

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

TETRA TECH CANADA INC.,
Petitioner

v.

GEORGETOWN RAIL EQUIPMENT COMPANY,
Patent Owner

Case IPR2019-01581
Patent No. 8,081,320

DECLARATION OF NIKOS PAPANIKOLOPOULOS, Ph.D.

TABLE OF CONTENTS

I.	Introduction.....	4
II.	Summary of Opinions.....	4
III.	Background Qualifications	5
IV.	Materials Reviewed	11
V.	Legal Standards	12
VI.	Overview of the '320 Patent.....	15
VII.	Level of Ordinary Skill in the Art	21
VIII.	Claim Construction.....	22
IX.	History of Rail Seat Abrasion Prior to 2009	22
X.	Analysis	25
	A. Unpatentability of Claims 1-2, 5-7, 10-14, and 16-17 over <i>Villar</i> , <i>Choros</i> , <i>Casagrande</i> , and <i>Szwilski</i>	25
	1. <i>Villar</i> 's automated machine vision railroad inspection system.	25
	2. <i>Choros</i> ' RSA measurement device and algorithm.	27
	3. It would have been obvious to combine the disclosures of <i>Villar</i> and <i>Choros</i> to make and use an automated railroad track inspection vision system to determine whether RSA is present along a railroad track.....	29
	4. Claim 1	35
	5. Claim 2	58
	6. Claim 5	61
	7. Claim 6	62

8.	Claim 7	63
9.	Claim 10	64
10.	Claim 11	65
11.	Claim 12	65
12.	Claim 13	67
13.	Claim 16	67
14.	Claim 17	67
B. Obviousness of Claims 3, 8, 14 Over <i>Villar</i> in Combination with <i>Choros</i> , <i>Casagrande</i> , <i>Szwilski</i> , and <i>Curtin</i>		
1.	Claim 3	68
2.	Claim 8	77
3.	Claim 14	77
C. Obviousness of Claims 4, 9, and 15 Over <i>Villar</i> in Combination with <i>Choros</i> , <i>Casagrande</i> , <i>Szwilski</i> , and <i>Andersson</i>		
1.	Claim 4	77
2.	Claim 9	80
3.	Claim 15	80
XI.	Conclusion	80
XII.	Declaration	80

I. Introduction

I, Nikos Papanikolopoulos, Ph.D., declare as follows:

1. I have been asked to submit this declaration on behalf of Tetra Tech Canada Inc. (Petitioner) in connection with a petition for *inter partes* review (IPR) of U.S. Patent No. 8,081,320 (the '320 patent), which I have been told is being submitted to the Patent Trial and Appeal Board of the United States Patent and Trademark Office by Petitioner. I understand that the '320 patent is Exhibit 1001 to the petition for IPR of the '320 patent.

2. Specifically, I have been retained as a technical expert by Petitioner to study and provide my opinions on the technology claimed in, and the patentability or unpatentability of, claims 1-17 of the '320 patent ("the challenged claims"). For purposes of this declaration, I was not asked to provide any opinions that are not expressed herein.

II. Summary of Opinions

3. This declaration is directed to the challenged claims of the '320 patent, and sets forth the opinions I have formed, the conclusions I have reached, and the bases for each. Based on my experience, knowledge of the art as of the effective filing date of the '320 patent, analysis of prior art references, and the understanding a person of ordinary skill in the art would have had of the claim terms in light of the specification as of the effective filing date, it is my opinion

that the challenged claims of the '320 patent are unpatentable over the prior-art references discussed below. In forming my opinions, I have been informed that the effective filing date of the '320 patent is its filing date, June 23, 2009.

III. Background Qualifications

A. Background

4. My name is Nikos Papanikolopoulos, Ph.D. I am currently employed as the McKnight Presidential Endowed Professor of Computer Science and Engineering at the University of Minnesota in Minneapolis, Minnesota. I am also the Director of the Minnesota Robotics Institute and the Director of SECTTRA (Security in Transportation Technology Research and Applications) at the University of Minnesota. I have been involved with the design and evaluation of computer vision systems, sensors, and lasers for approximately 30 years. My academic research has been in the areas of computer vision, robotics, intelligent transportation systems, sensor networks, object recognition, and sensor-based control in transportation systems. To avoid confusion, the terms “computer vision” and “machine vision” are used in this document interchangeably although there are some subtle differences. I have also been involved in consulting work since 1997 involving computer vision algorithms for vehicle tracking, camera calibration, inspection, object recognition, vehicle monitoring systems, and motion control devices. I have authored or co-authored several book chapters and numerous peer-

reviewed technical papers in these areas. My current *curriculum vitae* (CV) is included as Ex-1003.

5. I received my Diploma of Engineering in Electrical and Computer Engineering from the National Technical University of Athens in Greece in 1987. I obtained my Masters and Ph.D. in Electrical and Computer Engineering from Carnegie Mellon University in 1988 and 1992, respectively. My research at the time was in robotics, computer vision, and control, computer integrated manufacturing, and software engineering and my Ph.D. thesis was titled “Controlled Active Vision.” The work revolved around the use of images from a camera mounted on a robot manipulator to detect features on objects, track them, recognize the objects, and possibly grasp them. Some of the features used included edges, object profiles, and corners. The work had as an ultimate objective accurate 3D reconstruction of the target object and the surrounding space.

6. After receiving my Ph.D., I began my career as a full-time Assistant Professor at the University of Minnesota, transitioning to an Associate Professor in the fall of 1996, and becoming a full Professor in the fall of 2001. During my time at these positions, I have taught courses in Computer Vision, Artificial Intelligence, Algorithms and Data Structures, and Readings in Computational Vision. The courses in Computer Vision and Readings in Computational Vision cover a variety of topics that include 3D construction, extraction of depth,

inspection, tracking, light striping, lasers, structured light, structure from motion, occlusions, edge detection, and basic image processing. I also developed and introduced a course titled “Introduction to Intelligent Robotic Systems” beginning in 1994, that I continue to teach. My academic research has continued in the fields of computer vision systems, sensors, and lasers, with primary specialties in robotics, intelligent transportation systems, and sensor-based control in transportation applications. I currently work in the Center for Distributed Robotics and the Artificial Intelligence, Robotics and Vision Laboratory (AIRVL). I have received research grants for various projects involving computer vision as applied to the transportation industry, including assessing truck parking, detection of pedestrians, and obstacle avoidance. My industrial experience includes founding a robotics company in 2005 named ReconRobotics Inc. that develops different robotic platforms. I have also been a consultant since 1997 for numerous companies and provided technical expertise in developing computer vision algorithms for vehicle tracking, camera calibration, inspection, precision agriculture, human tracking, object recognition, and fingerprint recognition. In one of my consulting assignments, I had to develop computer vision algorithms for inspection of industrial parts by using different illumination sources (Banner Engineering). I have licensed my algorithms to several industries with the most

recent one being Sentra Inc., which is using computer vision for precision agriculture.

7. I have written extensively about computer vision and robotic visual servoing, having written numerous book chapters, peer-reviewed journal articles (more than eighty), and conference papers (more than two hundred eighty), a list of which is included as part of my CV. Some relevant works include “Robust Target Detection and Tracking Through Integration of Color, Motion, and Geometry”, published in *Computer Vision and Image Understanding* in August 2006, “3D Reconstruction of Periodic Motion from a Single View”, published in the *International Journal of Computer Vision* in October 2010, “Clustering of Vehicle Trajectories”, published in the *IEEE Transactions on Intelligent Transportation Systems* in September 2010, and “Optimal Image-Based Euclidean Calibration of Structured Light Systems in General Scenes”, published in the *IEEE Transactions on Automation Science and Engineering* in October 2011. My paper "Detection and Classification of Vehicles", published in the *IEEE Transactions on Intelligent Transportation Systems* in March 2002 is one of the most cited papers in the history of this journal (more than a thousand citations). I also have seven patents in pertinent areas. One should note that the majority of these papers deal with detection of cars, pedestrians, trucks, etc. by using a variety of techniques which

were all based on computer vision. The October 2011 paper deals with structured light systems.

8. Our research work has been funded by several government funding agencies. For example, we have received funding from the Department of Homeland Security to monitor threats at Mass Transit Sites like the 30th Street Station in Philadelphia, PA, and the Light Rail Station in the Minneapolis-Saint Paul International Airport. Monitoring the rail tracks and other associated rail components was an essential task for which we developed a variety of computer vision algorithms and tools.

9. Throughout my career, I also have served as chair, member, editor, and advisor in several divisions and committees of IEEE and am a Fellow of IEEE. For example, I have been involved with the IEEE Robotics and Automation Society (RAS) as an Editor of the RAS Conference Editorial Board from 2006 to 2009, Vice President for Conferences from 2010 to 2013, and Chair of the Publication Ethics Committee since 2015. I was also Chairman of the IEEE Robotics and Automation Technical Committee on Robot Vision from 2000 to 2006. I have also been either Program Chair or General Chair of the IEEE Robotics and Automation Conference numerous years. Since 2003, I have been an editor of the IEEE Transactions on Intelligent Transportation Systems Journal, first as an Associate Editor (since 2003) and then a Senior Editor since 2016. This is one of

top journals in the field and I handled the majority of the papers in computer vision with emphasis on various application domains including railroads.

10. I have received numerous honors and awards for my research and contributions. I have been a Distinguished McKnight University Professor at the University of Minnesota since 2007 and have been a McKnight Presidential Endowed Professor in Computer Science since 2016. Also in 2007, I was nominated and became an IEEE Fellow. In 2016, I received the IEEE RAS George Saridis Leadership Award in Robotics and Automation as well as the Center for Transportation Studies Research Partnership Award. I have also received the IEEE VTS 2001 Best Land Transportation Paper Award for the paper "A Novel Method for Tracking and Counting Pedestrians in Real-Time Using a Single Camera" (with Osama Masoud).

11. Overall, I have used my education, industry, teaching, writing, and membership and service experiences in the computer vision field, and my understanding of the knowledge, creativity, and experience of a person having ordinary skill in the art in forming the opinions expressed in this report, as well as any other materials discussed herein. My extensive experience with machine vision in the transportation industry is applicable to analyzing the '320 patent. For almost 30 years I have been involved in computer vision systems, sensors, and lasers which are directly applicable to analyzing the '320 patent.

B. Compensation

12. I am being compensated for services provided in this matter at my usual and customary rate of \$400.00 per hour plus travel expenses. My compensation is not conditioned on the conclusions I reach as a result of my analysis or on the outcome of this matter, and in no way affects the substance of my statements in this declaration. I have no financial interest in Petitioner, or any of its subsidiaries. I also have no financial interest in Patent Owner, Georgetown Rail Equipment Company. I do not have any financial interest in the '320 patent and have not had any contact with the named inventors of the '320 patent.

IV. Materials Reviewed

13. In forming my opinions, I read and considered the '320 patent and its prosecution history, as well as the other materials and exhibits referenced and discussed herein. I have also used my education, industry, teaching, mentoring, writing, and membership and service experiences in the Electrical and Computer Science and Engineering fields, and my understanding of the knowledge, creativity, and experience of a person having ordinary skill in the art in forming the opinions expressed in this report, as well as any other materials discussed herein. I have been asked to assume that each of prior art references identified in the analysis section of my declaration qualifies as prior art to the challenged claims of the '320 patent.

V. Legal Standards

14. It is my understanding that there are two ways that prior art references can render a patent claim unpatentable: anticipation and obviousness based on 35 U.S.C. §§ 102 and 103, respectively. I have been advised by Petitioner's counsel that the petitioner has the burden in an IPR to show unpatentability by a preponderance of the evidence.

A. Anticipation

15. I have been informed by counsel that for a claim to be anticipated under § 102, every limitation of the claimed invention must be found in a single prior art reference. I have also been informed that there is a set process as follows: a) the claims of a patent are properly construed, b) then, you must compare the claim language to the prior art on a limitation-by-limitation basis. I understand that an anticipatory reference does not have to recite word for word what is in the anticipated claims. Rather, anticipation can occur when a claimed limitation is "inherent" in the relevant reference. I have been advised that if the prior art necessarily functions in accordance with, or includes, the claims limitations, it can anticipate even though the limitation is not expressly recited.

B. Obviousness

16. I further understand that under 35 U.S.C. § 103(a), an invention is obvious when the differences between the subject matter sought to be patented and

the prior art are such that the subject matter as a whole would have been obvious at the time of the invention to a person having ordinary skill in the art. For this reason, I have been asked to consider the level of ordinary skill in the field that someone would have had at the time of the claimed invention. I have also been told and understand that whether a prior art reference renders a patent claim unpatentable as obvious is determined from the perspective of a person of ordinary skill in the art. I also understand that, while there is no requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, a suggestion to combine known elements to achieve the claimed invention may come from the prior art as a whole or individually, as filtered through the knowledge of one skilled in the art. I further understand that the inferences and creative steps a person of ordinary skill in the art would employ are also relevant to the determination of obviousness.

17. Counsel has instructed me that in an obviousness determination the factors to consider are: (1) the scope and content of the prior art, (2) the differences between the prior art and the asserted claims, (3) the level of ordinary skill in the pertinent art, and (4) the existence of secondary considerations of nonobviousness. Secondary considerations include: a long-felt need, commercial success, unexpected results, praise of the invention, licensing, copying, failure of others, and skepticism by experts.

18. Counsel has also instructed me that an obviousness inquiry may involve assessing the motivation of a person of ordinary skill to combine references. The prior art references themselves may provide a suggestion, motivation, or reason to combine, but other sources may also support a rationale for combining two or more prior art references. I have also been told that there is no rigid rule that a reference or combination of references must contain a “teaching, suggestion, or motivation” to combine references. But I also have been told that the “teaching, suggestion, or motivation” test can be a useful guide in establishing a rationale for combining elements of the prior art. I have been told that this test poses the question as to whether there is an express or implied teaching, suggestion, or motivation to combine prior art elements in a way that realizes the claimed invention, and that it seeks to counter impermissible hindsight analysis.

19. It is also my understanding through counsel that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. It is further my understanding that a proper obviousness analysis focuses on what was known or obvious to a person of ordinary skill in the art, not just the patentee. I have also been told that, when a work is available in one field, design alternatives and other market forces can prompt variations of it, either in the same field or in another. I have also been told

that if a person of ordinary skill in the art can implement a predictable variation and would see the benefit of doing so, that variation is likely to be obvious. I have been told that in many fields, there may be little discussion of obvious combinations, and in these fields market demand, not scientific literature, may drive design trends.

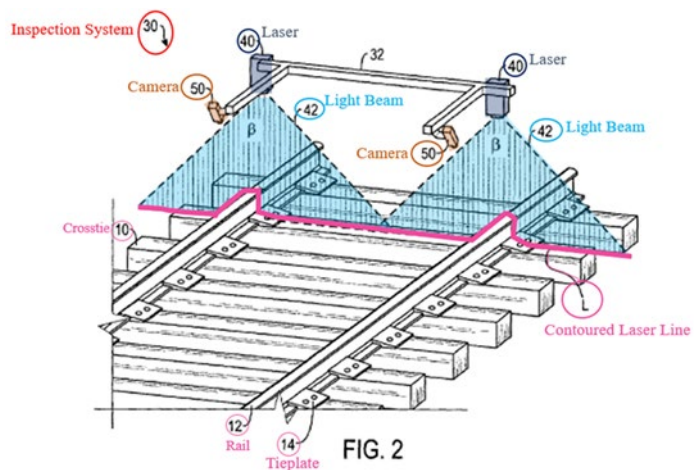
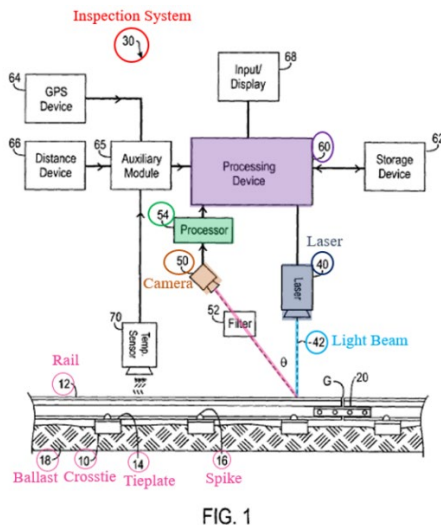
VI. Overview of the '320 Patent

A. Technology of the '320 Patent

20. The '320 patent provides “a system and method for determining rail seat abrasion of a railroad track.” '320 patent, Abstract. Rail seat abrasion (“RSA”) is a term for wear that occurs where the rail seats against the crosstie. *Id.*, 1:52-57, 1:52-54 (“Normal railroad traffic causes friction between ties and rails, as well as rails and spikes, bolts, screws, or clips, and the surface under the ties.”). RSA directly impacts the life of the tie by causing it to loosen from the rail. *Id.*, 1:55-57. The '320 patent describes a machine vision inspection system for determining whether RSA is present along a railroad track. *Id.*, 2:13-18.

21. As shown below in annotated FIGS. 1 and 2, the '320 specification describes an inspection system 30 (red) mounted on a rigid framework 32 attached to a vehicle (not labeled) for movement along a railroad track for inspecting features including, e.g., crossties 10, rails 12, tie plates 14, and spikes 16. *Id.*, 4:1-3, 10-20. The inspection system 30 includes a light generator, such as a laser 40

(navy), for projecting a beam of light 42 (blue). *Id.*, 3:54-55. The light beam 42 produces a projected line L (fuchsia, FIG. 2), which traces the contours of the surface of the railroad track components, along the projected line L. *Id.*, 4:3-5, 5:59-62. The inspection system 30 also includes an optical receiver, such as a camera 50 (orange), for receiving a portion of the light reflected from the contour of the surface of the railroad track components illuminated along the projected line L. *Id.*, 3:54-57, 4:9-14, 11:55-59.

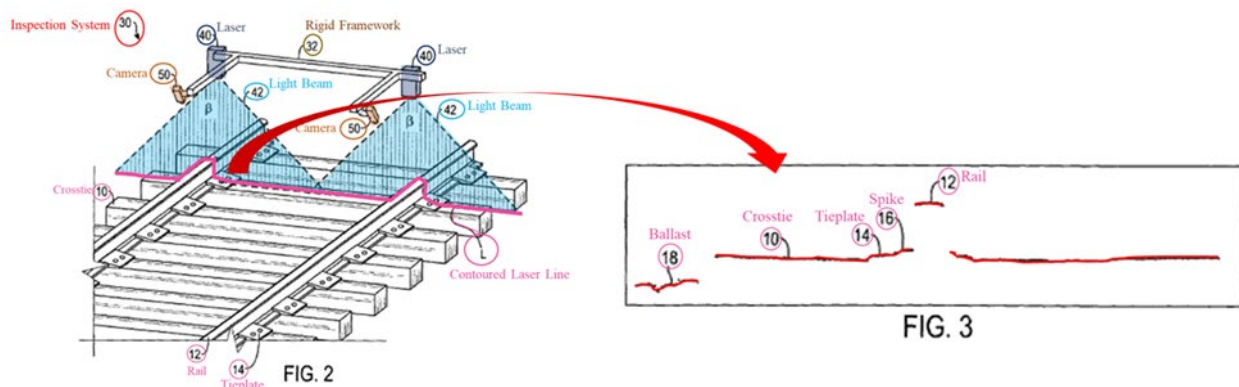


'320 patent, FIGS. 1, 2 (annotated).

22. The optical receiver includes a processor 54 (green) to convert (or format) the light reflected from the contour of the surface of the railroad track components illuminated along the projected line L into contour images representative of the profile of the scanned portion of the railroad track, which may then be sent to a processing device 60 (purple). *Id.*, 5:4-19, 63-66, 11:55-59.

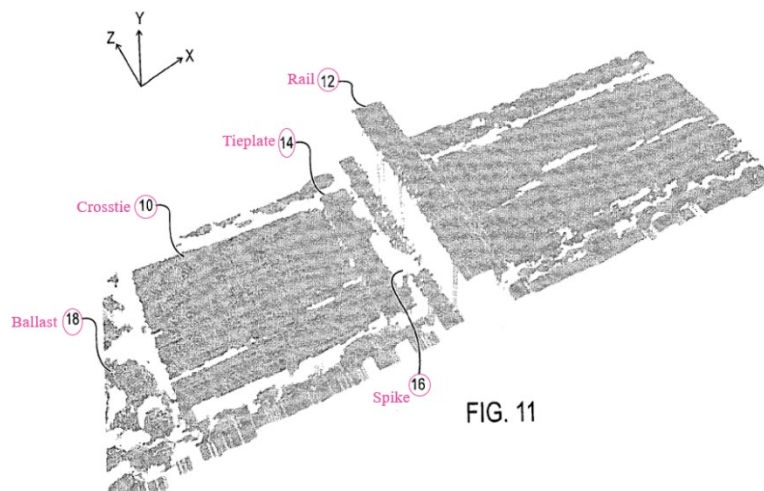
Processing device 60 “can have any suitable image processing software, such as Matrox MIL, Common VisionBlox, Labview, eVision, Halcon, and IVP Ranger.” *Id.*, 5:36-38. Similarly, processing device 60 can have “image processing tools known in the art for analyzing image data from the cameras 50 such as Region of Interest (ROI) tools, filtering tools, blob tools, edge finders, histogram tools, and others.” *Id.*, 5:39-42.

23. FIG. 3, annotated below (right), depicts an exemplary image showing the contour of the projected L of the railroad track received by the optical receiver. *Id.*, 5:62-63. The image (red) includes a collection or data structure of pixels, showing the height contour of the surface of the components along the projected L (fuchsia) of the railroad track (shown below (left) in annotated FIG. 2), captured by the optical receiver, including the ballast 18, crosstie 10, tie plate 14, spike 16, and rail 12. *Id.*, 5:59-66.



'320 patent, FIGS. 2, 3 (annotated).

24. As shown below in annotated FIG. 11, the '320 patent further describes that each range image is compiled together to form a 3D representation of the scanned railroad track with its 3D (X, Y, and Z coordinate) structure. *Id.*, 8:1-9; 3:18-19.



'320 patent, FIG. 11 (annotated).

25. After the system 30 performs a survey of the railroad track, the processing device 60 “or another computer system having image processing software known in the art” performs computer analysis of the obtained image data to detect the presence and location of track defects. *Id.*, 7:39-43. As one example, processing device 60 detects whether rail seat abrasion (“RSA”) is present along the railroad track. *Id.*, 12:49-51.

26. In one RSA measurement embodiment, as shown below in annotated FIG. 17, the '320 patent describes determining and comparing top surface rail base

heights of left (purple) and right (blue) rails 12 with respective crosstie 10 (fuchsia) top surface heights. *Id.*, 13:18-24. In this embodiment, the system first determines: (1) the top surface height (purple dashed line) of the left rail base H^{LRAIL} (purple), (2) the top surface height (blue dashed lined) of the right rail base, H^{RRAIL} (blue), (3) the crosstie top surface height (fuchsia dashed line), H^{LTIE} (fuchsia), adjacent the left rail base, and (4) the crosstie top surface height (fuchsia dashed line), H^{RTIE} (fuchsia), adjacent the right rail base. *Id.* The system then compares the left and right rail base heights to the respective crosstie heights (i.e., H^{LRAIL} to H^{LTIE} (purple arrow) and H^{RRAIL} to H^{RTIE} (blue arrow), respectively). *See id.* The '320 patent appreciates that there are a “variety of methods to determine the heights [of each rail base and tie].” *Id.*, 13:38-41.

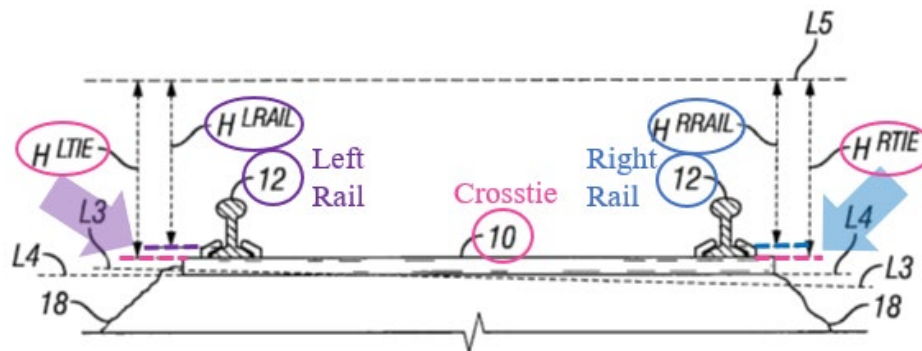


FIG. 17

'320 patent, FIG. 17 (annotated).

27. The '320 patent further explains that as the inspection system 30 moves along the track, it may encounter curves or bends in the track resulting in a

suspension lean of the system 30, which may alter the camera's 50 view of the railroad track. *Id.*, 12:54-13:5; *see also id.*, 13:13-17 (explaining that “tilt [may be] caused by variations in vehicle suspension, rail height placement standards, and other factors.”). In one example, shown below in annotated FIG. 17, the '320 patent explains that an angular tilt L4 (green dashed line) of crosstie 10 (fuchsia) associated with a curved portion of the track may tilt “slightly to the left” relative to normal (red dashed line) in which the “height of the right rail 12 [blue] would appear taller than left rail 12 [purple].” *Id.* at 13:1-10. The system 30 adjusts the imaged position data to compensate for the lean of the inspection system 30, as the system 30 moves along the tilted, curved portion of the track. *Id.*, 13:13-17.

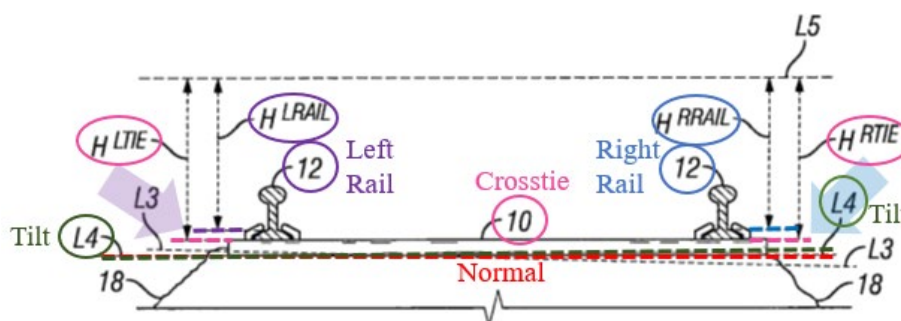


FIG. 17

'320 patent, FIG. 17 (annotated).

B. Analyzed Claims of the '320 Patent

28. For the purposes of this declaration, I was asked to analyze claims 1-17 of the '320 patent.

VII. Level of Ordinary Skill in the Art

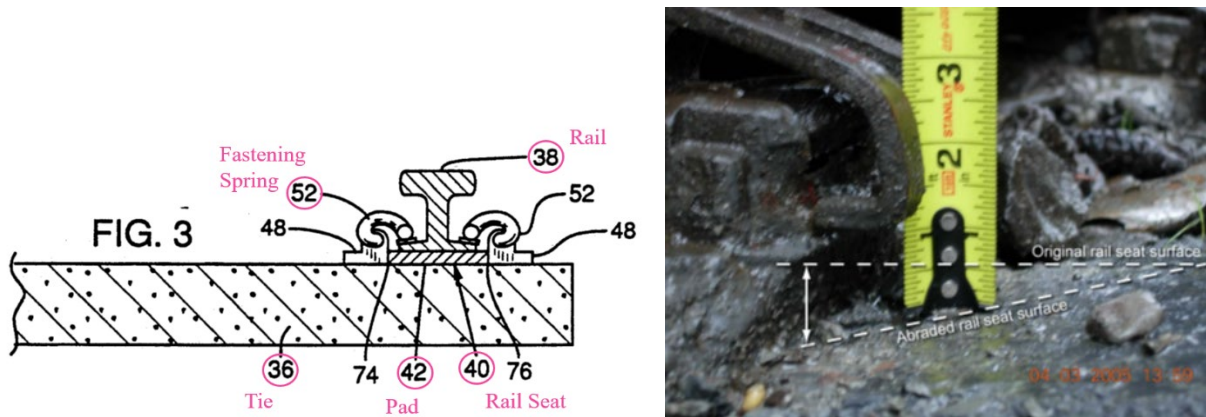
29. I understand a person of ordinary skill in the art (“POSITA”) is determined by looking at (A) type of problems encountered in the art, (B) prior art solutions to those problems, (C) rapidity with which innovations are made, (D) sophistication of the technology, and (E) educational level of active workers in the field. Based on my experience in this art and accounting for these factors, I believe a person of ordinary skill in the art would have had as of June 23, 2009 (which I understand is the earliest potential effective filing date of the ’320 patent), a bachelor’s degree in electrical engineering, computer engineering, mechanical engineering, computer science, physics, or a related field, and at least four years of experience (or the academic equivalent) in the field of computer or machine vision. An academic equivalent example may include a master’s degree in electrical engineering, computer engineering, computer science, physics (or a closely related field) and at least two years of experience (or the academic equivalent) in the field of computer or machine vision. Another academic equivalent example in this case may include a Ph.D. in electrical engineering, mechanical engineering, computer engineering, computer science, physics (or a closely related field) and at least a year of experience in the field of computer or machine vision. I was at least a person of ordinary skill in the art as of June 23, 2009.

VIII. Claim Construction

30. I have been told by counsel that a claim in a patent subject to *inter partes* review should be given their ordinary and customary meaning to a person of ordinary skill in the art at the time of the invention. Unless otherwise noted, my opinions in this declaration are consistent with plain and ordinary meaning of the claims to a person of ordinary skill in the art at the effective filing date.

IX. History of Rail Seat Abrasion Prior to 2009

31. Well before 2009, the railroad industry recognized rail seat abrasion (“RSA”) as a problem requiring constant monitoring. Ex-1012, 2; Ex-1013, 2-4; Ex-1015, 1. As shown below (left) in annotated FIG. 3, RSA occurs when concrete of the crosstie (or tie) beneath the rail, at the rail seat (e.g., element 40), degrades or deteriorates at an accelerated rate compared to the rest of the tie. Ex-1012, 2-3; Ex-1013, 4; Ex-1015, 1; Ex-1014, FIG. 3. Even with use of a polymer pad 42 placed between the concrete tie and the rail as a buffer, repeated train loading on the rail may create hydraulic pressures inside the air voids of the cement paste, resulting in an explosion of the cement paste at the rail seat. Ex-1014, 1:36-41, FIG. 3; Ex-1012, 2. FIG. 4(b) below (right) illustrates concrete crosstie abrasion of about ½ inch. Ex-1012, 7.



Ex-1014, FIG. 3 (annotated); Ex-1012, FIG. 4(b).

32. Factors contributing to RSA may include, e.g., moisture absorbed in the concrete, repeated freezing and thawing, high wheel loading/tonnage, presence of gritting agents, steep track grades, and track curves greater than two degrees. Ex-1012, 3-8; Ex-1014, 2:2-23; Ex-1015, 2; Ex-1018, 8. When RSA is untreated, it leads to instability and derailments. Ex-1012, 2, 4.

33. Early methods for identifying RSA required removing the rail and tie pad entirely to view the abrasion under the rail. Ex-1015, 2. Other methods included visual inspection and direct manual measurement using a measuring frame or a gage fitted between the abraded tie and the rail base. Ex-1015, 2-3; Ex-1014, 2:37-52. Later methods involved using automated track inspection vehicles to collect and measure track geometry, ride quality, and other track-related data measure parameters that identified critical RSA locations. Ex-1015, 2-4; Ex-1041,

4-6; Ex-1007, 11 (“Data collected on geometry cars is considered as an alternative method for identifying critical locations [of RSA].”); Ex-1019, 2-3, 18.

34. Following two high profile derailments in 2005 and 2006, the Federal Railroad Administration (“FRA”) made identifying RSA a priority. Ex-1019, 18; Ex-1018, 1, 12. In 2006, the FRA’s Railroad Safety Advisory Committee (“RSAC”) tasked a working group focused on track safety standards to develop abrasion limits, among other standards. Ex-1020, 81-83. On October 27, 2007, the working group formed the Concrete Crosstie Task Force (“CCTF”) subcommittee tasked with, among other things: “(5) develop[ing] specifications for ... establish[ing] wear limits for rail seat deterioration and rail fastener integrity; and (6) develop[ing] manual and automated methods to detect rail seat failure on concrete ties.” Ex-1020, 83.

35. Based on its findings, on December 10, 2008, the CCTF set forth (and the RSAC approved) a “concrete tie rule” announcing to the railroad industry that automated RSA identification was a priority and a standard the industries would soon have to meet. Ex-1021, 19; Ex-1020, 83; Ex-1016, 1-2; Ex-1040; Ex-1041, 2-6. Section §213.109(e)(4) of the rule stated that, to count towards the minimum number of crossties required per segment of track, the concrete cross tie could not have “[d]eteriorated or abraded at any point under the rail seat to a depth of ½ inch or more.” Ex-1041, 2-3. And section §213.234 (entitled “Automated Inspection of

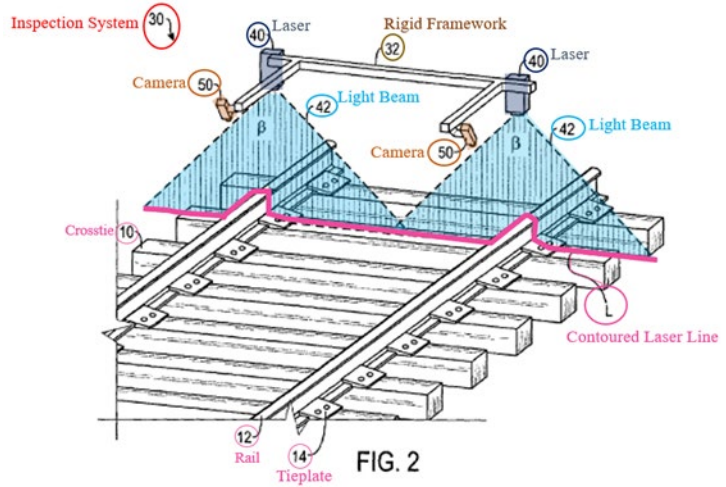
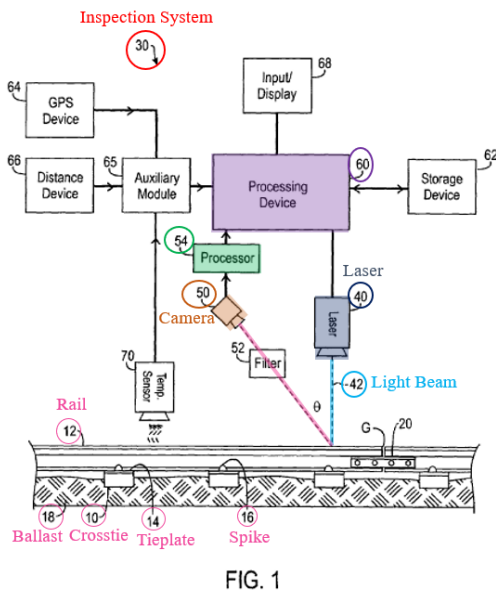
Track Constructed with Concrete Crossties”) required that an “automated inspection measurement system of concrete crossties must be capable of determining exceptions to §213.109(e)(4).” Ex-1041, 4-5. Taken collectively, the concrete tie rule thus required use of automated inspection measurement systems for determining the presence of a half inch or more of RSA along a railroad track. Ex-1016, 4-6.

X. Analysis

A. Obviousness of Claims 1-2, 5-7, 10-14, and 16-17 over *Villar*, *Choros*, *Casagrande*, and *Szwilski*

1. *Villar*’s automated machine vision railroad inspection system.

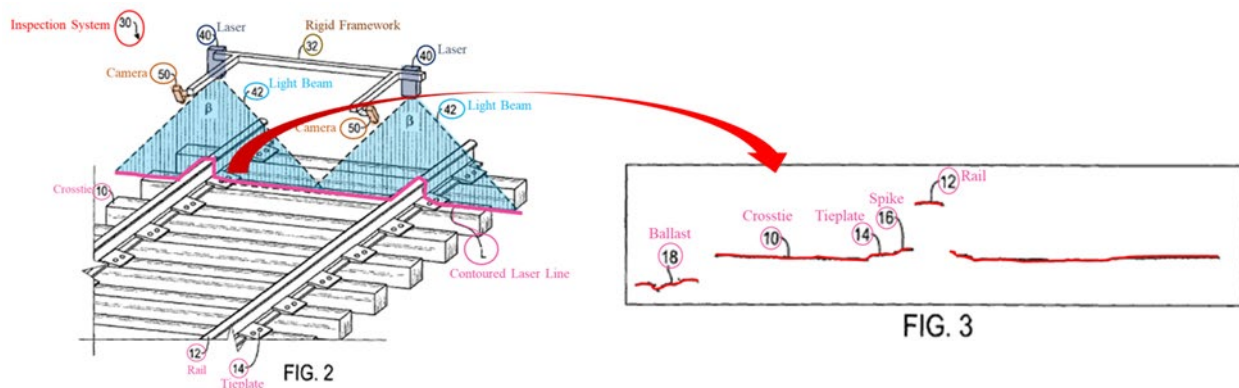
36. As shown below in annotated FIGS. 1 and 2, *Villar* discloses an inspection system 30 (red) for inspecting railroad track features including, e.g., rails 12 and the crossties 10 (fuchsia) to detect, e.g., misaligned tie plates, sunken tie plates, rail wear, gage of rail, and the angle of ties with respect to the rail. *Villar*, ¶¶[0008], [0023], [0047], [0050], [0052], claims 1, 15, 23. *Villar*’s inspection system 30 includes a light generator, such as a laser 40 (navy), a “device for receiving light reflected from the area to be inspected,” such as a camera 50 (orange), and a processing device 60 (purple, FIG. 1). *Id.*, ¶¶[0024]-[0025], [0028]-[0029], [0033], claims 1, 15.



Villar, FIGS. 1, 2 (annotated).

37. The laser 40 projects a beam 42 of laser light (**blue**) at the track bed, which produces a projected line L (**fuchsia**) that follows the contours of the surfaces and track bed components. *See id.* The cameras 50 receive a portion of the light reflected from the contour of the surface of the railroad track components illuminated along the projected line L. *Id.*, ¶¶[0024]-[0025], [0027], [0031]-[0032], and [0035]. FIG. 3, annotated below (right), depicts an exemplary range image showing the contour of the projected L of the railroad track received by the cameras 50. *Id.*, ¶[0035]. The range image (**red**) includes a collection or data structure of pixels, showing the height contour of the surface of the components along the projected L (**fuchsia**) of the railroad track (shown below (left) in

annotated FIG. 2), captured by the cameras 50, including the crosstie 10 and rail 12. *Id.*, ¶¶[0024]-[0025], [0027], [0031]-[0032], and [0035].



Villar, FIGS. 2, 3 (annotated).

38. *Villar* explains that processing device 60 operates with any suitable image processing software for storing and analyzing various image data obtained with the inspection system 30 “to determine various measurable aspects of the railroad track” and determine railroad track component defects. *See, e.g., id.*, Abstract, ¶[0047] (determining crosstie/rail angle by line-fitting and comparing rail head and crosstie angular orientations); *id.*, ¶[0052] (determining rail spacing or gage from track bed image data); and *id.*, ¶[0055] (detecting misaligned tie plates from track bed image data by line-fitting and comparing tie plate and crosstie contour orientations), FIGS. 5, 7-8.

2. *Choros*’ RSA measurement device and method.

39. *Choros* examines the history and causes of rail seat abrasion (“RSA”), as well as methods for measuring and controlling RSA. *Choros*, 7-14. As one RSA

measurement method, shown below in FIG. 7 and annotated FIG. 8, *Choros* discloses using a measurement gauge (FIG. 7, left) to determine RSA by measuring a vertical distance between a top surface of rail base and a top surface of the crosstie adjacent the rail (FIG. 8, red arrow). *Id.*, 7-9, 11. It should be noted that I reference color versions of FIGS. 7 and 8 from an online version of *Choros* (Ex-1042) below, but that is all that I referenced from Ex-1042.



Figure 7. A Typical rail abrasion measurement device

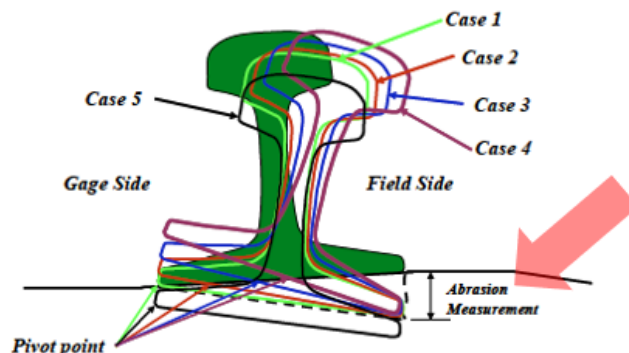


Figure 8. Five possible cases of concrete tie abrasion.

Choros, FIGS. 7 and 8 (annotated).

40. *Choros* also discloses using geometry cars to collect pertinent data for identifying critical locations that have excessive rail seat abrasion and present a safety issue. *Id.*, 11 (“Data collected on geometry cars is considered as an alternative method for identifying critical locations [of RSA].”), 13 (recognizing the impact of improved measurement methodologies from either automated inspection vehicles or hand-held measurement devices).

3. Obviousness of combining the disclosures of *Villar* and *Choros* to make and use an automated railroad track inspection vision system to determine whether RSA is present along a railroad track.

a. One of ordinary skill in the art would have been motivated to make the combination

41. In my opinion, it would have been obvious to one of ordinary skill at the relevant time to combine the disclosures of *Villar* and *Choros* to make and use an automated railroad track inspection vision system including: (1) a light generator, such as a laser, for projecting a beam of light across railroad track components, including rails and ties; (2) a receiver, such as a sensor or camera, for receiving a portion of the light reflected from the railroad track and generating at least one image representative of a profile of at least a portion of the railroad track; and (3) an image processor for analyzing the at least one image to determine whether rail seat abrasion is present along the railroad track by measuring a vertical distance between rail base and crosstie top surface heights.

42. In my opinion, one of ordinary skill in the art at the relevant time would have been motivated to implement *Villar*'s automated railroad track inspection vision system with *Choros*'s method of measuring RSA (i.e., measuring a vertical distance between rail base and crosstie top surface heights), to yield an "automated" RSA detection and measurement system. The automated system would provide important, reliable, and objective performance measures of crosstie

health, for addressing and correcting (or renewing) crossties. Indeed, automating manual inspection tasks has been the target of extensive research efforts and sensing methodologies for railroad inspection (as well as many other domains including manufacturing, safety, agriculture, services, healthcare, and other transportation areas) well before the '320 patent to “achieve a high inspection rate and high reliability in inspection. Ex-1026, 545-546, *see also id.*, 73, 107, 248-250, 361, 406; Ex-1027; Ex-1028, 5; Ex-1025, 15; Ex-1029, 18; Ex-1030, 9; 1031, 2; Ex-1032, 1:13-29; Ex-1033, 6; Ex-1034, 3. Automation through use of a machine vision system would obviate time, accuracy, and safety issues associated with a human inspector’s RSA inspection and measurement. Ex-1026, 545-546; Ex-1035, 4. Unlike humans, automated machine vision inspection systems do not get tired or bored, which may lead to inaccurate RSA measurements. Nor do automated inspection systems make subjective decisions. Ex-1035, 4. The modification would thus allow for more frequent measurement of critical track parameters while avoiding the issues associated with manual inspection.

43. Additionally, many automated railroad applications have arisen in response to government railroad industry regulations requiring certain automated metrics, tolerances, and other specifications based on safety concerns, and consistency of the measurements and processes associated with manual railroad inspections. The RSA application is no different, in my opinion. Indeed, as

discussed above, following two high profile derailments in 2005 and 2006, the Federal Railroad Administration (“FRA”) made automated RSA identification a priority and a standard for railroad industries in 2008 by approving a “concrete tie rule” requiring use of automated inspection measurement systems for determining whether RSA is present along a railroad track. Ex-1016, 1-2; Ex-1040; Ex-1041, 2-6; Ex-1021, 19; Ex-1020, 81. Thus, incorporating an RSA measurement algorithm, like *Choros*’, into *Villar*’s automated railroad track inspection vision system is further to and consistent with rules promulgated to the railroad industry by the Federal Government at the relevant time.

44. In addition, automation would also yield more meaningful and accurate top height contour and other geometric information about the measured rail and tie components. It was well-known before 2009 to use vehicle-mounted automated machine vision systems to quickly identify, inspect, assess, and evaluate the condition and alignment of railroad track components, including rails and ties. Ex-1005, Ex-1036; Ex-1037; Ex-1038. It was also well-known before 2009 to use 3D range vision systems, smart vision sensors, and associated image processing tools to generate and analyze images of inspected objects to ascertain and extract more accurate determinations of an object’s geometric properties, including the height of the object, for identifying defective components. Ex-1023; Ex-1026, 545-546; Ex-1032. Because of 3D vision range technology advances, using such

systems to identify and assess the condition of defective components had become the standard, not the exception, before 2009. Ex-1028, 5; Ex-1025, 15; Ex-1039, 18; Ex-1019, 6 (recognizing that “[m]ost of the advancements in [automated track inspection program or ATIP] technology come from the application of technologies that have been developed and refined by other industries.

Advancements in sensors, instrumentation, computers, data communications and data management currently come at a rapid pace. ATIP is continually evaluating these new and emerging technologies to assess their potential benefits for track inspection.”); Ex-1031; Ex-1024.

45. Thus, in my opinion, automating *Choros*’ method of measuring RSA through the use of *Villar*’s 3D vision technology railroad track inspection system would facilitate extraction of more meaningful and accurate geometric information of scanned railroad track components, and thus, fewer errors. Further, *Choros* describes using geometry cars to collect pertinent data for identifying critical locations that have excessive rail seat abrasion and present a safety issue. *Choros*, 11. *See also id.*, 13 (recognizing the impact of improved measurement methodologies from either automated inspection vehicles or hand-held measurement devices). And, that is exactly what the combination of *Villar* and *Choros* would help achieve, but in a much faster, objective, consistent, accurate, and safer way. Based on mathematical manipulation of these numerical values, in

my opinion, one of ordinary skill in the art could make an assessment about the type and the degree of damage to the assessed railroad track component; automating this process by using a machine vision system is an obvious step. Machine vision object detection, recognition, and measurement could supply all these numerical values accurately and in a consistent fashion.

46. Also, *Villar* expressly recognizes and appreciates the well-known utility of using its inspection system to measure various aspects of the railroad track for determining railroad track component defects including, e.g., detecting misaligned tie plates, sunken tie plates, rail wear, gage of rail, and the angle of ties with respect to the rail. *Villar*, ¶¶[0008], [0023], [0047], [0050], [0052], claims 1, 15, 23. Importantly, *Villar* does not limit the system to the measurable aspects disclosed. Rather, *Villar* fully appreciates that “other measurable aspects of the railroad track can be determined or detected from the image data of the track bed.” *Villar*, ¶[0043] (emphasis added).

47. Accordingly, in my opinion, implementing *Villar* with *Choros*’ method of measuring RSA (i.e., measuring a vertical distance between rail base and crosstie top surface heights) would simply provide another track component defect for *Villar*’s vision system to automatically identify and correct in furtherance of increasing railroad safety.

b. One of ordinary skill in the art could have easily made the combination

48. In my opinion, one of ordinary skill in the art at the relevant time could have easily implemented *Villar*'s automated railroad track inspection vision system to measure RSA, as taught by *Choros*'—i.e., measuring a vertical distance between rail base and crosstie top surface heights—and doing so would have yielded nothing more than predictable results.

49. *Villar* and *Choros* each describe a railroad track inspection device and method for identifying alignment defects of railroad track components (including rails and ties) by determining and comparing track top height surface contours and orientations of railroad track components. *Villar* appreciates the need to identify and assess a variety of railway track components, including ties and rails for defects and servicing by generating and comparing relevant contour orientations through various line-fitting comparison algorithms. *See, e.g., Villar*, ¶[0047] (determining crosstie/rail angle by line-fitting and comparing rail head and crosstie angular orientations); *id.*, ¶[0052] (determining rail spacing or gage from track bed image data); and *id.*, ¶[0055] (detecting misaligned tie plates from track bed image data by line-fitting and comparing tie plate and crosstie contour orientations), FIGS. 5, 7-8. *See also id.*, ¶[0043] (*Villar* further noting that “other measurable aspects of the railroad track can be determined or detected from the image data of

the track bed.”). Further, *Choros* itself acknowledges the existence of both manual and automatic inspection methods by disclosing that data collected on geometry cars is considered as an alternative method for identifying critical locations of RSA. *Choros* 11, 13.

50. As further explained below, it also would have been obvious to one of ordinary skill in the art at the relevant time to have implemented *Villar* and *Choros*’ railroad track inspection vision system with other well-known vision system compensation features, evidenced by, e.g., *Casagrande* and *Szwilski* to compensate for a tilt of the railroad track when determining whether rail seat abrasion is present along the railroad track.

51. As detailed below, in my opinion, *Villar* in combination with *Choros*, *Casagrande*, and *Szwilski* render obvious claims 1-2, 5-7, 10-13, and 16-17.

4. Claim 1

Claim 1[preamble]: “A system for determining rail seat abrasion of a railroad track, the system comprising:”

52. As shown below in annotated FIGS. 1-2, *Villar* discloses an inspection system 30 (red) for inspecting a railroad track that measures the height contour of railroad track components, including, e.g., crossties 10 and rails 12 (fuchsia). *Villar*, ¶[0023], claims 1, 15, 23.

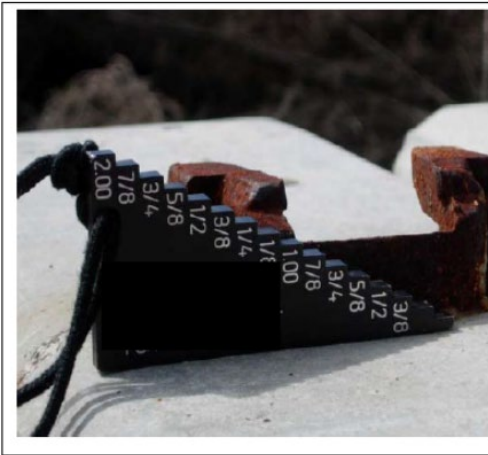


Figure 7. A Typical rail abrasion measurement device

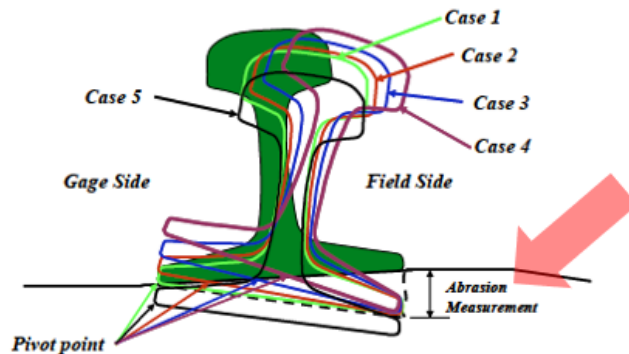


Figure 8. Five possible cases of concrete tie abrasion.

Choros, FIGS. 7 and 8 (annotated).

54. As discussed above, in my opinion, it would have been obvious to one of ordinary skill in the art to implement *Villar*'s automated railroad track inspection vision system with *Choros*'s method of measuring RSA (i.e., measuring a vertical distance between rail base and crosstie top surface heights) to automatically determine whether RSA is present along a railroad track. Accordingly, to the extent the preamble is limiting, *Villar* and *Choros* render it obvious, in my opinion.

Claim 1[a]: “at least one light generator positioned adjacent the railroad track, the light generator adapted to project a beam of light across the railroad track;”

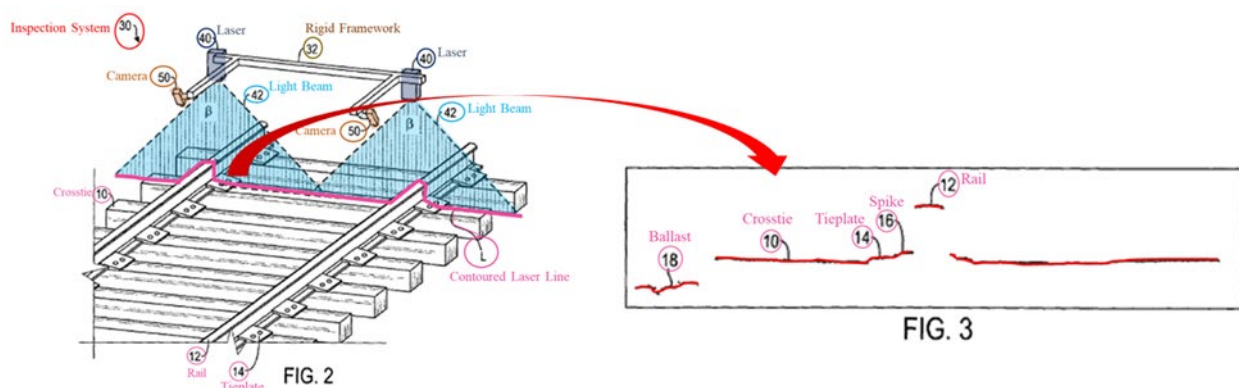
55. As shown above in annotated FIGS. 1-2, *Villar*'s inspection system 30 includes a light generator, such as a laser 40 (navy) (the claimed “at least one light

generator”) positioned adjacent the railroad track. *Villar*, ¶¶[0023], [0025], [0028], claims 1, 15. The laser 40 projects a beam 42 of laser light (blue) at the track bed, which produces a projected line L (fuchsia) (the claimed “beam of light”) that follows the contours of the surfaces and track bed components. *See id.*

56. *Villar* thus discloses these limitations of claim 1, in my opinion.

Claim 1[b]: “at least one camera positioned adjacent the railroad track for receiving at least a portion of the light reflected from the railroad track and for generating at least one image representative of a profile of at least a portion of the railroad track; and”

57. As shown below (left) in annotated FIGS. 2-3, *Villar*’s inspection system 30 includes a “device for receiving light reflected from the area to be inspected,” such as a camera 50 (orange) (the claimed “at least one camera”) positioned adjacent the railroad track. *Villar*, ¶¶[0024], [0047], [0050], [0052], claim 1.



Villar, FIGS. 2, 3 (annotated).

58. Cameras 50 receive a portion of the light reflected from the contour of the surface of the railroad track components illuminated along the projected line L (fuchsia, FIG. 2) projected on the track bed and include a processor 54 for generating an image (red, FIG. 3) representative of the profile of the scanned portion of the railroad track (the claimed “generating at least one image representative of a profile of at least a portion of the railroad track”). *Id.*, ¶¶[0024], [0028], [0030], [0032] (“Preferably, the camera 50 includes a processor 54 capable of converting or formatting the captured image of the projected line L into a dimensional profile.”), ¶[0035] (“The image data or frame includes a plurality of pixels given X-Y coordinates and shows a contour of the track bed captured by the cameras 50.”).

59. *Villar* thus discloses these limitations of claim 1, in my opinion.

Claim 1[c]: “at least one processor adapted to perform the steps comprising:”

60. As shown below in annotated FIG. 1, *Villar*’s inspection system 30 includes a processing device 60 (purple) which includes a microprocessor, inputs, outputs, and a data storage device 62. *Villar*, ¶¶[0024], [0033]. Processing device 60 operates with any suitable image processing software for storing and analyzing various image data obtained with the inspection system 30. *Id.*, ¶¶[0033]-[0034], [0046], [0049]. *Villar*’s system uses the processing device 60 to analyze image

data and perform steps determining the defects in the components of the railroad track. *Id.*, ¶[0008] (“[t]he processor formats the images so that they can be analyzed to determine various measurable aspects of the railroad track.”), *see also id.*, ¶¶[0033]-[0034], [0046], [0049].

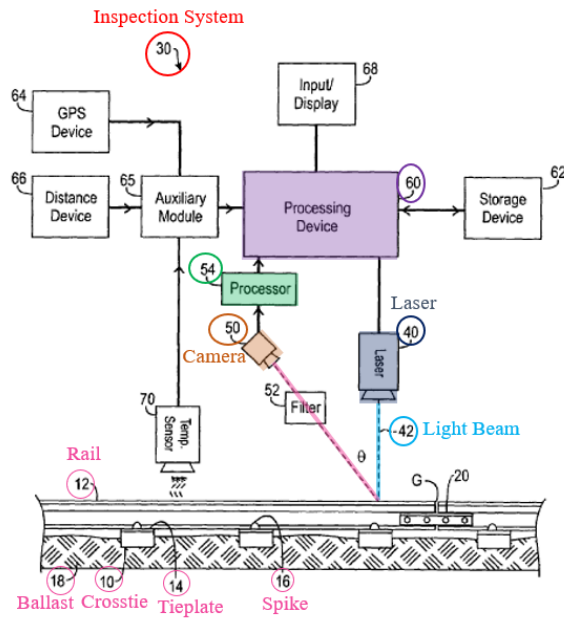


FIG. 1

Villar, FIG. 1 (annotated).

61. *Villar* thus discloses this limitation of claim 1, in my opinion.

Claim 1[d]: “analyzing the at least one image; and”

62. *Villar* explains that processing device 60 operates with any suitable image processing software for storing and analyzing various image data obtained with the inspection system 30 and performing steps determining the defects in the components of the railroad track. *Villar*, ¶[0008] (“[t]he processor formats the

images so that they can be analyzed to determine various measurable aspects of the railroad track.”) *see also id.*, ¶¶[0033]-[0034], [0046], [0049].

63. *Villar* thus discloses this limitation of claim 1, in my opinion.

Claim 1[e]: determining whether rail seat abrasion is present along the railroad track,”

64. As shown below (left) in FIG. 7, *Choros* discloses an RSA measurement gauge device that fits between an abraded tie and the rail base to measure rail seat abrasion. *Choros*, 11. As shown in annotated FIG. 8, the RSA device determines the “Abrasion Measurement” (red arrow) by determining the depth or vertical distance between a top surface height of the rail base and a top surface height of the crosstie. *Choros*, 11-12. Alternatively, *Choros* discloses using geometry cars to collect pertinent data for identifying critical locations that have excessive rail seat abrasion and present a safety issue. *Id.*, 11, 13.



Figure 7. A Typical rail abrasion measurement device

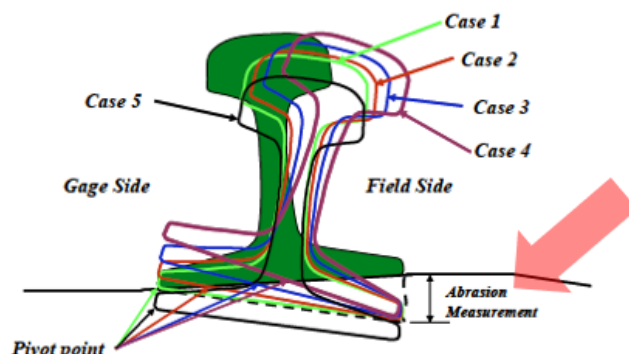
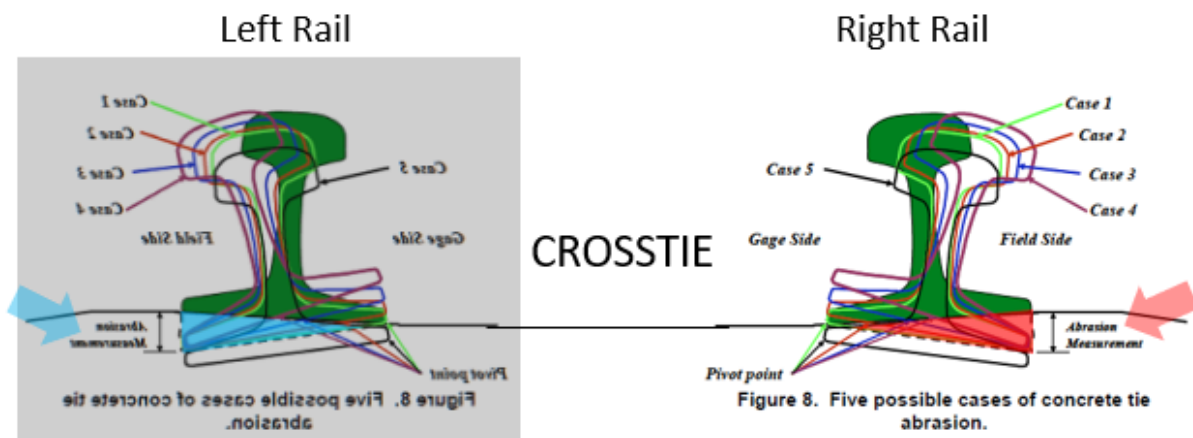


Figure 8. Five possible cases of concrete tie abrasion.

Choros, FIGS. 7 and 8 (annotated).

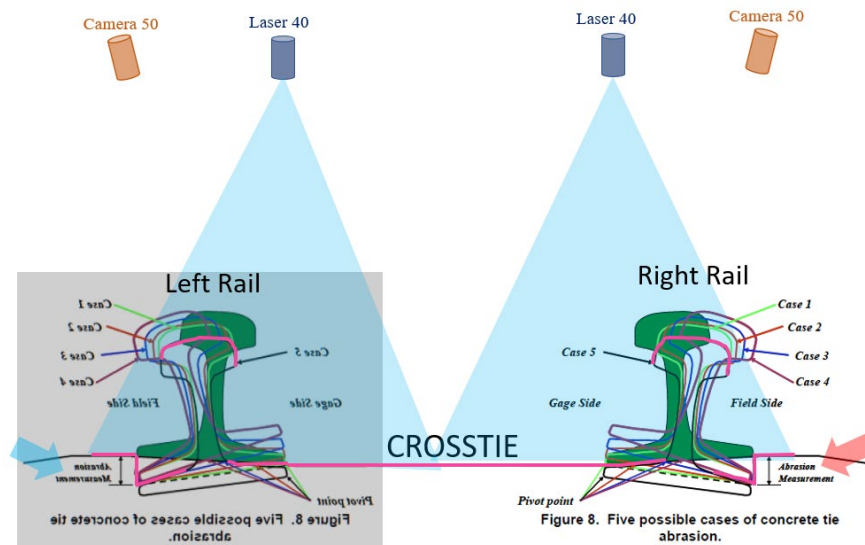
65. It was well known at the relevant time that each railroad track crosstie supports left and right parallel rails, thus forming left and right rail/tie seats. Accordingly, consistent with *Choros*' explanation that "[t]wo [abrasion] measurements should be taken one on each side of the tie," (*Choros*, 12), in my opinion, one of ordinary skill in the art would have understood that *Choros* discloses measuring RSA at each of the left rail/tie (blue) and right rail/tie (red) seats, as shown in the below exemplary annotation of *Choros*' FIG. 8.



Choros, FIG. 8 (annotated).

66. As discussed above, it would have been obvious to one of ordinary skill in the art to implement *Villar*'s automated railroad track inspection vision system with *Choros*'s method of measuring RSA (i.e., measuring a vertical distance between rail base and crosstie top surface heights) to automatically

determine whether RSA is present along a railroad track. As shown below in the exemplary annotation of *Choros*' FIG. 8, one of ordinary skill in the art would have implemented *Villar*'s vision inspection system 30 to move along the railroad track, the lasers 40 (navy) projecting beams of light at the track bed and producing a projected line (fuchsia) following the top surface contours of the left rail/tie and right rail/tie seats, pursuant to *Choros*' method of measuring RSA requiring measurement of the vertical distance between rail base and crosstie top surface heights.

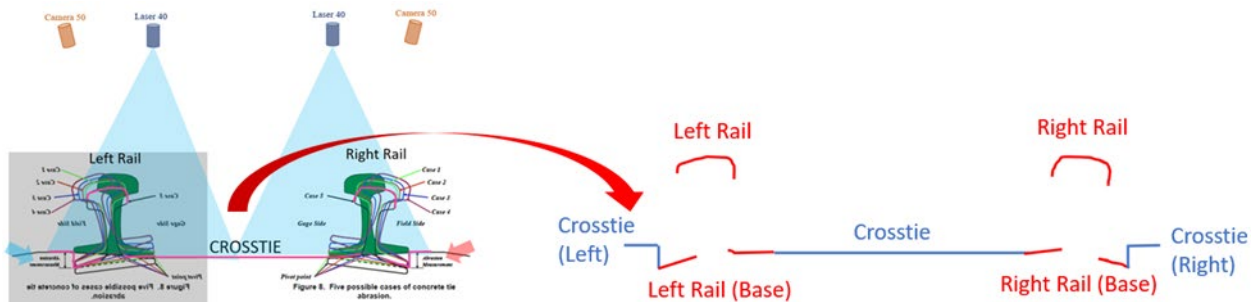


Choros, FIG. 8 (annotated).

67. And one of ordinary skill in the art would have implemented the cameras 50 (orange) of *Villar*'s system 30 to receive a portion of the light reflected from the contour of the surface of the railroad track components illuminated along the projected line L on the track bed and generate at least one image representative

of the profile of the scanned portion of the railroad track (i.e., the top surface contours of the left rail/tie and right rail/tie seats). *Villar*, ¶¶[0024], [0028], [0031], [0032], [0035].

68. Annotated FIG. 8 below illustrates an exemplary image of the crosstie and rails (blue and red, respectively, below right) obtained by *Villar*'s system 30 extending along the projected line (fuchsia, below left). The image depicts pixels forming a representation of a height contour of the surface of the rail and crosstie components, along the projected line L.



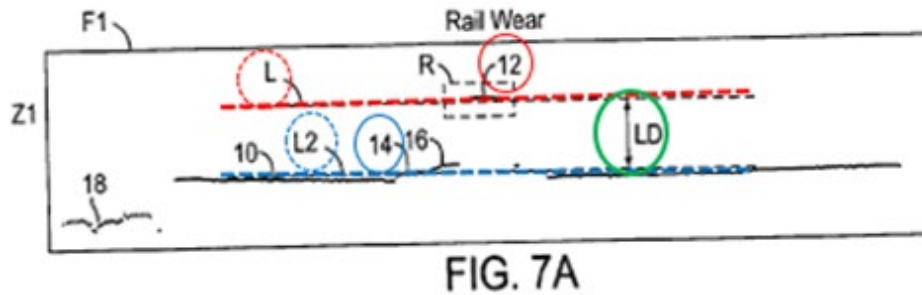
Choros, FIG. 8 (annotated).

69. Next, similar to how an inspector in *Choros* would manually measure RSA—i.e., by measuring the vertical distance between rail base and crosstie top surface heights—in my opinion, one of ordinary skill in the art would have implemented *Villar*'s processing device 60 to analyze whether RSA is present along the imaged portion of the railroad track by determining, in the generated contour image, the vertical distance between the imaged rail base and crosstie top surface heights. And one of ordinary skill in the art, in my opinion, would have

implemented *Villar*'s processing device 60 to do so via well-known machine vision contour line-fitting and orientation comparison algorithms, as taught by *Villar* itself.

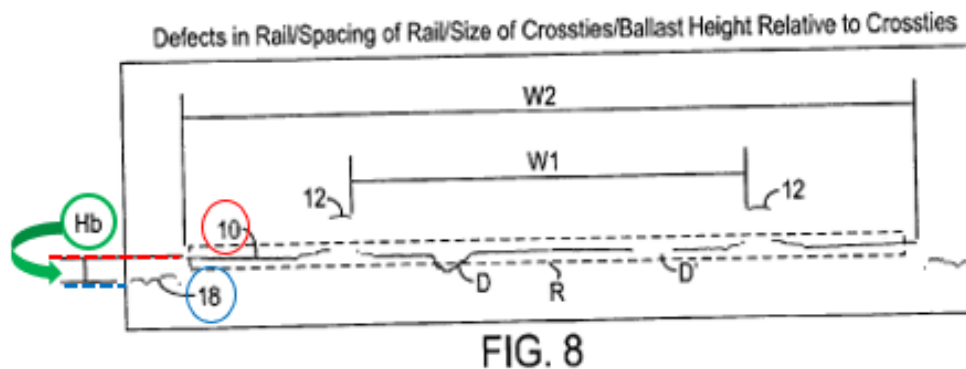
70. Evaluating and comparing contour features of an image to determine potential defects through various image processing tools, including, e.g., contour line-fitting and orientation comparison algorithms, moments, best-fit ellipses, and skeletons was well-known and within the skill of one of ordinary skill in the art at the relevant time, as evidenced by *Villar* and many others. *Villar*, ¶¶[0047], [0052], [0055], [0043]; Ex-1026, 553-557; Ex-1034, 5-8; Ex-1029, 132-134, 80-81; Ex-1026, 149-152, 227-229.

71. *Villar* appreciates the need to identify and assess a variety of railway track components for defects by generating and comparing relevant contour orientations through various rail and tie contour line-fitting and orientation comparison algorithms. In one embodiment, for example, shown below in annotated FIG. 7A, *Villar* discloses determining the distance in pixels, LD (green), between a contour of a rail 12 (red) at a level L (red dashed line) to a reference level L2 (blue dashed line) of, e.g., a tie plate 14 (blue). *Villar*, ¶[0050].



Villar, FIG. 7A (annotated).

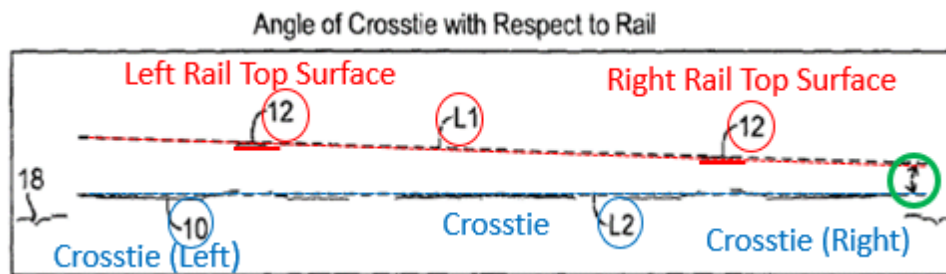
72. In another embodiment, as shown below in annotated FIG. 8, Villar discloses determining a height in pixels, H_b (green) of ballast 18 (blue dashed line) relative to crosstie 10 (red dashed line). *Id.*, ¶[0052]. See also *id.*, ¶[0047] (determining crosstie/rail angle by line-fitting the top surface height contours of rail heads and the crosstie with angular orientations L_1 , L_2 , respectively, and then comparing the two).



Villar, FIG. 8 (annotated).

73. And in yet another embodiment, as shown below in annotated FIG. 5, Villar discloses determining the crosstie/rail angle by line-fitting the top surface

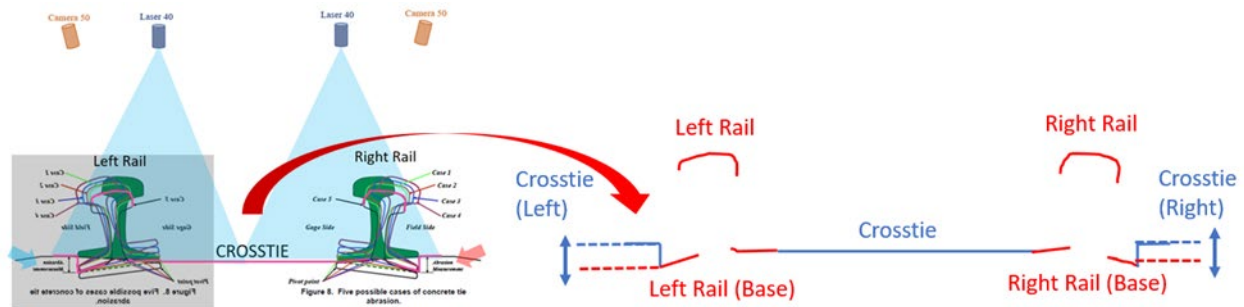
height contours of rail heads (red) and the crosstie (blue) with angular orientations L1 (red dashed line), L2 (blue dashed line), respectively, and then comparing the two (green). *Villar*, ¶[0047]. See also *id.*, ¶[0043] (*Villar* further noting that “other measurable aspects of the railroad track can be determined or detected from the image data of the track bed.”); and ’320 patent, 13:6-8 (explaining that rail height measurements can be taken “in accordance with the methods previously described.”).



Villar, FIG. 5 (annotated).

74. Accordingly, as shown below in annotated FIG. 8, in my opinion, it would have been obvious to one of ordinary skill in the art to have implemented *Villar*’s processing device 60 to line-fit (i.e., extend line tangents to) the top surface heights of the crosstie (blue dashed line) and the rail bases (red dashed line) in the generated contour image, and then compare the difference between the two for each tie and rail (blue arrows). Implementing *Villar*’s system in this way is further to and consistent with *Villar*’s disclosure yielding another track component

defect for *Villar*'s vision system to automatically identify and correct in furtherance of increasing railroad safety.



Choros, FIG. 8 (annotated).

75. The specification of the '320 patent describes one embodiment measuring the height of the rail bases and crossties relative to a line L5 ('320 patent, 13:24-26). But the claims do not require this specific technique. Nor does the specification require its importation into the claims. Instead, the '320 patent appreciates that “there are a variety of methods to determine the heights [of each rail base and tie].” '320 patent, 13:38-41. Further, in my opinion, one of ordinary skill in the art would understand that the measured distance between the top surface of each rail base and respective crosstie is the same under either measurement technique, because the height measurement under either technique is dependent upon the vertical distance between rail base and crosstie top surface heights.

76. Finally, one of ordinary skill in the art would have understood that the measured vertical distances between the rail base and crosstie top height surfaces

of the image profile would indicate whether RSA is present along the railroad track. The '320 patent does not provide any guidance as to the specific distance needed to “determine whether [RSA] is present along the railroad track.” To the extent RSA refers to the measurement of any vertical distance from normal that the rail base has cut into the crosstie, *Choros* discloses this. *Choros*, 7, 10. To the extent the claimed RSA refers to the measurement of a specific depth (in, e.g., inches), between the rail base and the tie—such as pursuant to the FRA’s approved “concrete tie rule”—*Choros* also discloses it. *Choros*, 7, 10 (*Choros* disclosing allowable RSA maximums, such as ½ inch); Ex-1020, Ex-1017. *See also* Ex-1012, FIG. 4(b). Indeed, similar to how an inspector in *Choros* would manually measure the vertical distance or depth of RSA and associate the vertical distance with a known criterion by which to determine actionable RSA, so too would a programmer implement *Villar*’s automated vision system to determine the presence of RSA along the railroad track in furtherance of increasing railroad safety.

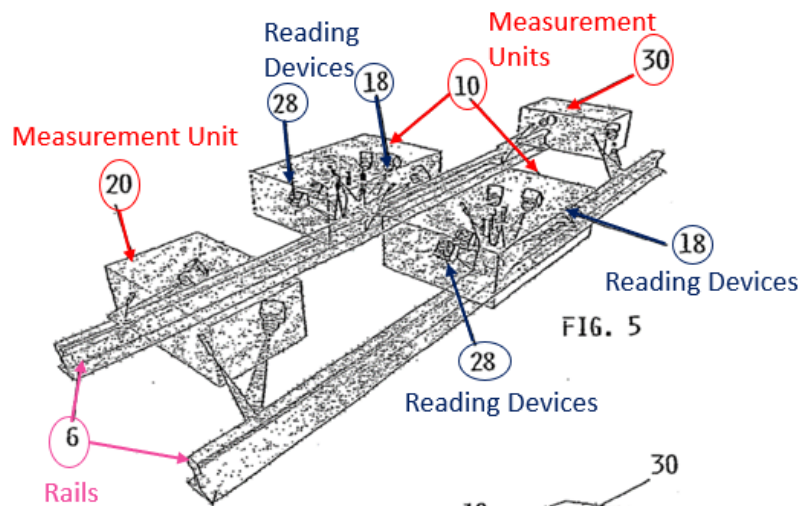
77. *Villar* and *Choros* thus render obvious this limitation of claim 1, in my opinion.

Claim 1[f]: wherein, when determining whether rail seat abrasion is present, the at least one processor compensates for a tilt of the railroad track.”

78. In my opinion, it would have been obvious to one of ordinary skill in the art to compensate for a tilt of a railroad track when determining whether RSA

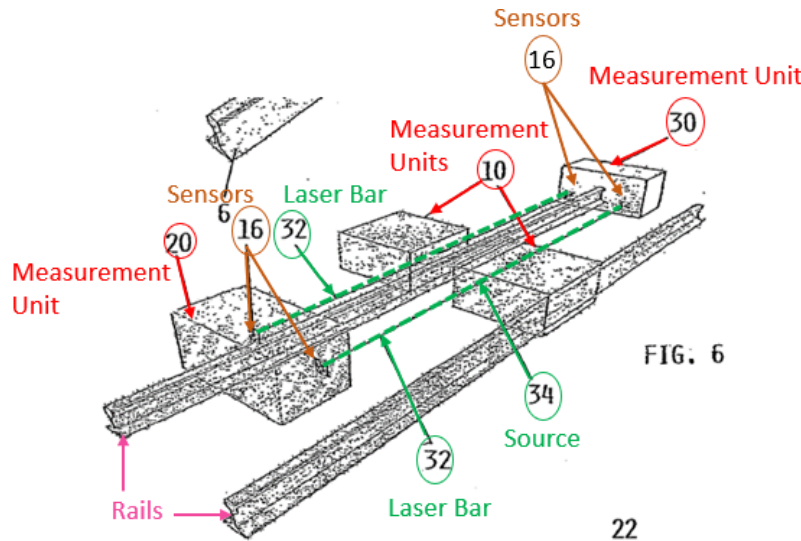
is present along the railroad track. It was well-known that a rail in the field may be slanted, tilted, canted, and/or banked at curves at some angle away from vertical either by design or due to the load of passing trains in some track portions. It was also well-known at the relevant time to compensate for this tilt of a railroad track when determining a railroad track component defect, as evidenced by, e.g., *Casagrande* (Ex-1008) and *Szwilski* (Ex-1009).

79. Like *Villar*, *Casagrande* discloses a mobile railroad track surveying and monitoring apparatus that uses image-capturing technology to obtain rail profiles, and other track geometry parameters. *Casagrande*, ¶¶[0009]-[0012], [0030]-[0035]. As shown below in annotated FIG. 5, *Casagrande*'s apparatus includes a central measurement unit 10 (red) for each rail with three reading devices 18 (navy) responsible for imaging the transverse profile of the rails 6 (fuchsia), as well as two longitudinally aligned reading devices 28 (navy) focused on the top of each rail head. *Casagrande*, ¶[0029]. The apparatus also includes front and rear-end units 20, 30 (red) with triangulation reading devices. *Id.*, ¶[0030]. The reading devices read vertical and horizontal coordinates at three longitudinally spaced apart points of each rail 6. *Id.* Based on the imaged coordinates, a processor unit calculates various parameters of the track geometry, including the gauge, radius of curvature, horizontal and vertical alignment, and the skew. *Casagrande*, ¶¶[0030]-[0035].



Casagrande, FIG. 5 (annotated).

80. Further, *Casagrande*'s apparatus includes software for automatically compensating the measured rail profile position data for any vertical alignment measurement errors due to "elastic deformation of the railway or tramway carriage." *Casagrande*, ¶¶[0009]-[0012], [0030]-[0036]. As shown below in annotated FIG. 6, a laser bar 32 (green dashed line) emitted by a source 34 (green) positioned in the central measurement unit 10 (red) monitors the height position of each triangulation reading device located in the end measurement units 20 and 30 (red). *Id.*, ¶[0036]. The laser bar 32 is received by a sensor 16 (orange) positioned in the end measurement units 20, 30 and is "able to constitute a precise alignment of the points of measurement." *Id.*



Casagrande, FIG. 6 (annotated).

81. According to *Casagrande*, any “[l]ack of alignment results in a signal which by means of suitable software is able to automatically compensate the resultant measurement errors.” *Id.* In my opinion, one of ordinary skill in the art would understand that because *Casagrande*’s apparatus measures any lack of alignment of “the position in height of each triangulation reading device located in the two end measurement units 20 and 30,” the system detects a vertical alignment error between each triangulation reading device caused by, e.g., a vertical deviation of the railway and/or tramway carriage. *Id.*, ¶[0036] (emphasis added).

82. It would have been obvious to one of ordinary skill at the relevant time to have implemented *Villar and Choros*’ automated RSA railroad track inspection vision system with *Casagrande*’s tilt compensation software to automatically compensate measurements of imaged railroad track components for

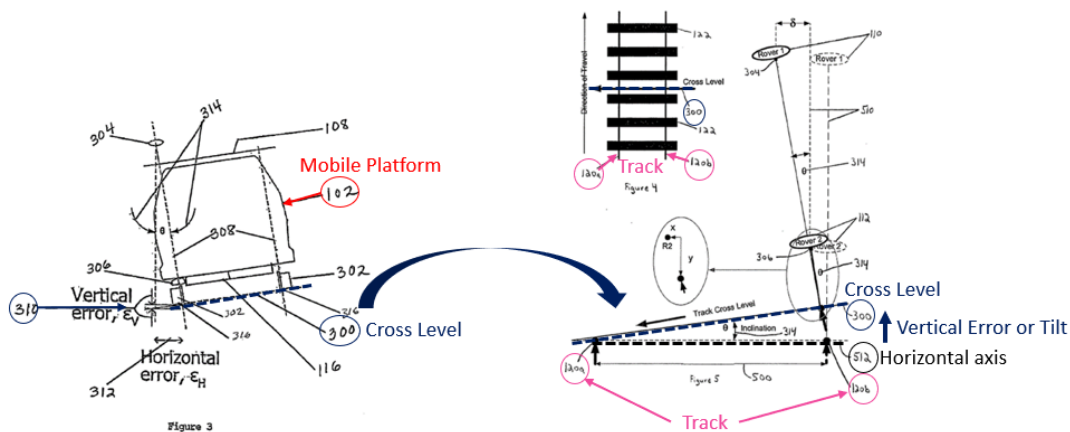
any vertical alignment errors associated with the deformation of the railway or vehicle-mounted vision system, as taught by *Casagrande*. In my opinion, one of ordinary skill in the art would have understood that, when *Villar*'s inspection system measures the height of components as viewed as the distance from the camera to that component, an adjustment would need to be made to compensate for the tilt of the track—and thus the tilt of the machine vision inspection system—when the track was banked, such as going around a curve.

83. One of ordinary skill in the art could have easily implemented *Villar* and *Choros*' automated RSA railroad track inspection system to compensate its RSA measurement for vertical tilt errors, as disclosed by *Casagrande*, and doing so would yield nothing more than predictable results. To the extent *Casagrande* does not explicitly disclose compensating an RSA measurement for vertical tilt error, *Casagrande* describes compensating imaged rail profile and other measured geometric parameters (e.g., gauge, radius of curvature, horizontal and vertical alignment, and skew) for vertical alignment errors. Moreover, *Villar*'s inspection system 30 stores and analyzes obtained image data “to determine various measurable aspects of the railroad track” and determine railroad track component defects. *See Villar*, ¶¶[0008], [0023], [0047], [0050], [0052], claims 1, 15, 23. And *Villar* appreciates that “other measurable aspects of the railroad track can be

determined or detected from the image data of the track bed.” *Villar*, ¶[0043]
(emphasis added).

84. Accounting for vertical track inclination errors to accurately represent imaged railroad component position data when determining rail defects is also evidenced by *Szwilski* (Ex-1009). *Szwilski*, like *Casagrande* and *Villar*, discloses a mobile railroad track surveying and monitoring apparatus using image-capturing technology to obtain railroad track component position data. *Szwilski*, title, 1, 11, 12.

85. As shown below in annotated FIGS. 3-5, *Szwilski* explains that as a mobile platform 102 (red, FIG. 3) travels along inspecting rails 120 (fuchsia, FIGS. 4-5), it is important to determine and account for any “track inclination perpendicular to the track 120a,b (also know[n] as Cross-level inclination).” *Szwilski*, 16. Otherwise, as *Szwilski* further explains, the “[p]osition data of the rail [being surveyed] will not be accurate.” *Id.* (“Position data of the rail will not be accurate if there is inclination of the track 120a,b, unless the vertical error 310 and the horizontal error 312 is accounted for.”).



Szwilski, FIGS. 3-5 (annotated).

86. To accurately represent the position of the rail being surveyed, *Szwilski*'s system determines the presence of any vertical 310 tilt error (navy dashed line, FIGS. 3, 5) relative to horizontal (black dashed line) and corrects position coordinate data of the imaged component to account for the tilt. *Szwilski*, 16. And *Szwilski* recognizes that tilt corrections “include, but are not limited to, determining rail displacement 234 or other rail 120a,b defects and for even non-railroad applications.” *Id.*, 20 (emphasis added).

87. Therefore, in light of *Szwilski*'s teachings extending vertical tilt compensation corrections to “other rail [] defects,” it would have been obvious and well within the skill of one of ordinary skill in the art, in my opinion, to implement *Villar* and *Choros*' automated RSA railroad track inspection system to account for vertical track inclination errors to accurately represent the imaged railroad component position data when determining whether a well-known “rail []

defect[],” such as RSA, is present on the railroad track. The combination would have yielded the claimed subject matter.

88. To the extent Patent Owner were to argue that claim 1’s “at least one processor compensat[ing] for a tilt of the rail road track,” requires determining the railroad track tilt from the image representative of a profile of the scanned railroad track, in my opinion, *Villar* in combination with *Choros*, *Casagrande*, and *Szwilski* also renders it obvious.

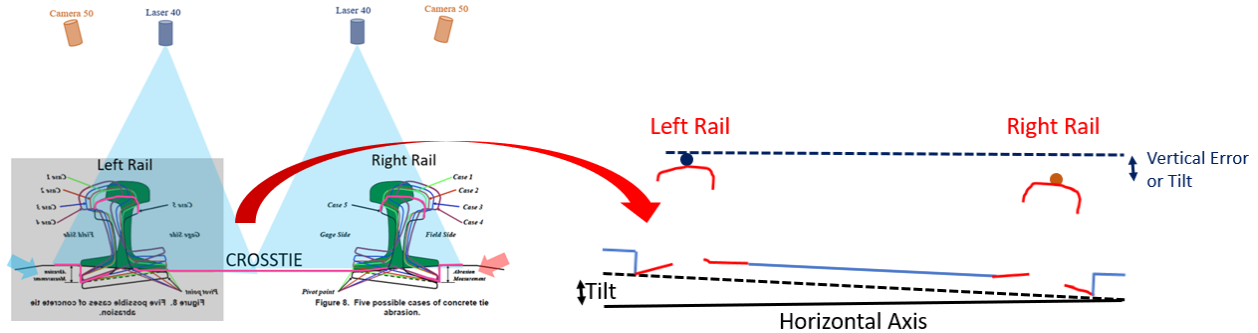
89. *Casagrande* uses image-capturing technology to calculate various parameters of the track geometry, including the “vertical alignment” or tilt of the track. *Casagrande*, ¶¶[0030], [0034]; *see also id.*, ¶[0011] (“Another object of the invention is to measure the geometry parameters of the rails, including their difference in height.”). *Casagrande* explains that triangulation reading devices read “at least three longitudinally spaced-apart points of each rail to the two characteristic coordinates of the point at that instant, i.e., the vertical coordinate, measured on the top of the horizontal surface of the rail, and the horizontal coordinate, ... These two coordinates ... enable the processor unit to calculate [] various parameters of the track geometry, and in particular: ... the vertical alignment.” *Casagrande*, ¶¶[0030], [0034].

90. It would have been obvious to implement *Villar* and *Choros*’ automated RSA railroad track inspection system to determine the vertical tilt of the

railroad track from the image representative of a profile of the scanned railroad track, as taught by *Casagrande*. *See id.* *Villar* identifies and assesses numerous railway track components, including ties and rails for defects and servicing through the use of “image processing tools known in the art for analyzing image data.” *See, e.g., Villar*, ¶¶[0047], [0052], [0055], FIGS. 7-8. And *Villar* does not limit the system to the measurable aspects disclosed; rather, *Villar* fully appreciates that “other measurable aspects of the railroad track can be determined or detected from the image data of the track bed.” *Villar*, ¶[0043] (emphasis added). Thus, implementing *Villar*’s system 30 to determine the vertical alignment, or tilt of the railroad track from the image representative of a profile of the scanned railroad track, as taught by *Casagrande*, would simply provide another track component defect for *Villar*’s vision system to automatically identify and correct in furtherance of increasing railroad safety.

91. Accordingly, as shown below in annotated FIG. 8, in my opinion, it would have been obvious to one of ordinary skill in the art to further implement *Villar*’s processing device 60 to determine the vertical error or tilt (navy arrow, right) of the track from the image by analyzing the “vertical coordinate, measured on the top of the horizontal surface” of each of the left rail (navy dot) and right rail (orange dot), as taught by *Casagrande*. *Casagrande* ¶¶[0030], [0034]. And further to *Casagrande* and *Szwilski*’s teachings, when determining whether RSA is present

along the railroad track, *Villar*'s system would compensate the RSA measurement for any vertical alignment error.



Choros, FIG. 8 (annotated).

92. *Villar*, *Choros*, *Casagrande*, and *Szwilski* thus render obvious this limitation of claim 1, and thus also claim 1, in my opinion.

5. Claim 2

Claim 2[a]: “A system as defined in claim 1, wherein the processor compensates for the tilt of the railroad track by the steps comprising:”

93. As discussed above regarding claim 1[f], *Villar*, *Choros*, *Casagrande*, and *Szwilski* render obvious claim 2’s preamble, in my opinion.

Claim 2[b]: “determining a height of a left rail base, right rail base, left crosstie and right crosstie;”

94. As discussed above regarding claim 1[e], in my opinion, *Villar* and *Choros* render obvious an automated RSA railroad inspection vision system for determining a vertical distance between each rail base and crosstie top height

surfaces. *Villar* and *Choros* thus render obvious this limitation of claim 2, in my opinion.

Claim 2[c]: “determining a tilt correction factor;”

95. As discussed above regarding claim 1[f], *Villar*, *Choros*, *Casagrande*, and *Szwilski* render obvious, in my opinion, an automated RSA railroad inspection vision system for determining the vertical alignment or tilt of the rails and compensating an RSA measurement for any vertical alignment or tilt error. In my opinion, one of ordinary skill in the art would have thus understood that the value used to compensate the RSA measurement for any vertical alignment or tilt error would constitute the claimed “tilt correction factor.”

96. *Villar*, *Choros*, *Casagrande*, and *Szwilski* thus renders obvious this limitation of claim 2, in my opinion.

Claim 2[d]: “determining an actual delta for the right and left rail bases; and”

97. As discussed above regarding claim 1[e], in my opinion, *Villar* and *Choros* render obvious an automated RSA railroad inspection vision system for determining each rail base and crosstie top surface height, and the distances between the left rail base and crosstie heights, and the right rail base and crosstie heights. Because *Villar* and *Choros*’ RSA railroad inspection vision system determines the distance or difference between the left rail base and crosstie heights,

and the right rail base and crosstie heights, *Villar*'s system determines an "actual delta" for the right and left rail bases.

98. *Villar, Choros, Casagrande, and Szwilski* thus, in my opinion, renders obvious this limitation of claim 2.

**Claim 2[e]: "determining a rail seat abrasion value
for the right and left rail bases."**

99. As discussed above regarding claims 1[e]-[f] and 2[b], [c], *Villar* and *Choros*' RSA railroad inspection vision system: (1) measures the heights of the right and left rail bases and crossties; (2) determines an actual delta for the right and left rail bases by determining the distance or difference between the left rail base and crosstie heights, and the right rail base and crosstie heights; (3) determines any tilt correction error, based on the vertical alignment of the left and right rails; and (4) compensates for any tilt correction error when determining the RSA value for the right and left rail bases (the claimed "determining a rail seat abrasion value for the right and left rail bases").

100. *Villar, Choros, Casagrande, and Szwilski* thus renders obvious this limitation of claim 2, in my opinion.

6. Claim 5

“A system as defined in claim 2, wherein the step of determining the actual delta is accomplished based upon the tilt correction factor.”

101. In my opinion, it would have been obvious to one of ordinary skill in the art to integrate the determined tilt correction factor into each actual delta to correct the coordinate position of the imaged data. Once the tilt correction factor was determined, it would have been obvious to adjust the difference in height between the rail base and the crosstie for both rails based upon the tilt correction factor. In my opinion, one would have been motivated to do so to ensure accurate height measurements where the rail is tilted, as when banked at curves in the track, as evidenced by, e.g., *Szwilski*. *Szwilski* discloses using “simple trigonometry,” to make track inclination and real-time “x” and “y” coordinate corrections to reflect the accurate position of the rail 120 being surveyed. *Szwilski*, 18; *see also id.*, 12-14, 16-20, 13 (“Entering the horizontal and vertical offset into the computer 126 corrects the coordinate data to correspond to the coordinates of the rail 120b being surveyed.”), 17-18 (“proper coordinate corrections can be calculated as seen in FIG. 7c by simple trigonometry.”), FIG. 9.

102. To compensate the imaged coordinate position data for any tilt of the railroad track, it would have been obvious to one of ordinary skill in the art, in my opinion, to correct the position coordinates of the components in the contour image

by implementing “x” and “y” coordinate corrections to each rail, thus correcting the imaged railroad track component position data. For example, to “accurately represent the position of the rail[] being surveyed,” in a case where the track was tilting to the left (with the right rail in a higher position than the left rail due to the tilt), it would have been obvious to one of ordinary skill in the art to correct the imaged position data through the use of simple calculations incorporating “x” and/or “y” tilt correction values to each of the left and right rail delta calculations, as taught by *Szwilski*. *Szwilski*, 17.

103. *Villar, Choros, Casagrande*, and *Szwilski* thus renders obvious this additional limitation of claim 5, in my opinion.

7. Claim 6

“A system as defined in claim 2, wherein the step of determining the rail seat abrasion value is accomplished based upon the actual delta.”

104. As discussed above regarding claim 2[e], *Villar, Choros*, and *Casagrande* render obvious this limitation of claim 6, in my opinion.

8. Claim 7

Claim 7[preamble]: “A method for determining rail seat abrasion of a railroad track, the method comprising the steps of:”

Claim 7[a]:

“(a) determining a height of a left rail base, right rail base, left crosstie and right crosstie;

(b) recording the heights of the left rail base, right rail base, left crosstie and right crosstie;”

Claim 7[b]: “(c) determining a tilt correction factor;”

Claim 7[c]: “(d) determining an actual delta for the right and left rail bases; and”

Claim 7[d]: “(e) determining a rail seat abrasion value for the right and left rail bases.”

105. As discussed above regarding claims 1 and 2, *Villar, Choros, Casagrande*, and *Szwilski* render obvious these limitations of claim 7. The only difference from the limitations in claims 1 and 2 and those in claim 7 is claim 7’s recitation of: “(b) recording the heights of the left rail base, right rail base, left crosstie and right crosstie.” As discussed in claim 1[e] and 2[b], *Villar* and *Choros* render obvious an RSA railroad inspection vision system for “determining a height of a left rail base, right rail base, left crosstie and right crosstie,” as recited by claim 7[a]. In my opinion, it would have been obvious to one of ordinary skill in the art to implement *Villar* and *Choros*’ system to store these determined heights.

106. *Villar*'s system 30 includes a storage device 62 which "allows for sustained real-time storage of the data obtained with the disclosed inspection system 30." *Villar*, ¶[0034] (emphasis added). *See also id.*, ¶[0033] ("The processing device 60 operates with suitable software programs for storing and analyzing the various data obtained with the disclosed inspection system 30."); and *id.*, ¶[0034] ("To effectively store all of the data obtained with the disclosed inspection system 30, the storage device 62 preferably includes two large-capacity hard drives."), FIG. 1. Accordingly, in my opinion, it would have been obvious to one of ordinary skill in the art to implement *Villar*'s storage device 62 to record the determined heights because the determined heights would be "obtained with [*Villar*'s] disclosed inspection system 30," and for real-time storage and analyzation by processing device 60, as taught by *Villar*. *Villar*, ¶¶[0033]-[0034].

107. *Villar*, *Choros*, *Casagrande*, and *Szwilski* thus renders obvious claim 7, in my opinion.

9. Claim 10

"A method as defined in claim 7, wherein step (d) is accomplished based upon the tilt correction factor.

108. As discussed above regarding claim 5, *Villar*, *Choros*, *Casagrande*, and *Szwilski* render obvious this limitation of claim 10, in my opinion.

10. Claim 11

“A method as defined in claim 7, wherein step (e) is accomplished based upon the actual delta for the right and left rail bases.

109. As discussed above regarding claims 1 and 5, *Villar, Choros, Casagrande*, and *Szwilski* render obvious this limitation of claim 11, in my opinion.

11. Claim 12

Claim 12[preamble]: “A method for determining rail seat abrasion of a railroad track, the method comprising the steps of:”

110. As discussed above regarding claim 1[preamble], *Villar* and *Choros* render obvious claim 12’s preamble, in my opinion.

Claim 12[a]: “(a) moving an inspection system along the track;”

111. *Villar*’s inspection system 30 is assembled onto a rigid framework 32 that can be “mounted on an inspection vehicle ... or other device moving along the track.” *Villar*, ¶¶[0026], [0028], claim 1, preamble. *Villar* thus discloses this limitation of claim 12, in my opinion.

Claim 12[b]: “(b) receiving image data corresponding to at least a portion of the track;

112. As discussed above for claim 1[b], *Villar*’s system 30 includes cameras 50 that receive a portion of the light reflected from the contour of the surface of the railroad track components and generate image data representative of

the profile of the scanned portion of the railroad track. *Villar*, ¶¶[0024], [0028], [0032], [0035]. *Villar* thus discloses this claim element, in my opinion.

Claim 12[c]: “(c) determining a measurement of the rail seat abrasion for the portion of the track,”

113. As discussed above regarding claim 1[e], in my opinion, *Villar* and *Choros* render obvious this limitation of claim 12, in my opinion.

Claim 12[d]: “wherein the measurement are adjusted for tilt encountered as the inspection system moves along the track; and”

114. As discussed above regarding claim 1[f], in my opinion, *Villar*, *Choros*, *Casagrande*, and *Szwilski* render obvious this limitation of claim 12, in my opinion.

Claim 12[e]: “(d) determining whether rail seat abrasion exists based upon the adjusted measurement.”

115. As discussed above regarding claim 1[f], *Villar*, *Choros*, *Casagrande*, and *Szwilski* render obvious this limitation of claim 12, and thus also claim 12, in my opinion.

12. Claim 13

Claim 13[a]: “A method as defined in claim 12, wherein step (c) further comprises the steps of:”

Claim 13[b]: “determining a height of a left rail base, right rail base, left crosstie and right crosstie;”

Claim 13[c]: “determining a tilt correction factor;”

Claim 13[d]: “determining an actual delta for the right and left rail bases; and”

Claim 13[e]: “determining a rail seat abrasion value.”

116. As discussed above regarding claims 1 and 2, *Villar, Choros, Casagrande*, and *Szwilski* and render obvious these limitations of claim 13, in my opinion.

13. Claim 16

“A method as defined in claim 13, wherein the step of determining the actual delta is accomplished based upon the tilt correction factor.”

117. As discussed above regarding claim 5, *Villar, Choros, Casagrande*, and *Szwilski* render obvious this additional limitation of claim 16, in my opinion.

14. Claim 17

“A method as defined in claim 13, wherein the step of determining the rail seat abrasion value is accomplished based upon the actual delta.”

118. As discussed above regarding claim 6, *Villar, Choros, Casagrande*, and *Szwilski* render obvious this additional limitation of claim 17, in my opinion.

B. Obviousness of Claims 3, 8, 14 Over *Villar* in Combination with *Choros*, *Casagrande*, *Szwilski*, and *Khattak*

1. Claim 3

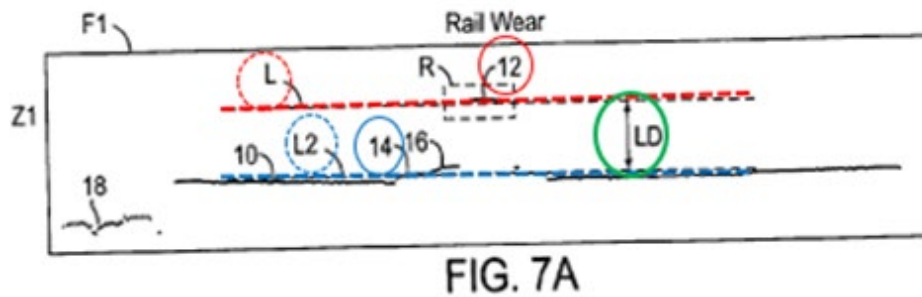
“A system as defined in claim 2, wherein the step of determining the heights further comprises the steps of: determining vertical pixel counts for each of the heights of the left rail base, right rail base, left crosstie and right crosstie; and normalizing the vertical pixel counts based upon a measurement index.”

119. As discussed above regarding claims 1[f] and 2, in my opinion, it would have been obvious to one of ordinary skill in the art to implement the processing device 60 of *Villar* and *Choros*’ automated RSA railroad track inspection vision system to determine whether RSA is present along the scanned railroad track by determining, from the generated at least one image representative of a profile of at least a portion of the railroad, track heights of the left rail base, right rail base, left crosstie and right crosstie via well-known machine vision contour line-fitting and orientation comparison algorithms. Such algorithms would necessarily include determining vertical pixel counts for each rail base and crosstie top surface heights, as evidenced by *Villar* and others. *Villar*, ¶¶[0047]; [0052], [0055].

120. *Villar* identifies and assesses railway track components for defects in the image via contour line-fitting and orientation comparison algorithms. To identify a railroad component in an image, *Villar* discloses using computer analysis

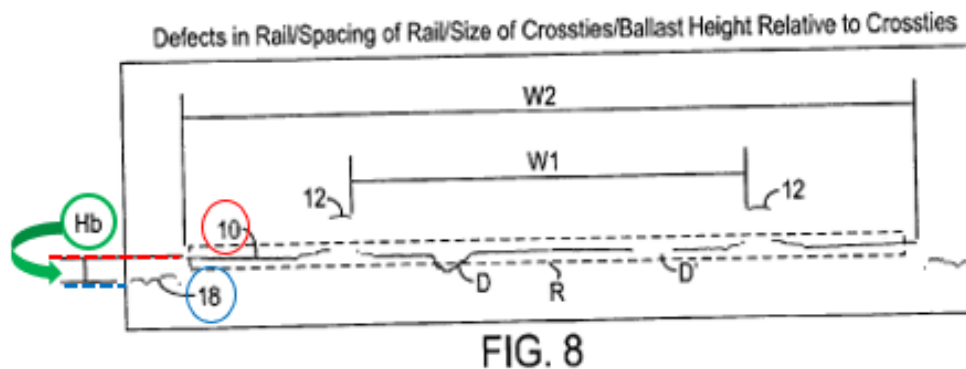
to search a region of interest R of the image or frame for pixels indicating the presence of a railroad track component. According to *Villar*, this may be done “by averaging or summing the value of pixels in the region of interest.” *Id.*, ¶[0046]. Because the contour of the railroad component is composed of dark pixels, the region of interest R having a railroad track component present will have a different average or sum than another region of the image that does not have this component. *Id.*; see also ¶¶[0049], [0035].

121. Once *Villar*’s system identifies contours of railroad track components in the image, it next assesses the components for defects via contour line-fitting and orientation comparison algorithms. *Villar*, ¶¶[0050], [0052], [0047]. In my opinion, one of ordinary skill in the art would understand that *Villar*’s system accomplishes these and other line-fitting and orientation comparison algorithms through determining and comparing the vertical pixel counts of the imaged contoured railroad track components. In one embodiment, for example, shown below in annotated FIG. 7A, *Villar* discloses determining the distance in pixels, LD (green) between a contour of a rail 12 (red) at a level L (red dashed line) to a reference level L2 (blue dashed line) of, e.g., a tie plate 14 (blue). *Villar*, ¶[0050].



Villar, FIG. 7A (annotated).

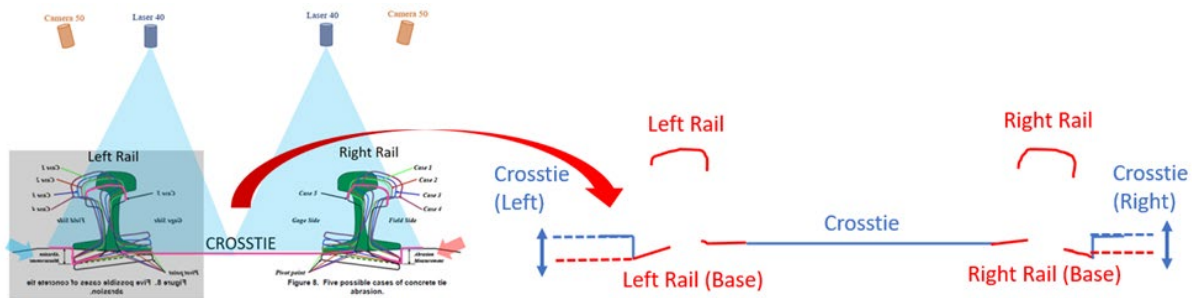
122. In another embodiment, as shown below in annotated FIG. 8, Villar discloses determining a height in pixels, Hb (green) of ballast 18 (blue dashed line) relative to crosstie 10 (red dashed line). *Id.*, ¶[0052]. See also *id.*, ¶[0047] (determining crosstie/rail angle by line-fitting the top surface height contours of rail heads and crosstie with angular orientations L1, L2, respectively, and then comparing the two).



Villar, FIG. 8 (annotated).

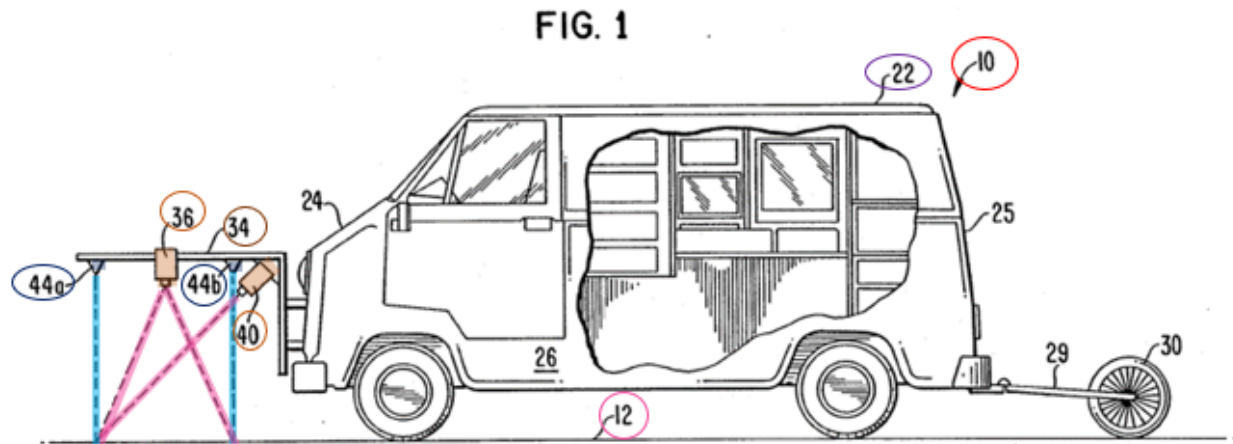
123. Accordingly, it would have been obvious to one of ordinary skill in the art, in my opinion, to implement Villar's system to identify and assess the rail

base and crosstie top surface height contours via contour line-fitting and orientation comparison algorithms by determining the left and right rail base and crosstie heights by determining and comparing vertical pixel counts in the image for the left and right rail base heights (blue dashed lines) and left and right crosstie heights (red dashed lines), as shown below in annotated FIG. 8. Implementing Villar's system in this way would simply provide another track component defect for Villar's vision system to automatically identify and correct in furtherance of increasing railroad safety.



Choros, FIG. 8 (annotated).

124. It also would have been obvious to one of ordinary skill in the art to convert (or normalize) the measured vertical pixel count between the crosstie and rail base top surface heights through a common computed measurement index or lookup table into commonly used units such as, e.g., inches, as evidenced, e.g., by *Khattak* (Ex-1010). As shown below in annotated FIG. 1, *Khattak*, like the '320 patent, discloses a vehicle mounted machine vision inspection apparatus 10 (red). *Khattak*, Abstract, 4:50-5:8, FIG. 1.



Khattak, FIG. 1 (annotated).

125. *Khattak*'s apparatus 10 includes a vehicle 22 (purple), which has a camera support frame 34 (brown) with mounted video cameras 36 and 40 (orange) and lasers 44a and 44b (navy) for inspection of pavement 12 (fuchsia) forward of the vehicle 22. *Id.*, 5:15-47, FIG. 1. *Khattak* explains that the video camera 36 “projects downward normal [fuchsia] to the surface of the pavement 12 and produces a first set of frames of raw electric video pixel signals or data, concerning or the magnitude of the light radiation reflected [blue of the lasers 44a, 44b] by the pavement and received by the camera in an X-Y array (multiple pixel line.)” *Id.*, 5: 21-26. *Khattak* notes that the video camera 36 may be a “CCD camera having very high resolutions exceeding 1,000,000 pixels.” *Id.*, 5:48-50.

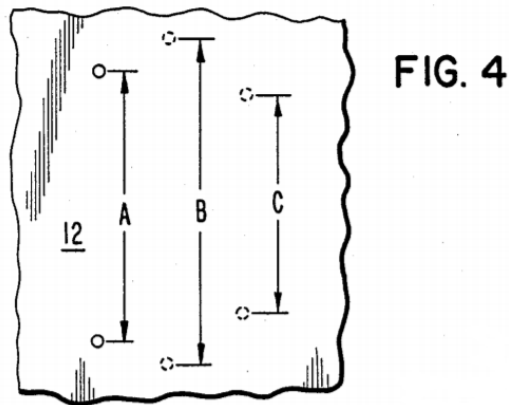
126. *Khattak* further discloses converting (or normalizing) the pixel counts based upon a measurement index, providing a surface distance to pixel correlation in terms of inches/pixel. *Khattak* explains, for example, that it is “preferable to

mount the cameras 36 and/or 40 at a spacing with respect to the pavement 13 so that a single pixel of the camera corresponds to an area on the surface of approximately one-tenth of an inch so that the resolution of the cameras is one-tenth inch/pixel.” *Id.*, 5:56-67. *See also id.*, 6:32-37 (“the apparatus 10 is designed with an approximate 0.1 of an inch/pixel resolution.”).

127. Further, *Khattak* discloses dynamically determining the pixel to surface distance relationship, ratio, or correlation on a real time basis and to adjust or calibrate the raw pixel accordingly to provide a much more accurate and dynamic (real time) determination of the surface distance to pixel correlation. *Id.*, 6:31-35, 6:38-40. To do so, *Khattak*’s apparatus 10 counts the number of pixels in a video frame between two defined reference points to determine if the number of pixels varies between frames, establishing a real-time correlation of the surface distance-to-pixel ratio. *Khattak*, 6:37-45.

128. According to the dynamic pixel to surface distance approach, *Khattak* explains that the imaged profile readings can be “initially calibrated when the vehicle is stationary.” *Khattak*, 6:56-58. “[L]asers 44a and 44b are spaced a preset precise distance such as four feet” with the beams directed downwards on the pavement 12, as shown in Fig. 4, reproduced below. *Id.*, 6:49-53. The beams form corresponding marks, and the marks separated by distance “A” indicate a view “when the vehicle is stationary in which the cameras are vertically stationary.” *Id.*,

6:58-61. In this example, distance “A” is exactly four feet, and with 480 pixels between the marks, the surface distance-to-pixel ratio is initially 0.100 inches/pixel. *Id.*, 6:61-65.



Khattak, FIG. 4

129. Vehicle movement may cause the cameras to move up or down depending on the surface profile. The marks in FIG. 4 separated by a distance “B” indicate an apparent change in the distance between the laser dots due to the vertical downward movement of the camera, such that there are now 488 pixels between the marks, and a corresponding surface distance-to-pixel ratio of 0.0984 inches/pixel. *Id.*, 6:66-7:7. And the marks separated by a distance “C” indicate a change in the distance due to vertical upward movement of the camera, leading to 472 pixels between the marks and a corresponding surface distance-to-pixel ratio of 0.1017 inches/pixel. *Id.*, 7:7-13. Accordingly, “each frame contains surface to

pixel information on a real time basis for adjusting the X-Y reference between the surface distance and the pixel data.” *Id.*, 7:13-16.

130. In my opinion, it would have been obvious to one of ordinary skill in the art to implement the automated RSA railroad track inspection vision system to convert (or normalize) pixel counts based upon a measurement index, as taught by *Khattak*. Pixel counts from an image must be converted into a corresponding unit of measurement (such as, e.g., inches, feet, or meters) to provide useful real-world information regarding the shape, size, contours, and position of imaged components relative to each other, as taught by *Khattak*, 14:44-62) (using surface distance-to-pixel ratios to determine elevational profile and surface distress features of imaged pavement). And, as *Khattak* recognizes, it was well-known at the relevant time that a measurement index, i.e., the number of pixels per unit of measurement, may vary based on the parameters, specifications (e.g., resolution), and placement of the vision system hardware, including the light generator and camera. *Khattak*, 5:48-7:16. Indeed, machine vision optical receivers may include, e.g., a charge-coupled device (“CCD”) (like *Khattak*, 5:48-49), and/or a complementary metal-oxide-semiconductor (“CMOS”) camera or sensor, including integrated sensor arrays and image/signal-processing units. Ex-1032, 5:32-42. Depending on the parameters and specifications of the specific optical receiver and its geometric placement within the overall system, the receiver’s field of view may

change, which in turn may impact the number of pixels per unit measurement, or measurement index. And finally, it would have been obvious to pre-emptively address these camera system variances through camera system calibration (a broader term that includes normalization), as also taught by *Khattak*, 6:31-7:16).

Id. Calibration is an area that involves computation of intrinsic and extrinsic parameter values that play a role in the conversion from pixels to 3D world units like inches or meters, and there being several standard techniques and standards at that time period used to compute these parameters; one of which is disclosed by *Khattak*.

131. Accordingly, in my opinion, it would have been obvious to one of ordinary skill in the art to convert (or normalize) the measured vertical pixel count between the crosstie and rail base top surface heights through an initially designed and/or dynamically adjusting computed measurement index into commonly used units like inches, as taught by *Khattak*.

2. Claim 8

“A method as defined in claim 7, wherein step (a) further comprises the steps of: determining vertical pixel counts for each of the heights of the left rail base, right rail base, left crosstie and right crosstie; and normalizing the vertical pixel counts based upon a measurement index.

132. As discussed above regarding claim 3, *Villar, Choros, Casagrande, Szwilski*, and *Khattak* render obvious these limitations of claim 8, in my opinion.

3. Claim 14

“A method as defined in claim 13, wherein the step of determining the heights further comprises the steps of: determining vertical pixel counts for each of the heights of the left rail base, right rail base, left crosstie and right crosstie; and normalizing the vertical pixel counts based upon a measurement index.”

133. As discussed above regarding claim 3, *Villar, Choros, Casagrande, Szwilski*, and *Khattak* render obvious these limitations of claim 14, in my opinion.

C. Obviousness of Claims 4, 9, and 15 Over *Villar* in Combination with *Choros, Casagrande, Szwilski*, and *Andersson*

1. Claim 4

“A system as defined in claim 2, wherein the step of determining the tilt correction factor is accomplished based upon the left and right rail base heights and a standard tilt correction factor.”

134. As discussed above regarding claims 1[d], 1[e], and 2, in my opinion, it would have been obvious to one of ordinary skill at the relevant time to have implemented *Villar* and *Choros*' automated RSA railroad track inspection vision

system, as taught by *Casagrande* and *Szwilski*, to automatically compensate left and right rail base height measurements of imaged railroad track components for vertical alignment tilt errors associated with the deformation of the railway or vehicle-mounted vision system caused by, e.g., a slanted, tilted, canted, and/or banked rail at curves at some angle away from vertical either by design or due to the load of passing trains in some track portions. It also would have been obvious to one of ordinary skill in the art, in my opinion, to implement a standard tilt correction factor to pre-emptively compensate imaged measurements for such vertical alignment tilt errors through use of a standard tilt correction factor, as evidenced by, e.g., *Andersson* (Ex-1011).

135. *Andersson* discloses a control system that uses a stored tilt correction factor associated with a track curve to tilt a train car body in real-time when the train passes through the track curve. *Andersson*, 3:45-49, 5:19-21, 4:55-57, 5:3-5. *Andersson* explains that the first time a train travels over a curved section of a track, the control system measures the geometry of the curve and stores the curve geometry in the memory of the control system. *Id.*, 5:16-19. The system determines the curve geometry by measuring two variables: the course curvature and the rail super-elevation (or cross-elevation, or tilt). *Id.*, 5:24-26. The train computer database stores sampled values of these variables as an updated reference-value profile for each track section. *Id.*, 5:49-55. The next time the train

travels over a certain track section, the previously measured and stored curve geometry is used to calculate “correct reference values for tilting of the car body for curves within the track section.” *Id.*, 5:66-6:4. The control system is self-correcting to allow for changes in curve-geometry data, and to reduce errors in determining this standard tilt correction factor, “the mean value of the two or three immediately preceding stored reference-value profiles may alternatively be used.” *Id.*, 6:12-18.

136. Accordingly, in my opinion, it would have been obvious to one of ordinary skill in the art to have implemented *Villar* and *Choros*’ automated RSA railroad track inspection vision and tilt correction system (as taught by *Casagrande* and *Szwilski*) with a standard tilt correction factor, as taught by *Andersson*, to preemptively compensate imaged measurements for known vertical alignment tilt errors associated with an upcoming track geometry. This would allow for faster image processing of the data and thus, faster identification of potential RSA issues. This enhanced data image processing would operate to protect the vehicle, optimize image processing (including faster identification of potential RSA issues), and enhance operational safety.

2. Claim 9

“A method as defined in claim 7, wherein step (c) is accomplished based upon the left and right rail base heights and a standard tilt correction factor.”

137. As discussed above regarding claim 4, *Villar, Choros, Casagrande, Szwilski*, and *Andersson* render obvious these limitations of claim 9, in my opinion.

3. Claim 15

“A method as defined in claim 13, wherein the step of determining the tilt correction factor is accomplished based upon the left and right rail base heights and a standard tilt correction factor.”

138. As discussed above regarding claim 4, *Villar, Choros, Casagrande, Szwilski*, and *Andersson* render obvious these limitations of claim 15, in my opinion.

XI. Conclusion

139. Therefore, it is my opinion that claims 1-17 are rendered obvious by the references described above.

XII. Declaration

140. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine

or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

141. I declare under penalty of perjury under the laws of the United States of America that the forgoing is true and correct.

Executed this 18th day of September 2019

Respectfully submitted,

A handwritten signature in black ink, appearing to be 'Nikos Papanikolopoulos', written on a light gray background.

Nikos Papanikolopoulos, Ph.D.