk drive (not illustrated) and temporarily stored in RAM **806** by CPU **802**. CPU **802** may then read the software or data from RAM **806**, process them, and store them in RAM **806** again.

The device may optionally communicate with a base station (not shown) or directly with another computing device. One or more network interfaces in peripheral devices **812** are sometimes referred to as a transceiver, transceiving device, or network interface card (NIC).

An audio interface in peripheral devices **812** produces and receives audio signals such as the sound of a human voice. For example, an audio interface may be coupled to a speaker and microphone (not shown) to enable telecommunication with others or generate an audio acknowledgment for some action. Displays in peripheral devices **812** may comprise liquid crystal display (LCD), gas plasma, light-emitting diode (LED), or any other type of display device used with a computing device. A display may also include a touch-sensitive screen arranged to receive input from an object such as a stylus or a digit from a human hand.

A keypad in peripheral devices **812** may comprise any input device arranged to receive input from a user. An illuminator in peripheral devices **812** may provide a status indication or provide light. The device can also comprise an input/output interface in peripheral devices **812** for communication with external devices, using communication technologies, such as USB, infrared, Bluetooth™, or the like. A haptic interface in peripheral devices **812** provides tactile feedback to a user of the client device.

A GPS receiver in peripheral devices **812** can determine the physical coordinates of the device on the surface of the Earth, which typically outputs a location as latitude and longitude values. A GPS receiver can also employ other geo-positioning mechanisms, including, but not limited to, triangulation, assisted GPS (AGPS), E-OTD, CI, SAI, ETA, BSS, or the like, to further determine the physical location of the device on the surface of the Earth. In one embodiment, however, the device may communicate through other components, providing other information that may be employed to determine the physical location of the device, including, for example, a media access control (MAC) address, Internet Protocol (IP) address, or the like.

The device may include more or fewer components than those shown in FIG. **8**, depending on the deployment or usage of the device. For example, a server computing device, such as a rack-mounted server, may not include audio interfaces, displays, keypads, illuminators, haptic interfaces, Global Positioning System (GPS) receivers, or cameras/sensors. Some devices may include additional components not shown, such as graphics processing unit (GPU) devices, cryptographic co-processors, artificial intelligence (AI) accelerators, or other peripheral devices.

The subject matter disclosed above may, however, be embodied in a variety of different forms and, therefore, covered or claimed subject matter is intended to be construed as not being limited to any example embodiments set forth herein; example embodiments are provided merely to be illustrative. Likewise, a reasonably broad scope for claimed or covered subject matter is intended. Among other things, for example, subject matter may be embodied as methods, devices, components, or systems. Accordingly, embodiments may, for example, take the form of hardware, software, firmware, or any combination thereof (other than software per se). The preceding detailed description is, therefore, not intended to be taken in a limiting sense.

Throughout the specification and claims, terms may have nuanced meanings suggested or implied in context beyond an explicitly stated meaning. Likewise, the phrase "in an embodiment" as used herein does not necessarily refer to the same embodiment and the phrase "in another embodiment" as used herein does not necessarily refer to a different

embodiment. It is intended, for example, that claimed subject matter include combinations of example embodiments in whole or in part.

In general, terminology may be understood at least in part from usage in context. For example, terms, such as "and," "or," or "and/or," as used herein may include a variety of meanings that may depend at least in part upon the context in which such terms are used. Typically, "or" if used to associate a list, such as A, B or C, is intended to mean A, B, and C, here used in the inclusive sense, as well as A, B or C, here used in the exclusive sense. In addition, the term "one or more" as used herein, depending at least in part upon context, may be used to describe any feature, structure, or characteristic in a singular sense or may be used to describe combinations of features, structures, or characteristics in a plural sense. Similarly, terms, such as "a," "an," or "the," again, may be understood to convey a singular usage or to convey a plural usage, depending at least in part upon context. In addition, the term "based on" may be understood as not necessarily intended to convey an exclusive set of factors and may, instead, allow for existence of additional factors not necessarily expressly described, again, depending at least in part on context.

The present disclosure is described with reference to block diagrams and operational illustrations of methods and devices. It is understood that each block of the block diagrams or operational illustrations, and combinations of blocks in the block diagrams or operational illustrations, can be implemented by means of analog or digital hardware and computer program instructions. These computer program instructions can be provided to a processor of a general-purpose computer to alter its function as detailed herein, a special purpose computer, application-specific integrated circuit (ASIC), or other programmable data processing apparatus, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, implement the functions/acts specified in the block diagrams or operational block or blocks. In some alternate implementations, the functions or acts noted in the blocks can occur out of the order noted in the operational illustrations. For example, two blocks shown in succession can in fact be executed substantially concurrently or the blocks can sometimes be executed in the reverse order, depending upon the functionality or acts involved.

These computer program instructions can be provided to a processor of a general purpose computer to alter its function to a special purpose; a special purpose computer; ASIC; or other programmable digital data processing apparatus, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, implement the functions or acts specified in the block diagrams or operational block or blocks, thereby transforming their functionality in accordance with embodiments herein.

For the purposes of this disclosure a computer readable medium (or computer-readable storage medium) stores computer data, which data can include computer program code or instructions that are executable by a computer, in machine readable form. By way of example, and not limitation, a computer readable medium may comprise computer readable storage media, for tangible or fixed storage of data, or communication media for transient interpretation of code-containing signals. Computer readable storage media, as used herein, refers to physical or tangible storage (as opposed to signals) and includes without limitation volatile and non-volatile, removable, and non-removable media implemented in any method or technology for the tangible storage of information such as computer-readable instructions, data structures, program modules or other data. Computer readable storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid-state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other physical or material medium which can be used to tangibly store the desired information or data or instructions and which can be accessed by a computer or processor.

For the purposes of this disclosure a module is a software, hardware, or firmware (or combinations thereof) system, process or functionality, or component thereof, that performs or facilitates the processes, features, and/or functions described herein (with or without human interaction or augmentation). A module can include sub-modules. Software components of a module may be stored on a computer readable medium for execution by a processor. Modules may be integral to one or more servers or be loaded and executed by one or more servers. One or more modules may be grouped into an engine or an application.

Those skilled in the art will recognize that the methods and systems of the present disclosure may be implemented in many manners and as such are not to be limited by the foregoing exemplary embodiments and examples. In other words, functional elements being performed by single or multiple components, in various combinations of hardware and software or firmware, and individual functions, may be distributed among software applications at either the client level or server level or both. In this regard, any number of the features of the different embodiments described herein may be combined into single or multiple embodiments, and alternate embodiments having fewer than, or more than, all the features described herein are possible.

Functionality may also be, in whole or in part, distributed among multiple components, in manners now known or to become known. Thus, a myriad or software, hardware, and firmware combinations are possible in achieving the functions, features, interfaces, and preferences described herein. Moreover, the scope of the present disclosure covers conventionally known manners for carrying out the described features and functions and interfaces, as well as those variations and modifications that may be made to the hardware or software or firmware components described herein as would be understood by those skilled in the art now and hereafter.

Furthermore, the embodiments of methods presented and described as flowcharts in this disclosure are provided by way of example to provide a more complete understanding of the technology. The disclosed methods are not limited to the operations and logical flow presented herein. Alternative embodiments are contemplated in which the order of the various operations is altered and in which sub-operations described as being part of a larger operation are performed independently.

While various embodiments have been described for purposes of this disclosure, such embodiments should not be deemed to limit the teaching of this disclosure to those embodiments. Various changes and modifications may be made to the elements and operations described above to obtain a result that remains within the scope of the systems and processes described in this disclosure.

What is claimed is:

1. A method comprising:

receiving, over a network from a camera device, a video comprising a set of image frames;

identifying one or more lines in the video using a predictive model, the one or more lines including a horizon line;

computing at least one camera parameter based on the one or more lines;

overlaying the one or more lines on the video to generate an overlaid video;

transmitting the overlaid video to an annotator device for manual review;

receiving a confirmation from the annotator device, the confirmation indicating that the one or more lines are accurate; and

transmitting data representing the at least one camera parameter to the camera device.

2. The method of claim **1**, wherein the one or more lines includes at least one lane line of a roadway.

3. The method of claim **1**, wherein computing the at least one camera parameter comprises predicting the at least one camera parameter using the predictive model.

4. The method of claim **1**, wherein computing the at least one camera parameter comprises predicting the at least one camera parameter using a second predictive model.

5. The method of claim **1**, wherein the at least one camera parameter comprises a camera height and road plane normal.

6. The method of claim **1**, further comprising:

receiving, over the network from the camera device, a second video comprising a second set of images;

transmitting the second video to the annotator device for manual review;

adding, by the annotator device, one or more lines to the second video to generate a second overlaid video;

predicting, using the one or more lines in the second overlaid video, at least one camera parameter; and

transmitting the at least one camera parameter to the annotator device.

7. The method of claim **6**, further comprising:

receiving a second confirmation from the annotator device, the second confirmation indicating that the at least one camera parameter are accurate; and

transmitting data representing the one or more lines of the second video to the camera device.

8. A method comprising:

receiving a video, the video comprising one or more image frames;

generating a set of intermediate features representing the video using a backbone network;

inputting the set of intermediate features into a lane or horizon prediction head, the lane or horizon prediction head comprising a neural network;

predicting a horizon line using the lane or horizon prediction head, the horizon line comprising a set of horizon markers; and

using the horizon line to compute at least one camera parameter.

9. The method of claim **8**, the backbone network comprising at least one convolutional layer.

10. The method of claim **8**, wherein the at least one camera parameter comprises one of a camera height, camera angle, and road plane normal.

11. The method of claim **8**, further comprising predicting, using the lane or horizon prediction head, at least one lane line, the at least one lane line comprising a set of lane line markers.

12. The method of claim **11**, wherein generating a plurality of lane key points comprises generating a plurality of lane key points for two lane lines on a roadway.

13. The method of claim **8**, further comprising detecting a movement of a camera that captured the video and re-initializing the at least one camera parameter in response.

14. The method of claim **8**, wherein the lane or horizon prediction head comprises at least one convolutional layer.

15. The method of claim **14**, wherein the lane or horizon prediction head further comprises at least one fully connected layer receiving an output of the convolutional layer.

16. The method of claim **14**, wherein the lane or horizon prediction head further comprises a layer selected from the group consisting of a recurrent neural network layer, long short-term memory layer, and gated recurrent unit layer.

17. A method comprising:

receiving a video, the video comprising one or more image frames;

generating a set of intermediate features representing the video using a backbone network;

inputting the set of intermediate features into a camera parameter estimation head, the camera parameter estimation head comprising a neural network; and

predicting at least one camera parameter using the camera parameter estimation head, the camera parameter estimation head trained using an output of the backbone network and an output of a lane and horizon line prediction head.

18. The method of claim **17**, wherein the backbone network, camera parameter estimation head, lane and horizon line prediction head are trained using a joint loss function, the joint loss function aggregating the losses of the lane and horizon line prediction head and the neural network.

19. The method of claim **17**, further comprising predicting a horizon line using the lane and horizon line prediction head, the lane and horizon line prediction head comprising a neural network configured to receive the set of intermediate features as an input.

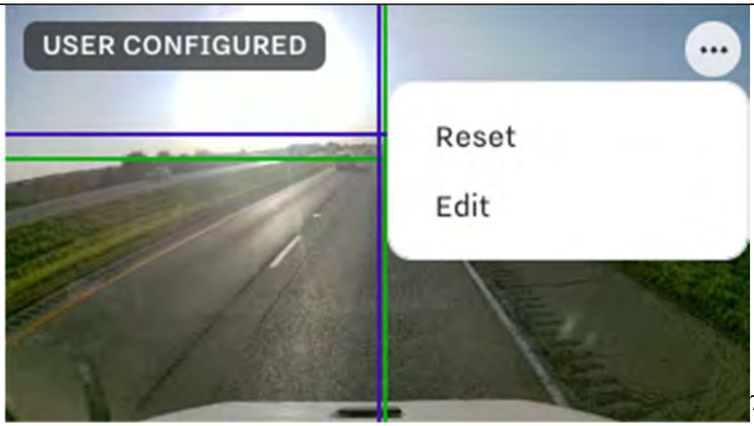
20. The method of claim **17**, wherein the camera parameter estimation head comprises at least one convolutional layer.

* * * * *

EXHIBIT B

Claim 1 of the '580 Patent	**Defendant's Infringing Products**
A method comprising:	To the extent the preamble is limiting, Defendant's Infringing Products perform methods that utilize AI-enabled dashcams.[1] As part of these operations, Defendant's Infringing Products perform a calibration method to calibrate its dashcam's prior to use. This calibration is automatic and repeated on a regular or periodic basis as well as on-demand by Defendant's customers.[2]
receiving, over a network from a camera device, a video comprising a set of image frames;	Defendant's Infringing Products include a windshield-mounted dashcam (e.g., the Infringing Dashcams) that includes an outward-facing camera that captures images and "automatically uploads HD video footage to the Samsara Cloud."[3] After installation, the dashcams of Defendant's Infringing Products are automatically calibrated.[4] As part of this operation, the dashcams capture images of the roadway for "30 minutes at speeds greater than 45 mph."[5] Upon information and belief, this video stream (which includes a set of image frames) is transmitted to the Defendant's Infringing Platform for processing and calibration.[6] For example, in a "Fleet menu" of Defendant's Infringing Platform, users can view these image frames captured during calibration:

[1] Samsara, *Harness the Power of Your Data,* https://www.samsara.com/products/platform; Samsara, *CM32,* https://www.samsara.com/products/models/cm32/.
[2] Samsara, *Dash Cam Calibration*, https://kb.samsara.com/hc/en-us/articles/360045297011-Dash-Cam-Calibration.
[3] Samsara, *CM32,* https://www.samsara.com/products/models/cm32/.
[4] Samsara, *Dash Cam Calibration*, https://kb.samsara.com/hc/en-us/articles/360045297011-Dash-Cam-Calibration.
[5] *Id.*
[6] *Id.*

	[7]
identifying one or more lines in the video using a predictive model, the one or more lines including a horizon line;	Based on the captured images, and upon information and belief, Defendant's Infringing Platform uses image processing and machine learning-based predictive modeling to determine where in the series of image frames a horizon line appears.[8] Upon information and belief, Defendant's Infringing Platform also identifies a vertical center line within the captured image.[9]

[7] *Id.*
[8] *Id.*
[9] *Id.*

	 [10]
computing at least one camera parameter based on the one or more lines;	Upon information and belief, based on these lines, Defendant's Infringing Platform can automatically determine the dash cam height.[11] As indicated below, upon information and belief, Defendant's Infringing Platform determines the camera height based on the positioning of a vanishing point on the horizon line.[12]
overlaying the one or more lines on the video to generate an overlaid video;	Defendant's Infringing Platform provides a "Fleet Menu" that displays captured video with the horizon line and center line:

[10] *Id.*
[11] *Id.*
[12] *Id.*

	 [13]
transmitting the overlaid video to an annotator device for manual review;	The "Fleet Menu" provided as part of Defendant's Infringing Platform is a webpage that includes the above image and is transmitted to a user's computing device for "Manual[] … Calibration."[14] This webpage provides an "image thumbnail" that includes the captured image and controls for reviewing the captured image.
receiving a confirmation from the annotator device, the confirmation indicating that the one or more lines are accurate; and	Upon information and belief, after viewing the detected horizon line and camera height, Defendant's Infringing Platform can confirm the horizon line by receiving a confirmation or acceptance of the lines as predicted.[15] Alternatively, Defendant's Infringing Platform can adjust a horizon line based on user feedback, improving the accuracy of the horizon line as indicated by the green lines:

[13] *Id.*
[14] *Id.*
[15] *Id.*

	[16]
transmitting data representing the at least one camera parameter to the camera device.	Upon acceptance or editing of a horizon line, upon information and belief, Defendant's Infringing Platform receives a confirmation or new horizon from end user devices.[17] Upon information and belief, Defendant's Infringing Platform is configured to update and transmit the camera height and horizon parameters to Defendant's dashcam devices.

[16] *Id.*
[17] *Id.*