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Abstract

A communication management device (**10**) estimates communication quality between a control device (**30**) mounted on a moving object (**70**) and a driving assistance device (**20**) to provide a driving assistance service for the control device (**30**), at a scheduled time when the moving object (**70**) passes through a communication area, which includes a scheduled path where the moving object (**70**) passes. The communication management device (**10**) notifies the driving assistance device (**20**) when the communication quality is outside a range of quality being a standard. When it is notified, the driving assistance device (**20**) changes the driving assistance service to be provided for the control device (**30**).

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) This application is a Continuation of PCT International Application No. PCT/JP2021/004424, filed on Feb. 5, 2021, which is hereby expressly incorporated by reference into the present application.

TECHNICAL FIELD

(1) The present invention relates to a driving support technique of a moving object.

BACKGROUND ART

(2) These days, development of automatic driving technologies has been accelerated. By spreading automatic driving cars using the automatic driving technologies, efforts to realize reduction of traffic accidents, easing of traffic congestion, improvement in logistical efficiency, movement assistance of aged people, etc. have been advanced.

(3) As a method to utilize automatic driving cars, it has been considered an unmanned automatic driving service in a limited area. The unmanned automatic driving service is a remote-type automatic driving system by remote monitoring or remote operation, and the use of the unmanned automatic driving service in small-sized mobility, a bus, a taxi, etc. is considered.

(4) In a remote-type automatic driving system, monitoring of a travelling state of a vehicle and a driving instruction by remote operation, etc. are performed via a communication network by a driving assistance device disposed remotely. Therefore, when communication quality adjusted beforehand is not kept due to traffic situation, etc. around a vehicle, etc., stability of vehicle control is lowered, and safety and comfortability may be affected.

(5) Therefore, there is a necessity to improve techniques in the remote-type automatic driving system such as management of communication quality and path generation in accordance with the communication quality, etc.

(6) Patent Literature 1 discloses acquisition of communication quality in a plurality of geographical locations, and setting of a path routed through an area with high communication quality. In Patent Literature 1, by setting a path so as not to pass an area with low communication quality, a path of a moving object that meets the requirements of communication quality is set.

CITATION LIST

Patent Literature

(7) Patent Literature 1: JP2020-165832 A

SUMMARY OF INVENTION

Technical Problem

(8) The communication quality changes in accordance with circumstances. Therefore, there may be a case wherein necessary communication quality is not obtained. Patent Literature 1 does not take into account occurrence of a situation wherein necessary communication quality cannot be obtained. Therefore, there is a possibility that necessary communication quality cannot be obtained, and safety of and comfortableness on a moving object are degraded.

(9) The present invention is aimed at making it possible to realize suitable control in accordance with communication quality in a remote-type driving assistance system.

Solution to Problem

(10) There is provided according to one aspect of the present invention A communication management device includes: a quality estimation unit to estimate a communication quality between a control device that is mounted on a moving object and a driving assistance device to provide a driving assistance service for the control device, at a scheduled time when the moving object passes through a communication area, which includes a scheduled path where the moving object passes, and a notification unit to notify the driving assistance device when the communication quality estimated by the quality estimation unit is outside a range of a standard quality.

Advantageous Effects of Invention

(11) In the present invention, when communication quality between a control device and a driving assistance device with respect to a communication area at a scheduled time when a moving object passes through the communication area becomes outside a range of quality, a notification is made. In this manner, it is possible for the driving assistance device to perform control such as to change a

type of a driving assistance service. As a result, it is possible to realize appropriate control in accordance with communication quality.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a configuration diagram of a driving assistance system **100** according to a first embodiment;

(2) FIG. **2** is a configuration diagram of a communication management device **10** according to the first embodiment:

(3) FIG. **3** is a configuration diagram of a driving assistance device **20** according to the first embodiment;

(4) FIG. **4** is a configuration diagram of a control device **30** according to the first embodiment;

(5) FIG. **5** is a configuration diagram of a wireless relay device **40** according to the first embodiment:

(6) FIG. **6** is a processing flowchart of a learning process according to the first embodiment:

(7) FIG. **7** is a processing flowchart of a driving assistance process according to the first embodiment;

(8) FIG. **8** is an explanatory diagram of quality information **231** according to the first embodiment;

(9) FIG. **9** is an explanatory diagram of communication quality according to the first embodiment;

(10) FIG. **10** is a processing flowchart of the driving assistance process according to a first variation;

(11) FIG. **11** is a processing flowchart of the driving assistance process according to a second variation;

(12) FIG. **12** is an explanatory diagram of a quality estimation process according to a third variation;

(13) FIG. **13** is a configuration diagram of the driving assistance system **100** according to a second embodiment:

(14) FIG. **14** is a configuration diagram of a road-side unit **80** according to the second embodiment; and

(15) FIG. **15** is a processing flowchart of an operation of the driving assistance system **100** according to the second embodiment.

DESCRIPTION OF EMBODIMENTS

First Embodiment

(16) ***Description of Configuration***

(17) With reference to FIG. **1**, description will be made on a configuration of a driving assistance system **100** according to a first embodiment.

(18) The driving assistance system **100** includes a communication management device **10**, a driving assistance device **20**, one or more control devices **30**, a plurality of wireless relay devices **40** and an information provision device **50**.

(19) The communication management device **10**, the driving assistance device **20**, the wireless relay devices **40** and the information provision device **50** are connected to a communication network **60**. Each control device **30** is connected to the communication network **60** via any of the wireless relay devices **40**. In this manner, it is possible for the communication management device **10**, the driving assistance device **20**, each control device **30**, each wireless relay device **40** and the information provision device **50** to transmit and receive information with one another.

(20) A wireless network system **101** is constituted by the plurality of wireless relay devices **40** and the communication network **60**.

(21) The communication management device **10** is a computer to manage quality of end-to-end

communication between the driving assistance device **20** and the control device **30**, and communication quality of the wireless network system **101**.
(22) The driving assistance device **20** is a computer to provide a driving assistance service to the control device **30** mounted on a moving object **70**.
(23) The control device **30** is a computer to control the moving objects **70** based on the driving assistance service provided from the driving assistance device **20**. The control device **30** is mounted on the moving object **70**. The moving object **70** is a vehicle such as a four-wheeled vehicle and a two-wheeled vehicle, etc. in the first embodiment. The moving object **70** is not limited to a vehicle, but may be of another kind such as a vessel.
(24) The wireless relay devices **40** are computers to connect the control devices **30** to the communication network **60**. The wireless relay devices **40** are computers constituting base stations in the communication network **60**, as a concrete example.
(25) The information provision device **50** is a computer to provide related information that influences control over the moving objects **70**, such as weather information and road traffic information.
(26) The communication network **60** is a wireless network such as a mobile communication network. The communication network is, for example, a 3G (3rd generation) network, an LTE (long term evolution) network, a 5G (5th generation) or a 6G (6th generation) network. Further, the communication network **60** may include a network such as a wireless LAN (local area network) and a wireless MAN (metropolitan area network).
(27) With reference to FIG. **2**, description will be made on a configuration of the communication management device **10** according to the first embodiment.
(28) The communication management device **10** includes hardware components of a processor **11**, a memory **12**, a storage unit **13** and a communication interface **14**. The processor **11** is connected to other hardware components via a signal line, to control these other hardware components.
(29) The communication management device **10** includes, as functional components, an information acquisition unit **111**, a communication learning unit **112**, a communication adjustment unit **113**, a quality estimation unit **114** and a notification unit **115**. Functions of each functional component of the communication management device **10** are realized by software.
(30) The storage unit **13** stores a program to realize the functions of each functional component of the communication management device **10**. This program is read into the memory **12** by the processor **11**, and executed by the processor **11**. In this manner, the functions of each functional component of the communication management device **10** are realized.
(31) The storage unit **13** stores a learning model **131**.
(32) With reference to FIG. **3**, description will be made on a configuration of the driving assistance device **20** according to the first embodiment.
(33) The driving assistance device **20** includes hardware components of a processor **21**, a memory **22**, storage unit **23** and a communication interface **24**. The processor **21** is connected to other hardware components via a signal line, to control these other hardware components.
(34) The driving assistance device **20** includes, as functional components, an information acquisition unit **211**, a communication monitoring unit **212**, a service determination unit **213**, a communication adjustment unit **214** and a service provision unit **215**. The functions of each functional component of the driving assistance device **20** are realized by software.
(35) The storage unit **23** stores a program to realize the functions of each functional component of the driving assistance device **20**. The program is read into the memory **22** by the processor **21**, and executed by the processor **21**. In this manner, the functions of each functional component of the driving assistance device **20** are realized.
(36) The storage unit **23** stores quality information **231** and area information **232**.
(37) With reference to FIG. **4**, description will be made on the control device **30** according to the first embodiment.

(38) The control device **30** includes hardware components of a processor **31**, a memory **32**, storage unit **33** and a communication interface **34**. The processor **31** is connected to other hardware components via a signal line, to control these other hardware components.
(39) The control device **30** includes, as functional components, an information acquisition unit **311**, an input reception unit **312** and an integrity control unit **313**. The functions of each functional component of the control device **30** are realized by software.
(40) The storage unit **33** stores a program to realize the functions of each functional component of the control device **30**. This program is read into the memory **32** by the processor **31**, and executed by the processor **31**. In this manner, the functions of each functional component of the control device **30** are realized.
(41) With reference to FIG. **5**, description will be made on a configuration of wireless relay devices **40** according to the first embodiment.
(42) The wireless relay device **40** includes hardware components of a processor **41**, a memory **42**, a storage unit **43** and a communication interface **44**. The processor **41** is connected to other hardware components via a signal line, to control these other hardware components.
(43) The wireless relay device **40** includes, as functional components, a communication monitoring unit **411** and a communication adjustment unit **412**.
(44) Functions of each functional component of the wireless relay device **40** are realized by software.
(45) The storage unit **43** stores a program to realize the functions of each functional component of the wireless relay device **40**. This program is read into the memory **42** by the processor **41**, and executed by the processor **41**. In this manner, the functions of each functional component of the wireless relay device **40** are realized.
(46) The processors **11**, **21**, **31** and **41** are ICs (integrated circuits) to perform processing. The processors **11**, **21**, **31** and **41** are, for example, CPUs (central processing units), DSPs (digital signal processors) or GPUs (graphics processing units).
(47) The memories **12**, **22**, **32** and **42** are storage devices to temporarily store data.
(48) The memories **12**, **22**, **32** and **42** are SRAMs (static random access memories) and DRAMs (dynamic random access memories).
(49) The storage units **13**, **23**, **33** and **43** are storage devices to store data. The storage units **13**, **23**, **33** and **43** are HDDs (hard disk drives), for example. Further, the storage units **13**, **23**, **33** and **43** may be portable recording media such as SD (registered trademark, secure digital) memory cards, CF (CompactFlash, registered trademark), NAND flash, flexible disks, optical disks, compact disks, Blue-ray (registered trademark) disks. DVDs (digital versatile disks).
(50) The communication interfaces **14**, **24**, **34** and **44** are interfaces to connect with the communication network **60**. The communication interfaces **14**, **24**, **34** and **44** are communication antennas, for example.
(51) In FIG. **2**, only one processor **11** is illustrated. However, there may be a plurality of processors **11**, and the plurality of processors **11** may perform a program to realize each function in cooperation with one another. Similarly, there may be a plurality of processors **21**, **31** and **41**, and the plurality of processors **21**, **31** and **41** may perform a program to realize each function in cooperation with one another.
(52) ***Description of Operation***
(53) With reference to FIG. **6** through FIG. **9**, description will be made on the driving assistance system **100** according to the first embodiment.
(54) The operation procedure of the communication management device **10** in the driving assistance system **100** according to the first embodiment corresponds to a communication management method according to the first embodiment. Further, a program to realize the operation of the communication management device **10** in the driving assistance system **100** according to the first embodiment corresponds to a communication management program according to the first

embodiment.
(55) The operation procedure of the driving assistance device **20** in the driving assistance system **100** according to the first embodiment corresponds to a driving assistance method according to the first embodiment. Further, a program to realize the operation of the driving assistance device **20** in the driving assistance system **100** according to the first embodiment corresponds to a driving assistance program according to the first embodiment.
(56) The operation of the driving assistance system **100** includes a learning process and a driving assistance process.
(57) With reference to FIG. **6**, description will be made on the learning process according to the first embodiment.
(58) The learning process is a process to make a learning model **131** to estimate communication quality between the driving assistance device **20** and the control device **30** learn.
(59) (Step S**101**: Data Communication Process)
(60) Data communication is started between the driving assistance device **20** and the control device **30**. The process until data communication is started will be described in a description of the driving assistance process.
(61) (Step S**102**: Quality Monitoring Process)
(62) Each wireless relay device **40** and the driving assistance device **20** specify communication quality.
(63) The communication monitoring unit **411** of each wireless relay device **40** monitors a transmission and reception status of data via the communication interface **44**. In this manner, the communication monitoring unit **411** specifies the communication quality of the wireless network system **101**.
(64) Specifically, the communication monitoring unit **411** measures indexes such as transmission power and a bit error rate. The communication monitoring unit **411** calculates indexes representing communication quality such as radio field intensity, a delay time of data transmission, and uplink and downlink data rates in the communication network **60**, from the indexes measured. Then, the communication monitoring unit **212** specifies statistical information such as the mean value, the maximum value, the minimum value and a standard deviation in a certain time of the indexes representing the communication quality, as the communication quality of the wireless network system **101**. In this case, the communication monitoring unit **411** also measures the number of connection of a device existing under control of the wireless relay devices **40**, and calculates the statistical information. The device existing under control of the wireless relay devices **40** is the control device **30** and a smartphone of a pedestrian, etc.
(65) Since the measurement method of communication quality of the communication network **60** is already known, details thereof are omitted.
(66) The communication monitoring unit **212** of the driving assistance device **20** monitors the transmission and reception status of data via the communication interface **24**. In this manner, the communication monitoring unit **212** specifies end-to-end communication quality between the driving assistance device **20** and the control device **30**.
(67) Specifically, the communication monitoring unit **212** measures an index such as an RTT (round trip time) and a packet loss, etc. between the driving assistance device **20** and the control device **30**. The communication monitoring unit **212** calculates an index representing communication quality such as a delay time of end-to-end data transmission, and uplink and downlink data rates, from the index measured. Then, the communication monitoring unit **212** specifies statistical information such as the mean value, the maximum value, the minimum value and a standard deviation in a certain time of the index representing the communication quality, as the end-to-end communication quality.
(68) The measurement method of an RTT, etc. between the driving assistance device **20** and the control device **30** by the communication monitoring unit **212** will be described.

(69) In the data communication started in Step S**101**, the service provision unit **215** of the driving assistance device **20** sets driving assistance information inside a message for the control device **30**, and also sets a sequence number to identify the message and a data transmission time. The driving assistance information is information such as a vehicle speed, a steering angle and a target position if a type of the driving assistance service is a remote operation service. Further, the service provision unit **215** sets the sequence number included in the message received from the control device **30** and a reception time of this message in the message for the control device **30**.
(70) In the data communication started in Step S**101**, the integrity control unit **313** of the control device **30** sets vehicle state information such as a vehicle speed and a steering angle of the moving object **70**, and photographing information and object information around the moving object **70**, and also sets a sequence number to identify the message and a data transmission time, in a message for the driving assistance device **20**. Further, the integrity control unit **313** sets the sequence number included in the message received from the driving assistance device **20** and the reception time of this message.
(71) By setting the sequence number and the transmission and reception times of the message in the message in this manner, the communication monitoring unit **212** is capable of calculating a time (RTT) required in receiving and transmitting the message, a transfer time of the message from the driving assistance device **20** to the control device **30**, and a transfer time of the message from the control device **30** to the driving assistance device **20**.
(72) (Step S**103**: Quality Notification Process)
(73) The communication monitoring unit **411** of each wireless relay device **40** and the communication monitoring unit **212** of the driving assistance device **20** transmit communication quality information indicating communication quality specified to the communication management device **10**. In this case, with respect to a communication area of each wireless relay device **40**, the communication monitoring unit **212** of the driving assistance device **20** also transmits a type of the driving assistance service provided for the control device **30** mounted on the moving object **70** existing in the communication area to the communication management device **10**.
(74) The information acquisition unit **111** of the communication management device **10** integrates and writes into the storage unit **13** the communication quality information and the type of the driving assistance service.
(75) (Step S**104**: Related Information Acquisition Process)
(76) The information acquisition unit **111** of the communication management device **10** acquires related information with respect to the communication area of each wireless relay device **40**, which influences control over the moving object **70**, such as weather information and road traffic information, from the information provision device **50**. The information acquisition unit **111** writes the related information in the storage unit **13**.
(77) (Step S**105**: Communication Learning Process)
(78) The communication learning unit **112** of the communication management device **10** generates a learning model **131** to estimate the communication quality, from quality statistics indicating communication quality in the past with respect to each communication area indicated in the communication quality information acquired in Step S**103**, and a control condition in the past with respect to each communication area indicated in the related information, etc. acquired in Step S**104**. The communication learning unit **112** generates the learning model **131** by analyzing a correlation between the communication quality and the control condition with respect to each communication area. The learning model **131** is a model to output an estimated value of the communication quality when the control condition is provided as an input. The learning model **131** may be also regarded as a model to output the estimated value of the communication quality by using communication quality at a time close to the time to be estimated, in addition to the control condition, as an input.
(79) Specifically, the communication learning unit **112** analyzes a correlation between the communication quality and the control condition by using a machine learning method such as a

neural network and a support vector machine. In this case, the communication learning unit **112** generates a learning model **131** to estimate communication quality of the wireless network system **101**, and a learning model **131** to estimate end-to-end communication quality between the driving assistance device **20** and the control device **30**. The communication learning unit **112** may generate a learning model **131** to estimate the communication quality of the wireless network system **101** for each communication area of the wireless relay device **40**. The communication leaning unit **112** may generate a learning model to estimate the end-to-end communication quality for each pair of the driving assistance device **20** and each control device **30**. The communication learning unit **112** writes the learning model **131** generated in the storage unit **13**.

(80) The quality statistics used as an input in generating a learning model **131** by the communication learning unit **112** specifically include information as follows: (1) communication quality for each time and date in the past with respect to each communication area (2) weather condition such as weather, temperature, humidity, precipitation probability, and wind speed with respect to each communication area; (3) traffic condition such as whether it is during a long vacation, whether there is a large event in each communication area, whether an accident occurs in each communication area, and whether there is a voluntary restraint on outings in each communication area; (4) the number and an attribute of a moving object in or in the vicinity of the communication area; and (5) type of a driving assistance service provided in each communication area. (2), (3) and (4) are control conditions indicated in the related information, and (5) is the control condition acquired in Step S**103**.

(81) With reference to FIG. **7**, description will be made on a driving assistance process according to the first embodiment.

(82) The driving assistance process is a process to predict communication quality in the future by using the learning model **131** generated in the learning process, and to control the driving assistance service provided based on the communication quality predicted.

(83) (Step S**201**: Connection Request Process)

(84) The input reception unit **312** of the control device **30** mounted on the moving object **70** receives input of a type of a driving assistance service to be used from a driver of a vehicle being the moving object **70**. When the type of the driving assistance service is input, the input reception unit **312** transmits a request to connect with the communication network **60** to the wireless relay device **40**.

(85) The driving assistance service is a service provided by the driving assistance device. As types of the driving assistance service, there are a remote operation service of remote-type automatic driving, a remote monitoring service of remote-type automatic driving, a dynamic map generation service of autonomous automatic driving, and a surrounding environment information provision service. The remote operation service of remote-type automatic driving is a service to provide the control device **30** with operation information to operate the moving object **70** from the driving assistance device **20**, and to control the moving object **70** based on the operation information. The remote monitoring service of remote-type automatic driving is a service to acquire information on the moving object **70** from the control device **30** by the driving assistance device **20**, and to monitor a traveling state of the moving object **70**. The dynamic map generation service of autonomous automatic driving is a service to provide the control device **30** with a dynamic map around the moving object **70** from the driving assistance device **20**, and to make the control device **30** control the moving object **70** based on the dynamic map. The surrounding environment information provision service is a service to provide the control device **30** with surrounding environment information required to control the moving object **70** such as an obstacle around the moving object **70**, from the driving assistance device **20**.

(86) (Step S**202**: Connection Reply Process)

(87) The communication adjustment unit **412** of the wireless relay device **40** receives a connection request transmitted in Step S**201**. Then, the communication adjustment unit **412** transmits a

connection reply to allow connection to the control device **30**.
(88) (Step S**203**: Type Notification Process)
(89) The integrity control unit **313** of the control device **30** receives the connection reply transmitted in Step S**202**. Then, the integrity control unit **313** of the control device **30** transmits a start request of the driving assistance service to the driving assistance device **20**. The start request of the driving assistance service includes an identification number to uniquely represent the moving object **70**, destination information representing a destination, location information representing a location of the moving object **70**, and a type of the driving assistance service input in Step S**201**.
(90) (Step S**204**: Related Information Acquisition Process)
(91) The information acquisition unit **211** of the driving assistance device **20** acquires related information with respect to the communication area of each wireless relay device **40**, the related information being related to automatic driving, such as weather information and road traffic information, from the information provision device **50**. The communication area of each wireless relay device **40** is indicated in the area information **232**. The information acquisition unit **211** writes the related information in the storage unit **23**.
(92) (Step S**205**: Path Specification Process)
(93) The service determination unit **213** of the driving assistance device **20** receives the start request of the driving assistance service transmitted in Step S**203**. Then, the service determination unit **213** specifies a scheduled path being a path from a location indicated in location information included in the start request of the driving assistance service to a destination indicated in destination information. The service determination unit **213** specifies, as a scheduled path, a path being a shortest distance, or a path which makes it possible to reach the destination in a shortest time by using congestion information included in the road traffic information, etc.
(94) (Step S**206**: Required Quality Specification Process)
(95) The communication adjustment unit **214** of the driving assistance device **20** specifies communication quality required based on the type of the driving assistance service included in the start request of the driving assistance service. Specifically, the communication adjustment unit **214** specifies communication quality required for the type of the driving assistance service by referring to the quality information **231**.
(96) As illustrated in FIG. **8**, the quality information **231** stores required communication quality for each type. In FIG. **8**, the quality information **231** stores required communication quality for each of a case wherein a high-quality driving assistance service is provided, a case wherein a standard driving assistance service is provided and a case wherein a low-quality driving assistance service is provided. The contents of the driving assistance service are determined for each quality of the driving assistance service. For example, the contents of data to be transferred, and information such as a compression rate are determined for each quality of the driving assistance service. As illustrated in FIG. **9**, the communication quality represents a delay time, a data rate (UL) and a data rate (DL). The data rate (UL) is an uplink data rate, and the data rate (DL) is a downlink data rate. As illustrated in FIG. **9**, it is described that the smaller the value set in the communication quality is, the higher the quality is. By referring to the quality information **231**, and specifying the communication quality corresponding to the type of the driving assistance service, the communication adjustment unit **214** specifies required communication quality. For example, the communication adjustment unit **214** specifies the value of the communication quality in the case wherein a high-quality driving assistance service is provided.
(97) It is necessary to specify required communication quality for the wireless network system **101**, and required quality of end-to-end communication between the driving assistance device **20** and the control device **30**. In the first embodiment, a piece of quality information **231** is prepared separately for each communication quality. Then, the communication adjustment unit **214** refers to corresponding quality information **231**, and specifies each piece of communication quality.
(98) (Step S**207**: Communication Start Request Process)

(99) The communication adjustment unit **214** of the driving assistance device **20** transmits a communication start request to the communication management device **10**. The communication start request includes an identification number of the moving object **70** whereon the control device **30** being a communication destination is mounted, and quality information indicating the communication quality specified in Step S**206**.
(100) When receiving the communication start request, the communication adjustment unit **113** of the communication management device **10** transmits the communication start request to the wireless relay device **40** whereto the control device **30**, whereon the moving object **70** specified from an identification number included in the communication start request is mounted, is connected. The communication adjustment unit **113** transmits information indicating the communication quality of the wireless network system **101** in the quality information included in the communication start request by replacing the information with information corresponding to the wireless network system **101**. For example, when the wireless communication network is an LTE network, the communication adjustment unit **113** replaces the information indicating communication quality of the communication network **60** with a value of a QCI (QoS (quality of service) class indicator) being a value of the communication quality defined by a 3GPP (3rd generation partnership project) standard. Further, when the wireless communication network is a 5G network, the communication adjustment unit **113** replaces the information indicating the communication quality of the communication network **60** with a value of a 5QI (5G QoS indicator).
(101) (Step S**208**: Resource Allocation Process)
(102) The communication adjustment unit **412** of the wireless relay device **40** receives the communication start request transmitted in Step S**207**. Then, the communication adjustment unit **412** decides whether it is possible to allocate communication quality of the communication network **60** in the quality information included in the communication start request.
(103) When allocation is possible, the communication adjustment unit **412** transmits a communication resource allocation notification including information of the communication quality allocated to the control device **30**, and indicating permission to start communication. Then, the communication adjustment unit **412** transmits a communication start reply to the communication management device **10**. The communication adjustment unit **113** of the communication management device **10** receives the communication start reply, and transmits the communication start reply to the driving assistance device **20**.
(104) When allocation is impossible, the communication adjustment unit **412** transmits a communication start reply indicating non-permission to start communication to the communication management device **10**. The communication adjustment unit **113** of the communication management device **10** receives the communication start reply, and transmits a communication start reply to the driving assistance device **20**. When receiving the communication start reply indicating non-permission to start communication, the communication adjustment unit **214** of the driving assistance device resets communication quality, and transmits the communication start request again. For example, the communication adjustment unit **214** resets communication quality by specifying required communication quality in a case wherein quality to provide the driving assistance service is reduced.
(105) (Step S**209**: Communication Monitoring Process)
(106) When receiving the communication start reply indicating permission to start communication, the communication adjustment unit **214** of the driving assistance device **20** transmits a monitoring notification registration of communication quality to the communication management device **10**. The communication monitoring notification registration includes information indicating a communication destination to be monitored, a communication monitoring object area and a parameter for monitoring.
(107) The information indicating the communication destination to be monitored is an

identification number of the moving object **70** and a type of the communication assistance service. The communication monitoring object area specifies a communication area including a scheduled path based on the scheduled path and the area information **232**, and sets the wireless relay device **40** corresponding to the communication area specified. The parameter for monitoring includes a range of standard quality, a communication monitoring cycle, a communication quality estimation time and a change time of communication quality.

(108) The range of the standard quality is a threshold value to detect change in communication quality, and is set in accordance with settings of the quality information **231**. By storing the same quality information **231** in the communication management device **10** and the driving assistance device **20**, it is possible to easily communicate information between devices. The communication monitoring cycle is a cycle to monitor the communication quality. As the communication monitoring cycle, 100 times worth of the time taken for transmitting driving assistance information from the driving assistance device **20** to the control device **30** is set. That is, if a transmission cycle of the driving assistance information is 10 milliseconds, the communication monitoring cycle is 10 seconds. The communication quality estimation time is a time in the future at which the communication quality is to be estimated. As the communication quality estimation time, a scheduled time to pass through the area concerned is set based on the scheduled path. The change time of communication quality is a time required to change the driving assistance service. That is, the change time of communication quality is set based on the time, etc. required on the side of the control device **30** in switching the type of driving assistance service. The time required on the side of the control device **30** is a time, etc. to transfer to a driver who becomes necessary in switching from automatic driving to manual driving.

(109) The communication adjustment unit **113** of the communication management device **10** receives the monitoring notification registration of the communication quality from the driving assistance device **20**. The communication adjustment unit **113** transmits a communication quality monitoring request to the wireless relay device **40** set in the communication monitoring object area included in the monitoring notification registration. The communication quality monitoring request includes the communication monitoring cycle as the parameter for monitoring.

(110) (Step S**210**: Data Communication Process)

(111) When the communication adjustment unit **214** receives the communication start reply, the service provision unit **215** of the driving assistance device **20** transmits a driving assistance service start notification to the control device **30**. Then, data communication is started between the driving assistance device **20** and the control device **30**. After that, the service provision unit **215** of the driving assistance device **20** generates driving assistance information in accordance with the type of the driving assistance service, and regularly transmits the driving assistance information to the control device **30**.

(112) The integrity control unit **313** of the control device **30** acquires environment information around the moving object **70** and state information of the moving object **70**, and regularly transmits the environment information and the state information to the driving assistance device **20**. The environment information is information around the moving object **70** acquired by a camera mounted on the moving object **70**, and a sensor such as a LiDAR (light detection and ranging), etc. The environment information is, for example, photographed data by a camera and information of a surrounding object acquired as a result of analyzing the photographed data, etc. The state information is information indicating a behavior of the moving object **70** acquired from various apparatuses mounted on the moving object **70**, being information such as a vehicle speed and a steering angle. The integrity control unit **313** transmits the environment information and the state information, etc. after changing a compression ratio of the environment information and the state information, etc. based on the communication quality notified by a communication resource allocation notification from the wireless relay device **40**.

(113) The integrity control unit **313** of the control device **30** determines a moving method of the

moving object **70** using the driving assistance information transmitted from the driving assistance device **20**, and the environment information and the state information, and controls the behavior of the moving object **70**.

(114) The processes from Step S**211** through Step S**213** are the same as the processes from Step S**102** through Step S**104** of FIG. **6**.

(115) (Step S**214**: Quality Estimation Process)

(116) The quality estimation unit **114** of the communication management device **10** sets a communication area of each wireless relay device **40** set in the communication monitoring object area included in the monitoring notification registration, as a communication area being an object. The quality estimation unit **114** estimates communication quality at a scheduled time between the driving assistance device **20** and the control device **30** with respect to the communication area as the object, by using present communication quality and a control condition indicated in the related information with respect to the communication area being the object, and the learning model **131** generated in the process indicated in FIG. **6**, at a time prior to the change time of the communication quality with respect to the scheduled time to pass through the communication area being the object. For example, when it comes to a time prior to the scheduled time by a time obtained by adding a fixed period to the change time of the communication quality, the quality estimation unit **114** estimates communication quality at the scheduled time with respect to the communication area being the object. In this case, the quality estimation unit **114** estimates the communication quality at the scheduled time with respect to the communication area being the object by providing the learning model **131** with the present communication quality and the control condition indicated in the related information, etc. of the communication area being the object, as input, and acquiring an estimated value of the communication quality output.

(117) When the communication quality of the wireless network system **101** is estimated, the quality estimation unit **114** uses the learning model **131** for the wireless network system **101**, and w % ben the quality of end-to-end communication is estimated, the quality estimation unit **114** uses the leaning model **131** for end-to-end. When the learning model **131** is generated for each communication area of the wireless relay devices **40**, the quality estimation unit **114** uses a learning model **131** corresponding to the communication area to be estimated. When a learning model **131** is generated for each pair of the driving assistance device **20** and the control device **30**, the quality estimation unit **114** uses a learning model **131** corresponding to the pair to be estimated.

(118) Above, the quality estimation unit **114** has acquired the estimated value of the communication quality at the scheduled time. However, the quality estimation unit **114** may classify the communication quality by levels, and acquire a probability of the communication quality to become each level at the scheduled time. Then, for example, the quality estimation unit **114** may estimate the communication quality to be at a level of the highest probability.

(119) (Step S**215**: Quality Notification Process)

(120) When the communication quality estimated in Step S**214** is outside the range of the standard quality, the notification unit **115** of the communication management device **10** transmits a communication quality change notification to notify the driving assistance device **20** of the communication quality estimated. When at least any of the communication quality of the wireless network system **101** and the quality of end-to-end communication is outside the range of the standard quality, the notification unit **115** transmits the communication quality change notification.

(121) As the range of the standard quality, it is assumed that a lower limit of the communication quality is set. Therefore, when any communication quality estimated in Step S**214** becomes lower than the lower limit of the standard quality, the notification unit **115** transmits the communication quality change notification. The communication quality change notification indicates a communication area where change in communication quality is predicted, and communication quality estimated. When a probability of being the communication quality estimated is calculated, the communication quality change notification may indicate the probability.

(122) (Step S**216**: Service Resetting Process)
(123) The communication adjustment unit **214** of the driving assistance device **20** receives the communication quality change notification transmitted in Step S**215**. Then, the communication adjustment unit **214** decides whether it is possible to continue the driving assistance service based on the communication monitoring object area and the communication quality indicated in the communication quality change notification. Specifically, the communication adjustment unit **214** decides whether it is possible to provide the driving assistance service currently provided, with the communication quality indicated in the communication quality change notification. When it is possible to provide the driving assistance service currently provided, the communication adjustment unit **214** decides that it is possible to continue the driving assistance service, and when it is impossible to provide the driving assistance service currently provided, the communication adjustment unit **214** decides that it is impossible to continue the driving assistance service.
(124) As a specific example, it is assumed that when a remote operation service of remote-type automatic driving is being operated with “communication quality level=high-quality”, the communication adjustment unit **214** receives a communication quality change notification indicating “communication quality level=normal communication quality”. In this case, since it is possible to perform the remote operation service of remote-type automatic driving even with the communication quality estimated, the communication adjustment unit **214** decides that it is possible to continue the driving assistance service. Further, as another specific example, it is assumed that when a remote operation service of remote-type automatic driving is being operated with “communication quality level=low-quality”, the communication adjustment unit **214** receives a communication quality change notification indicating “communication quality level=less than low-quality”. In this case, since it is impossible to perform the remote operation service of remote-type automatic driving with the communication quality estimated, the communication adjustment unit **214** decides that it is impossible to continue the driving assistance service.
(125) The service provision unit **215** of the driving assistance device **20** resets the driving assistance service based on whether is it possible to continue the driving assistance service and the decision result.
(126) Specifically, when it is decided to be possible to continue the driving assistance service, the service provision unit **215** performs resetting so as to reduce the communication traffic volume while continuing providing the driving assistance service currently provided. For example, the service provision unit **215** makes a change such as to increase a compression ratio of the photographed data notified from the control device **30** in the remote operation service of remote-type automatic driving.
(127) Further, when it is decided that continuing the driving assistance service is impossible, the service provision unit **215** switches the driving assistance service to be provided to a driving assistance service which can be provided in the communication quality estimated. For example, the service provision unit **215** makes a change such as to switch the remote operation service of remote-type automatic driving to a surrounding environment information provision service.
(128) The service provision unit **215** of the driving assistance device **20** transmits a driving assistance service change notification to notify the control device **30** of a change content of the driving assistance service.
(129) (Step S**217**: Control Method Change Process)
(130) The integrity control unit **313** of the control device **30** receives the driving assistance service change notification transmitted in Step S**216**. Then, in response to the change content indicated in the driving assistance service change notification, the integrity control unit **313** changes a control method of the moving object **70**.
(131) As a specific example, when the compression ratio of the photographed data is increased, the integrity control unit **313** increases the compression ratio of photographed data to be transmitted to the driving assistance device **20** by one level, and reduces the size of photographed image data to

be transmitted. Further, when the remote operation service of remote-type automatic driving is switched to the surrounding environment information provision service, the integrity control unit **313** displays start of manual driving associated with suspension of the automatic driving function on a display device, etc. mounted on the moving object **70**, and notifies a driver of the moving object **70** of switching to manual driving. After that, the integrity control unit **313** stops control over apparatuses such as an accelerator, a brake and a steering, and switches to control notifying the driver of surrounding information.

Effect of First Embodiment

(132) As describe above, in the driving assistance system **100** according to the first embodiment, the communication management device **10** notifies when the communication quality between the driving assistance device **20** and the control device **30** with respect to a communication area at a scheduled time at which the moving object **70** passes through the communication area becomes outside a range of standard quality. Then, when it is notified, the driving assistance device **20** resets the driving assistance service in accordance with the communication quality estimated. In this manner, it becomes possible to realize suitable control in accordance with the communication quality.

(133) As a result, it becomes possible for the driving assistance device **20** and the control device **30** to recognize degradation of communication quality beforehand, and to take action to prevent degradation of the communication quality. In addition, it is possible to prevent emergency operation of the moving object **70** associated with sudden decline in communication quality, and to improve stability of control over the moving object **70**.

(134) ***Other Configuration***

(135) <First Variation>

(136) In the first embodiment, when communication quality is estimated to decline, resetting of the driving assistance service is performed. As a first variation, when the communication quality is estimated to decline, the communication adjustment unit **214** may allocate a communication resource between each of the plurality of control devices **30** and the driving assistance device **20**.

(137) That is, the communication adjustment unit **214** may adjust a communication resource allocated to communication with each of the plurality of control devices **30**, the communication resource being used to provide the driving assistance service to each of the plurality of control devices **30**. Specifically, the communication adjustment unit **214** reduces a communication resource allocated to communication with a control device **30** with which a driving assistance service of low priority is provided among the plurality of control devices **30**, and increases a communication resource allocated to communication with a control device **30** whereof the communication quality is estimated to decline. In this manner, there is a possibility to prevent communication quality from declining.

(138) With reference to FIG. **10**, description will be made on a driving assistance process according to the first variation.

(139) The processes from Step S**301** through Step S**306** are the same as the processes from Step S**210** through Step S**215** in FIG. **7**.

(140) (Step S**307**: Quality Adjustment Process)

(141) The communication adjustment unit **214** of the driving assistance device **20** receives the communication quality change notification transmitted in Step S**306**. Then, the communication adjustment unit **214** decides whether to allow decline in communication quality based on a communication monitoring object area and communication quality indicated in the communication quality change notification. Specifically, the communication adjustment unit **214** decides whether the communication quality indicated in the communication quality change notification is communication quality of the communication wireless network system **101**. When the communication quality indicated in the communication quality change notification is the communication quality of the wireless network system **101**, the communication adjustment unit

214 decides to allow decline in communication quality, and when the communication quality indicated in the communication quality change notification is quality of end-to-end communication, the communication adjustment unit **214** decides not to allow decline in communication quality.
(142) When the communication adjustment unit **214** decides not to allow decline in communication quality, the communication adjustment unit **214** specifies a driving assistance service of the lowest priority among driving assistance services being provided by the driving assistance device **20**. The communication adjustment unit **214** degrades the communication quality allocated to communication with a control device **30** providing the driving assistance service specified. That is, the communication adjustment unit **214** reduces the communication resource allocated to communication with the control device **30** providing the driving assistance service specified. In this manner, the communication adjustment unit **214** secures the communication resource. Then, the communication adjustment unit **214** allocates the communication resource secured to communication with the control device **30** whereof the communication quality is estimated to decline. When the communication quality of the wireless network system **101** does not decline but the quality of end-to-end communication declines, congestion in a wired network between the driving assistance device **20** and the wireless relay device **40**, etc. is considered to be a cause. Therefore, by reducing the communication resource allocated to others, and allocating the reduced part of the communication resource, it is possible to improve the quality of end-to-end communication.
(143) The priority of the driving assistance service is, for example, the highest as for the remote operation service of remote-type automatic driving performing so far as driving control, and the lowest as for the surrounding environment information provision service only performing information provision. That is, the higher a degree to which suspension of the driving assistance service has an influence on safety, the higher the priority is.
(144) (Step S**308**: Communication Start Request Process)
(145) When it is decided to allow decline in communication quality in Step S**307**, the communication adjustment unit **214** of the driving assistance device **20** transmits a communication quality adjustment request to the communication management device **10**. The communication quality adjustment request includes an identification number of the moving object **70** whereon the control device **30** being a communication destination is mounted, and quality information indicating communication quality of the wireless network system **101** indicated in the communication quality change notification transmitted in Step S**306**. According to this, change in allocation of the communication resource is requested so as to be the communication quality of the wireless network system **101** indicated in the communication quality change notification.
(146) (Step S**309**: Resource Control Process)
(147) The communication adjustment unit **412** of the wireless relay device **40** receives the communication start request transmitted in Step S**308**. Then, the communication adjustment unit **412** transmits a communication quality change notification to the driving assistance device **20**. The communication quality change notification indicates communication quality after change and a time to change the communication quality. The communication quality after change is in general the same as the communication quality indicated in the communication quality adjustment request.
(148) (Step S**310**: Switching Timer Setting Process)
(149) The communication adjustment unit **412** of the wireless relay device **40** sets a switching timer to be activated at the time to change the communication quality.
(150) (Step S**311**: Service Resetting Process)
(151) When it is decided to allow decline in communication quality in Step S**307**, the service provision unit **215** of the driving assistance device **20** resets the driving assistance service as with Step S**216** in FIG. **7**. The service provision unit **215** of the driving assistance device **20** transmits a driving assistance service change notification to notify the control device **30** of a change content of the driving assistance service.

(152) (Step S**312**: Control Method Change Process)
(153) When the driving assistance service change notification is received, the integrity control unit **313** of the control device **30** changes a control method of the moving object **70** in accordance with the change content indicated in the driving assistance service change notification.
(154) (Step S**313**: Resource Allocation Process)
(155) When the switching timer is activated, the communication adjustment unit **412** of the wireless relay device **40** changes the communication quality into the communication quality after change indicated in the communication quality change notification.
(156) As described above, when the quality of end-to-end communication is estimated to decline, the communication adjustment unit **214** of the driving assistance device **20** changes allocation of the communication quality between each of the plurality of control devices **30** and the driving assistance device **20**. In this manner, it is possible to prevent the driving assistance service provided from being unstable due to sudden decline in communication quality while continuing provision of the driving assistance service of a high priority.
(157) <Second Variation>
(158) In the first embodiment, resetting of the driving assistance service is performed in accordance with communication quality in a communication area including a scheduled path after specifying the scheduled path. As the second variation, the scheduled path may be changed in accordance with the communication quality of the scheduled path.
(159) With reference to FIG. **11**, description will be made on a driving assistance process according to a second variation.
(160) The processes from Step S**401** through Step S**405** are the same as the processes from Step S**201** through Step S**205** in FIG. **7**.
(161) (Step S**406**: Quality Request Process)
(162) With respect to the communication area including the scheduled path specified in Step S**405**, the communication adjustment unit **214** of the driving assistance device **20** transmits a quality acquisition request to request communication quality at the scheduled time when the moving object **70** passes through the communication area, to the communication management device **10**. The quality acquisition request indicates a communication area and a scheduled time.
(163) (Step S**407**: Related Information Acquisition Process)
(164) The information acquisition unit **111** of the communication management device **10** acquires, from the information provision device **50**, related information with respect to the communication area indicated in the quality acquisition request, the related information being related to automatic driving such as weather information and road traffic information. The information acquisition unit **111** writes the related information in the storage unit **23**.
(165) (Step S**408**: Quality Estimation Process)
(166) The quality estimation unit **114** of the communication management device **10** sets each communication area indicated in the quality acquisition request as a communication area being an object. Then, the quality estimation unit **114** estimates communication quality at a scheduled time between the driving assistance device **20** and the control device **30** with respect to each communication area, as with the process in Step S**214** in FIG. **7**.
(167) The quality estimation unit **114** transmits a quality acquisition reply to the driving assistance device **20**. The quality acquisition reply indicates communication quality estimated with respect to each communication area indicated in the quality acquisition request.
(168) (Step S**409**: Path Re-Specification Process)
(169) The communication adjustment unit **214** of the driving assistance device **20** specifies necessary communication quality based on a type of the driving assistance service included in a start request of the driving assistance service, as with Step S**206** in FIG. **7**.
(170) The service determination unit **213** decides whether it is necessary to specify again a scheduled path by comparing the communication quality with respect to each communication area

indicated in the quality acquisition reply with the necessary communication quality. When there is a communication area in which the communication quality is lower than the necessary communication quality for providing a standard driving assistance service, the service determination unit **213** determines that it is necessary to specify the scheduled path again. When it is decided that it is necessary to specify the scheduled path again, the service determination unit **213** specifies again, as a scheduled path, a path which does not pass through a communication area in which the communication quality is lower than the necessary communication quality for providing a standard driving assistance service.

(171) (Step S**410**: Communication Start Request Process)

(172) The communication adjustment unit **214** of the driving assistance device **20** transmits a communication start request to the communication management device **10** as with Step S**207** in FIG. **7**.

(173) The processes from Step S**406** through Step S**409** may be repeatedly performed again until it is decided that it is unnecessary to specify the expected path again.

(174) As described above, when there is a communication area in which the communication quality is lower than the necessary communication quality, the service determination unit **213** of the driving assistance device **20** specifies a scheduled path again. This makes it possible to reduce the possibility that the driving assistance service scheduled cannot be provided due to decline in communication quality.

(175) <Third Variation>

(176) In the first embodiment, communication quality for each control device **30** has been estimated. As a third variation, it may be possible to update the learning model **131** by using communication quality estimated for a control device **30**, and communication quality measured by practically making communication by the control device **30**.

(177) With reference to FIG. **12**, description will be made on a quality estimation process according to the third embodiment.

(178) In FIG. **12**, the driving assistance device **20** provides a control device **30** mounted on a moving object **70**A and a control device **30** mounted on a moving object **70**B with a driving assistance service. The moving object **70**A exists in a communication area of a wireless relay device **40**A, and with respect to the control device **30** mounted on the moving object **70**A, communication quality with the driving assistance device **20** regarding the wireless relay device **40**A has been estimated in the past. Further, the moving object **70**A is in the communication area of the wireless relay device **40**A, and with respect to the control device **30** mounted on the moving object **70**A, communication quality with the driving assistance device **20** regarding the wireless relay device **40**A is practically measured.

(179) Then, the communication learning unit **112** of the communication management device **10** makes the learning model **131** learn by using a result of comparison between the communication quality estimated and the communication quality measured, as an input. In this case, the communication learning unit **112** makes the learning model **131** learn using a reinforcement learning method, for example.

(180) In FIG. **12**, the moving object **70**B is in the communication area of a wireless relay device **40**B, and the communication area of the wireless relay device **40** A is included in the scheduled path. Therefore, by using a learning model made to learn by using a result of comparison between communication quality estimated and communication quality measured as an input, with respect to the control device **30** mounted on the moving object **70**B, the quality estimation unit **114** of the communication management device **10** estimates communication quality with the driving assistance device **20** regarding the wireless relay device **40**A.

(181) As described above, the communication learning unit **112** of the communication management device **10** makes the learning model **131** learn by using communication quality estimated with respect to another control device **30**, and communication quality measured by making

communication practically by the other control device **30**. In this manner, it is possible to enhance estimation accuracy of the communication quality.
(182) <Fourth Variation>
(183) In the first embodiment, each functional component is realized by software. However, as a fourth variation, each functional component may be realized by hardware. With respect to the fourth variation, description will be made on points different from those in the first embodiment.
(184) When each functional component is realized by hardware, the communication management device **10** includes an electronic circuit instead of the processor **11**, the memory and the storage unit **13**. The electronic circuit is a dedicated circuit to realize functions of each functional component of the communication management device **10**, the memory **12** and the storage unit **13**.
(185) Similarly, when each functional component is realized by hardware, the driving assistance device **20** includes an electronic circuit instead of the processor **21**, the memory **22** and the storage unit **23**. The electronic circuit is a dedicated circuit to realize functions of each functional component of the driving assistance device **20**, the memory **22** and the storage unit **23**.
(186) Similarly, when each functional component is realized by hardware, the control device **30** includes an electronic circuit instead of the processor **31**, the memory **32** and the storage unit **33**. The electronic circuit is a dedicated circuit to realize functions of each functional component of the control device **30**, the memory **32** and the storage unit **33**.
(187) Similarly, when each functional component is realized by hardware, the wireless relay device **40** includes an electronic circuit instead of the processor **41**, the memory **42** and the storage unit **43**. The electronic circuit is a dedicated circuit to realize functions of each functional component of the wireless relay device **40**, the memory **42** and the storage unit **43**.
(188) As an electronic circuit, it is supposed a single circuit, a composite circuit, a processor made into a program, a processor made into a parallel program, a logic IC, a GA (gate array), an ASIC (application specification integrated circuit) or an FPGA (field-programmable gate array).
(189) Each functional component may be realized by one electronic circuit, or may be realized by a plurality of electronic circuits dispersedly.
(190) <Fifth Variation>
(191) As a fifth variation, a part of each functional component may be realized by hardware, and the other part of each functional component may be realized by software.
(192) The processor **11**, the memory **12**, the storage unit **13** and the electronic circuits are referred to as processing circuitry. That is, functions of each functional component are realized by the processing circuitry.
Second Embodiment
(193) A second embodiment is different from the first embodiment in that when communication quality is estimated to be lower than a range of standard quality, it is notified to the control device **30** via a road-side unit **80** existing around the moving object **70**. In the second embodiment, description will be made on this different point, and description on the same point will be omitted.
(194) ***Description of Configuration***
(195) With reference to FIG. **13**, description will be made on a configuration of a driving assistance system **100** according to the second embodiment.
(196) The driving assistance system **100** is different from the driving assistance system **100** illustrated in FIG. **1** in that it includes a plurality of road-side units **80**. Each road-side unit is connected to the communication network **60** via any wireless relay device **40**.
(197) With reference to FIG. **14**, description will be made on a configuration of the road-side unit **80** according to the second embodiment.
(198) The road-side unit **80** is a sensor system installed on a road side, and is a computer to provide the driving assistance device **20** and the control device **30** with information acquired.
(199) The road-side unit **80** includes hardware components such as a processor **81**, a memory **82**, a storage unit **83** and a communication interface **84**. The processor **81** is connected to other hardware

components via a signal line, and controls these other hardware components. Further, the road-side unit **80** is connected to a sensor **85** such as a camera and a LiDAR via the communication interface **84**.

(200) The road-side unit **80** includes, as functional components, a surrounding information acquisition unit **811**, a surrounding information transmission unit **812**, an assistance information acquisition unit **813** and an assistance information distribution unit **814**. Functions of each functional component of the road-side unit **80** are realized by software.

(201) The storage unit **83** stores a program to realize the functions of each functional component of the road-side unit **80**. This program is read into the memory **82** by the processor **81**, and executed by the processor **81**. In this manner, the functions of each functional component of the road-side unit **80** are realized.

(202) ***Description of Operation***

(203) With reference to FIG. **15**, description will be made on an operation of the driving assistance system **100** according to the second embodiment.

(204) (Step S**501**: Data Communication Process)

(205) Data communication is started between the driving assistance device **20** and the control device **30**. The process until data transmission is started is as described in the driving assistance process indicated in FIG. **7**.

(206) When data communication is started, the surrounding information acquisition unit **811** of the road-side unit **80** collects information around the road-side unit **80** by the sensor **85**. The surrounding information acquisition unit **811** analyzes the information collected, and specifies a type of a surrounding object. The type of object is a vehicle, a pedestrian, an animal, and an obstacle such as a falling object, etc. Further, the surrounding information acquisition unit **811** specifies a type of a vehicle. The type of the vehicle is a passenger car, a truck, and a motorbike, etc. Furthermore, the surrounding information acquisition unit **811** specifies a distance and a direction to the object. Then, the surrounding information transmission unit **812** transmits the information specified to the driving assistance device **20**.

(207) (Step S**502**: Quality Monitoring Process)

(208) As with Step S**102** in FIG. **6**, each wireless relay device **40** and the driving assistance device **20** specify communication quality.

(209) (Step S**503**: Quality Degradation Notification Process)

(210) When the communication quality of the communication network **60** specified in Step S**502** is lower than a lower limit of the range of the standard quality, the communication adjustment unit **113** of the communication management device **10** transmits a quality degradation notification to notify the control device **30** via the road-side unit **80**. That is, when it is decided that communication between the control device **30** and the wireless relay device **40** becomes difficult due to degradation of communication quality, the communication adjustment unit **113** transmits the quality degradation notification to the control device **30** via the road-side unit **80**.

(211) The assistance information acquisition unit **813** of the road-side unit **80** receives the quality degradation notification. Then, the assistance information distribution unit **814** of the road-side unit **80** transmits the quality degradation notification to all the control devices **30** existing in the communication range.

(212) (Step S**504**: Control Method Change Process)

(213) The integrity control unit **313** of the control device **30** receives the quality degradation notification transmitted in Step S**503**. Then, the integrity control unit **313** decides that communication from the driving assistance device **20** ceases, or a delay in communication with the driving assistance device **20** increases, and changes the control method of the moving object **70**.

(214) As a specific example, when a remote operation service of remote-type automatic driving is provided, the integrity control unit **313** displays start of manual driving associated with suspension of the automatic driving function on a display device, etc. mounted on the moving object **70**, and

notifies the driver of the moving object **70** of switching to manual driving. After that, the integrity control unit **313** stops control over apparatuses such as an accelerator, a break and a steering, and switches to control to notify the driver of surrounding information.

Effect of Second Embodiment

(215) As described above, in the driving assistance system **100** according to the second embodiment, when communication quality is actually degraded, it is notified to each control device **30** via the road-side unit **80**. Then, each control device **30** switches the control method of the moving object **70** upon receipt of the notification. In this manner, it is possible to realize suitable control in accordance with communication quality.

(216) “Unit” in the description above may be replaced with “circuit”, “step”, “procedure”. “process” or “processing circuit”.

(217) The above describes the embodiments and the variations of the present invention. It is also applicable to combine and perform some of these embodiments and variations. Further, it may be applicable to partially perform one or some. The present invention is not limited to the embodiments and the variations described above, for which various alterations are possible as needed.

REFERENCE SIGNS LIST

(218) **100**: driving assistance system; **10**: communication management device; **11**: processor; **12**: memory; **13**: storage unit; **14**: communication interface; **111**: information acquisition unit; **112**: communication learning unit; **113**: communication adjustment unit; **114**: quality estimation unit; **115**: notification unit; **131**: learning model; **132**: area information; **20**: driving assistance device; **21**: processor; **22**: memory; **23**: storage unit; **24**: communication interface; **211**: information acquisition unit; **212**: communication monitoring unit; **213**: service determination unit; **214**: communication adjustment unit; **215**: service provision unit; **231**: quality information; **232**: area information; **30**: control device; **31**: processor; **32**: memory; **33**: storage unit; **34**: communication interface; **311**: information acquisition unit; **312**: input reception unit; **313**: integrity control unit; **40**: wireless relay device; **41**: processor; **42**: memory; **43**: storage unit; **44**: communication interface; **411**: communication monitoring unit; **412**: communication adjustment unit; **50**: information provision device; **60**: communication network; **70**: moving object; **80**: road-side unit; **81**: processor; **82**: memory; **83**: storage unit; **84**: communication interface; **85**: sensor; **811**: information acquisition unit; **812**: information transmission unit; **813**: assistance information acquisition unit; **814**: assistance information distribution unit

Claims

1. A communication management device comprising: processing circuitry to: estimate a communication quality between a control device that is mounted on a moving object and a driving assistance device to provide a driving assistance service for the control device, at a scheduled time when the moving object passes through a communication monitoring area, which includes a scheduled path where the moving object passes, notify the driving assistance device when the estimated communication quality is outside a range of a standard quality, and estimate the communication quality prior to the scheduled time by a time equal to or more than a change time necessary for changing the driving assistance service provided by the driving assistance device.

2. The communication management device according to claim 1, wherein the processing circuitry estimates the communication quality in consideration of a quality statistic that indicates a quality of communication in the past and a control condition in the past with respect to the communication monitoring area, and of a scheduled condition that indicates the control condition at the scheduled time with respect to the communication monitoring area.

3. The communication management device according to claim 2, wherein the processing circuitry estimates the communication quality by using a learning model that is generated by using the

quality statistic as an input, the learning model outputting an estimated value of the quality of communication by using the control condition as an input.

4. The communication management device according to claim 3, wherein the processing circuitry makes the learning model learn by the estimated communication quality, and by a quality of communication that is measured when the moving object passes through the communication monitoring area.

5. The communication management device according to claim 1, wherein the moving object is a vehicle, and wherein the processing circuitry notifies the control device when the communication quality is lower than a lower limit of the range of the standard quality, via a road-side unit that exists around the moving object.

6. A communication management method comprising: estimating a communication quality between a control device that is mounted on a moving object and a driving assistance device to provide a driving assistance service for the control device, at a scheduled time when the moving object passes through a communication monitoring area, which includes a scheduled path where the moving object passes, notifying when the communication quality estimated is outside a range of a standard quality, and estimating the communication quality prior to the scheduled time by a time equal to or more than a change time necessary for changing the driving assistance service provided by the driving assistance device.

7. A non-transitory computer readable medium storing a communication management program to make a computer function as a communication management device to perform: a quality estimation process to estimate a communication quality between a control device that is mounted on a moving object and a driving assistance device to provide a driving assistance service for the control device, at a scheduled time when the moving object passes through a communication monitoring area, which includes a scheduled path where the moving object passes, and a notification process to notify when the communication quality estimated by the quality estimation process is outside a range of a standard quality, wherein in the quality estimation process, the communication quality is estimated prior to the scheduled time by a time equal to or more than a change time necessary for changing the driving assistance service provided by the driving assistance device.

8. A driving assistance device to provide a driving assistance service for a control device that is mounted on a moving object, the driving assistance device comprising: processing circuitry to: determine a type of the driving assistance service provided for the control device, based on a communication quality with the control device at a scheduled time when the moving object passes through a communication monitoring area, which includes a scheduled path where the moving object passes, and provide the control device with the determined driving assistance service of the type.

9. The driving assistance device according to claim 8, wherein the processing circuitry acquires quality information that indicates the communication quality, and determines the type of the driving assistance service again based on the communication quality indicated in the quality information when the acquired quality information.

10. The driving assistance device according to claim 8, wherein the processing circuitry provides the driving assistance service to a plurality of control devices, and the processing circuitry adjusts a communication resource that is allocated to communication with each of the plurality of control devices based on the communication quality, the communication resource being used to provide the driving assistance service for each of the plurality of control devices.

11. The driving assistance device according to claim 10, wherein the processing circuitry reduces a communication resource allocated to communication with a control device that is provided with a driving assistance service of low priority among the plurality of control devices, and increases a communication resource allocated to communication with a control device with which the communication quality is lower than a lower limit of a range of a standard quality.

12. The driving assistance device according to claim 8, wherein the processing circuitry changes

the scheduled path in accordance with the communication quality.

13. A driving assistance method to provide a driving assistance service for a control device that is mounted on a moving object, the driving assistance method comprising: determining a type of the driving assistance service that is provided for the control device, based on a communication quality between the control device and a driving assistance device at a scheduled time when the moving object passes through a communication monitoring area, which includes a scheduled path where the moving object passes, and providing the control device with the driving assistance service of the type determined.

14. A non-transitory computer readable medium storing a driving assistance program to make a computer function as a driving assistance device, providing a driving assistance service for a control device that is mounted on a moving object, the driving assistance program performing: a service determination process to determine a type of the driving assistance service that is provided for the control device, based on a communication quality between the control device and a driving assistance device at a scheduled time when the moving object passes through a communication monitoring area, which includes a scheduled path where the moving object passes, and a service provision process to provide the control device with the driving assistance service of the type determined by the service determination process.