DETERMING ENVIRONMENTAL CONTEXT FOR GNSS RECEIVERS

TECHNICAL FIELD

The present disclosure relates to positioning systems, and in particular to receivers that determine a location of the receiver based on signals from satellites in orbit around a planet, such as the Global Navigation Satellite System (GNSS) on planet Earth. The present disclosure further relates to finely determining a specific environmental context of a standard GNSS receiver using statistical information of received GNSS signals and machine learning tools.

BACKGROUND

In recent years, with the rapid evolvement of smartphones, there has been increasing demand for location based services (LBS). The backbone of such services is a GNSS receiver embedded in a portable device such as a smartphone of a user. The GNSS receiver may be capable of receiving signals from satellites belonging to any one or any combination from satellites belonging to satellite systems such as Global Positioning System (GPS), Beidou Navigation Satellite System, Global Navigation Satellite System (GLONASS), Galileo, IRNSS/NavIC etc. The GNSS receiver can provide accurate and timely location information. Inside a GNSS receiver there is an acquisition engine responsible for coarse search of satellites, and a tracking engine which is responsible for fine search and tracking of signals.

However, due to challenging physical environments and design constraints, the obtained location information may be offset. For example, in urban areas where there are many high-rise buildings, the received satellite signal(s) may come from building reflection. As a result, the distance information obtained by the GNSS receiver is inaccurate, and so is the location. To combat this, several software algorithms, which are resource consuming, have to be activated to remove such bad signals to improve location accuracy. On the other hand, when the receiver is in clear open sky, such as the countryside, good location information can be well anticipated, to the extent that

some of the hardware resources can be switched off to save power. The GNSS receiver itself is a high power drain, for example around 100mW, which is noticeable in battery-powered portable devices such as a mobile phone.

To strike a balance between location accuracy and resource usage, information on environmental context is used. The environmental context relates to the receiving environment of the GNSS receiver. Environmental contexts may be divided into indoor environment and outdoor environment. These types may then be subdivided into subcategories such as indoor – parking garage, indoor – tunnel, outdoor – open sky, outdoor – under obstruction such as bridge/viaduct, outdoor – built up area. The information on environmental context is used in order to facilitate the decision-making process within the GNSS receivers.

Conventional solutions for determining the environmental context may be divided into types according to their respective technical approach. A first type is based on the GNSS received signals only. A second type uses additional hardware.

The first type of conventional solutions is capable of detecting a specific indoor environment only. This specific environment is usually a vehicle, in which the GNSS receiver is located, entering a parking garage. This is determined as follows.

The GNSS receiver monitors the Signal to Noise (SNR) or similarly, carrier to noise spectral density (C/N_O), of the satellites transmitting the GNSS signals. Specifically, the GNSS receiver separately monitors the SNR for high elevation satellites (90 degrees to 60 degrees), medium elevation satellites (60 degrees to 30 degrees) and low elevation satellites (less than 30 degrees). The GNSS receiver is then able to compare the SNR values of the high elevation satellites, medium elevation satellites and low elevation satellites to each other in order to determine if the vehicle is in an open sky scenario or is located in a parking garage.

In an open sky scenarios, there is an expectation in prior research that high elevation satellites have the highest SNR, medium elevation satellites have the medium SNR and low elevation satellites have the lowest SNR. Such correlation will be hugely distorted if the user is entering a parking garage.

This relies on the following assumptions:

i. high and medium elevation satellites experiences obstruction and their SNR drops considerably; and

ii. low elevation satellites experiences little or no obstruction, as a parking garage typically includes at least one side opening (e.g., open to the sky).

By detecting the SNR change of each category, the receiver is supposed to be capable of determining the specific context when the user is entering a garage.

The moment the GNSS receiver detects an entry to parking garage, the GNSS receiver will label the location. After that, it will suppresses GNSS position output, as in a blocked environment such as parking garages, position fixes are usually highly inaccurate. The GNSS receiver will resume outputting position fixes only when it detects that the computed location is very close to the previously labeled position, as this indicates the exit from the parking garage.

The first type of conventional solution may also be able to identify extreme cases such as indoor/in-tunnel contexts from the SNR. For example, that all satellites have SNR lower than unusable thresholds indicates the environment could be an indoor or in-tunnel environment.

In a second type of conventional solution, camera and image processing techniques are used to extract environmental information from photos taken. 3D maps and light sensors may also be used to assist in obtaining context information.

Such sensors mainly include inertial sensors (e.g., gyroscopes, accelerometers), light sensors, barometers and thermometers to determine whether the GNSS receiver is in indoor or outdoor environments.

For gyroscopes and accelerometers, they are jointly used to determine the user dynamics. When the value of accelerometer exceeds some threshold, the user is considered to be moving. Given that the user is moving, gyroscopes are used to count how many "effective turns" the user has made during a given time interval. In general,

frequent turns indicate an indoor environment while infrequent turns indicate an outdoor environment. The thresholds for moving/static using accelerometers and for turn counter using gyroscopes can be pre-trained using empirical data.

Other sensors include light sensor, barometer and thermometer. These sensors makes use of the fact that light intensity, atmospheric pressure and temperature are distinctly different between indoor and outdoor environments.

SUMMARY

Conventional solutions for determining the environmental context are confined to specific use-case scenarios as explained herein. In general, they also suffer from additional cost, complexity and consume power.

In more detail, the said first type of conventional solution is primarily used for detecting a specific context only, i.e., entering a parking garage. Thus said conventional solution is unable to differentiate among different contexts in an outdoor environment such as urban/CBD and blockage areas (such as under-flyover). Further, the inventors have found that there is an assumption that there is strong correlation between SNR and elevation in a "default" scenario which cannot be generally justified. Since in actual applications, such correlation almost does not exist, especially in GNSS receivers in smartphones where SNR could be affected by antenna design, user gesture and phone orientation.

In the said second type of conventional solution, the sensors can only differentiate between indoor and outdoor environment but are usually unable to further differentiate among different types of outdoor environments. Further, the use of sensors typically requires calibrations and thresholds used are usually application-specific. These may not suitable for GNSS receivers in certain mobile devices. Deploying an additional sensor(s) has a corresponding increase in cost, hardware complexity and power.

In contrast, embodiments of the present disclosure provide methods, apparatus, and computer programs that enable finely determining environmental contexts from

received GNSS signals. This may be without using additional hardware, such as sensors, or processing images. Further, embodiments of the present disclosure that are not using additional hardware have substantially no increase in power consumption compared to a conventional GNSS receiver, as they may make use of by-product information produced from a GNSS receiver. There is thus substantially no consumption of additional power, except the negligible portion of running the model In certain embodiments, a plurality, e.g. three or more, of environmental contexts can be determined with high accuracy, such as 95% accuracy or above.

Herein, "and/or" indicates three possibilities of either each option independently or both together e.g. A and/or B may indicate any one of A, B or both of A and B.

According to one aspect, the present disclosure provides a method of determining environmental context for a Global Navigation Satellite System (GNSS) receiver, comprising

- Providing a set of characteristic features of received Global Navigation Satellite System (GNSS) signals to a computational model; and
- Determining, by the computational model, a specific environmental context of the GNSS receiver according to the set of characteristic features of the received GNSS signals.

The method may further comprise, before providing:

- Processing the received GNSS signals to obtain the set of characteristic features of the received GNSS signals.

A Global Navigation Satellite System (GNSS) receiver may comprise a receiver capable of receiving signals from any group of satellites that send a time-based signal which is used for determining location on or near to a planet's surface. Preferably the GNSS receiver may receive a signal from the satellites which comprise the GNSS system, such as GPS, Beidou, GLONASS, Galileo, but may be capable of receiving less than all of these systems, e.g. a GPS-only receiver.

The GNSS receiver may obtain GNSS signals from an antenna, as are known to the skilled person. The GNSS receiver may be located in a mobile device e.g. a smartphone.

When GNSS signals are received, the characteristics of the signals can be obtained. Such information typically includes signal-to-noise ratio (SNR, or carrier-to-noise ratio, C/N0), number of satellites received, geometry distribution of each satellite (e.g., elevation and azimuth), pseudorange and Doppler measurements, multipath indicators (e.g., extracted from correlation peak shape). These may constitute raw data. These characteristics of the received signals may be obtained by the GNSS receiver. The characteristic features may comprise suitably transformed or raw data from the characteristics of the signals.

By processing, a statistical analysis may be performed on the raw data to obtain the set of characteristic features. Various types of statistical processing or transformations may be performed. A "set" may refer to a group of characteristic features, but does not imply that they are grouped, stored or input together or at the same time necessarily.

The computational model may take various forms. In principle, any computational model which can learn to categorize, with high accuracy, the environmental context based on the provided inputs may be used.

The computational model may be a neural network. For example, an artificial neural network with two hidden layers. Each layer may have 8 nodes. The input layer may have 8+7+2 nodes, and the output layer outputs the probabilities for each context. Altogether there may be 4 layers in the neural network Different number of hidden layers or with different types of activation functions can also be used.

As another example, the computational model can also take a polynomial form such as $R = x_1*F_1 + x_2*F_2 \ldots + x_n*F_n$ where x_i is trained coefficient and F_n is the input features.

The neural network may be provided on the performing entity e.g. the GNSS receiver, or in an application processor of a mobile device.

Other machine learning models can be used for the computational model, which include but are not limited to decision tree, support vector machine, logistic regression, random forest, as are known to the skilled person.

A suitable training dataset may be used to train the computational model. This may a one-time offline process to obtain trained parameters for the computational model. The training enables the real-time environmental context recognition.

The training process may involve first collecting representative samples of GNSS signals with known contexts. These can be compiled into training data, which has been collected across different cities with different modes (e.g., driving/walking) in different environments to provide reliable data. With known inputs and outputs, the training of the neural network may be completed by basic backward propagation using e.g. Gradient descent or similar optimization techniques known to the skilled person.

The method provides an accurate determination of the environmental context using analysis of received GNSS signals.

In a possible design, the computational model determines the specific environmental context from a group of environmental contexts comprising: a first outdoor context, a second outdoor context, and a third outdoor context.

An outdoor context is considered the opposite of an indoor context. An indoor context is one which has no signal or signal below usable SNR threshold. An outdoor context may be an environment in which the receiver is currently located which is fully or partially open to the sky.

The first outdoor context may be an open sky context. This may be in open countryside with no buildings, or sparse or comparatively low building height and/or density. Similarly, the topography may be substantially flat e.g. not a mountainous

area. An open sky context represents one extreme of a range where satellite reception may be expected to be optimal. In an open sky context, there is generally almost no obstruction of signals.

The second outdoor context may be a dense urban context. In a dense urban context a significant proportion of the sky above and around a receiver located at or near local ground level may be obscured by buildings such as high rises, skyscrapers, malls etc. When the receiver is on a street in the dense urban context, said context may be also referred to as an urban canyon. An urban canyon may be defined by the term "aspect ratio". The aspect ratio is determined by the building height to street width. For a CBD scenario, the aspect ratio may be at least 2 (a.k.a. deep canyon). Satellite signals are typically obstructed by or reflected from buildings: reflected signals may be a characterizing feature of a dense urban context. This may be typified by any major city's Central Business District (CBD), such as Lujiazui in Pudong area of Shanghai in China.

The third outdoor context may be a blockage area, such as under a viaduct, flyover or bridge. Compared to the second outdoor context, an even larger proportion of the sky may be obscured. For example, the sky directly above the receiver may be blocked by the viaduct when the receiver is under the viaduct.

By accurately determining between three different outdoor contexts, further actions can be taken. For example, if an open-sky context is detected, the GNSS receiver can switch to low-power mode without compromising the performance.

If an urban-area context is detected, additional multipath-detection modules in a GNSS receiver will be activated, which ensures good accuracy of the receiver in such areas. Position uncertainty reported by the receiver can be made to reflect the actual signal conditions.

If a blockage area is determined, knowing whether the GNSS receiver is under flyover or on the flyover helps maps properly plan the route. Conventional GNSS receivers

typically struggle in such environments as these two could have almost the same latitude and longitude.

In a possible design, the group of environmental contexts further comprises: a first indoor context.

A first indoor context may be an indicator of a general indoor context – such as that found inside a building, inside a garage, inside a tunnel, inside a fully confined basement,– . These may have a very weak signal from only a reduced number of satellites, which may be less than the total number of satellites typically used for certain operations, as discussed below. There may be substantially no signal from other satellites.

Other indoor context which may be an indoor context are such as inside an apartment near a window, where a minimal level of usable signal may be received.

By detecting an indoor context or a specific indoor context, further optimization actions can be performed. For example, when indoor/garage mode is detected, an acquisition engine of the GNSS receiver can also be further optimized or actions taken in the GNSS receiver.

In a preferred, practical implementation, not only can the method determine between a first indoor context and another context, but can also distinguish between different subtypes of that another context, such as first, second and third outdoor contexts.

In a possible design, the group of environmental contexts further comprises: a second indoor context.

A second indoor context may be a specific indoor context which is different to the first indoor context – such as inside a building, inside a garage, inside a tunnel, inside a fully confined basement. These may have substantially no usable signal.

The minimal/usable level of signal strength varies from receiver to receiver. Herein, for each satellite signal received, the carrier-to-noise ratio being greater than 10 db*Hz is considered as a usable signal. Other thresholds for or measurements of the signal may be used.

The first indoor context may have a reduced number of usable satellites whose signal each equals or exceeds the minimal level of usable signal. Typically, this will be a few satellites only. For example, the number of usable satellites is less than the minimal number of satellites required to get a position fix (e.g., 4 satellites in the event of GPS-only mode and 3+N when N constellations are involved.)

For the second indoor context, no satellites will have a usable signal.

In a possible design, the said characteristic features are obtained (e.g. by processing, as maybe for all the obtaining steps relating to the characteristic features) by statistically extracting three features of received GNSS signals to form three characteristic features for received GNSS signals.

The set of characteristic features may comprise the at least three characteristic features. In one embodiment, only three characteristic features may be used, and no others for comparatively faster and efficient computation. In other embodiments, other characteristic features may be used. The same characteristic features may be used for each of the received GNSS signals so that for each signal the same type of characteristic features are obtained as inputs for the computational model.

The features may be extracted from at least one, some or each of the received GNSS signals to form corresponding characteristic features.

In a possible design, the said determining comprises selecting the specific environmental context to correspond to an output of the computational model having a higher probability compared to other outputs of the computational model. This may mean that the most likely environmental context, out of provided possible environmental contexts, is selected as the actual environmental context.

In a possible design, the set of characteristic features comprises statistical information corresponding to satellite angle, satellite signal strength and multipath indicator. In a preferred design, only these characteristic features are used as input.

Satellite angle and satellite strength are typically available at conventional GNSS receivers.

In a possible design, the set of characteristic features further comprises one or more of statistical information comprising number of satellites in tracking.

Using statistical information about the number of satellites in tracking may improve accuracy. In general, the more satellites in tracking, the less blocked the area is. In particular, the notion of "acquisition ratio", which is determined by the number of satellites in tracking to the number of satellites presently available in a given location, could be used to indicate the blockage from the surroundings. The higher the ratio, the less blocked the environmental context is.

In a possible design, the satellite angle comprises azimuth angle or elevation angle.

Either or both of azimuth angle and elevation angle may be used. Using both may improve the accuracy. Elevation angle may be a comparatively better indicator of an urban context or blockage area context, as when there is obstruction e.g. from high-rises, some or all low-elevation signal will be blocked.

In a possible design, the satellite signal strength comprises signal to noise ratio (SNR) or carrier to noise ratio (C/NO).

Either or both of SNR and C/NO may be used. Using both may improve the accuracy. Signal strength is a practical indicator of context. For example, in open sky, most of the received GNSS signals have a C/N0 of 40-45 dbHz. If the actual signal profile is far below this, the environmental context may not be an open sky scenario.

In a possible design, the method e.g. the processing comprises

obtaining statistical information characterizing the satellite angle or satellite signal strength, comprising

obtaining a plurality of states having an associated probability for each of the satellite angle and satellite signal strength.

In a possible design, obtaining the statistical information comprises

obtaining a probability distribution for the received GNSS signals, and

obtaining an indicator for each received GNSS signal to determine the presence of multipath.

Here, obtaining may be performed by calculation or computation. The indicator may indicate the presence or not of multipath.

The probability distribution may be over all or a part of a range of angles or signal strengths of the received GNSS signals. The probability distribution may be obtained for each received GNSS signal, or a subset thereof. The probability distribution may correspond to the states, e.g. such that a distinct probability is assigned to each discrete state.

In a possible design, the method e.g. processing comprises:

for each time unit, given a number N of satellites which are sources of received GNSS signals, obtaining the probability of distribution for C/N0, elevation angle and multipath indicator; and

the probability for each category is obtained.

The time unit may be seconds.

The number N may be satellites in tracking, and may be an integer with a value of 1 or more. If N satellites are acquired, they may all be used. N could range from 1 to as many as possible. An upper bound on N is the number of satellites that can be acquired in a very open sky context. The exact upper number of N is of evolving nature, as more and more satellites are being launched, and is not limited. Currently, N may take the max value of 40 to 50, depending on locations as well.

In a possible design, the said processing comprises for C/NO and for elevation angles, probability distribution of each is divided into probability bins.

The terms "categories" and "bins" may be used interchangeably herein and may have equivalent meaning.

A probability is allocated to each bin. This may be achieved by calculating the number of occurrences for each bin and then normalized by the total number of satellites.

For example for elevation, compute the number of satellites falling into Bin1, Bin2, Bin3.... etc. Then this is normalized by the total number of satellites, and so the probability for each bin is obtained.

The bins may be the same size or heterogeneous. Cumulatively the range of all of the bins may equal a whole range of the relevant characteristic of the GNSS signal.

Other forms of statistical processing such as the max, min, standard deviation may be used as alternatives to probability bins and distributions, as they may also be indicative of characteristics of the environmental contexts.

In a possible design, the said processing comprises there are seven probability bins for each of the probability distributions.

Other numbers of probability bins may be freely chosen and the invention is not so limited.

In experiments, seven probability bins for one or both of the probability distributions has proven to be effective.

In a possible design, the said processing comprises

for C/N0, the C/N0 range is divided into said 7 categories being:

[0-10; 10-18; 18-23; 23-28; 28-33; 33-38; 38-50];

for elevation angles, the range of 0-90 degrees is divided into 8 categories being: [0-14;14-24;24-34;34-44;44-54;54-64;64-74;74- 90].

The numbers in square parentheses are ranges of each bin, where the bins are shown for convenience in ascending order of value of the end points of each bin.

For C/NO, the normalized probability of each category may be computed for the current second. Other suitable rates may be used.

For elevation angles, the normalized probability of each category may be computed for the current second. Other suitable rates may be used.

Other end limits of the probability bins may be chosen.

In a possible design, such as comprised in the said processing, the method comprises for multipath indicators, two categories are used which indicate multipath and not multipath respectively. These may be achieved by indicators e.g. flags or being_multipath and is_not_multipath respectively, or by other means

is_multipath indicates that the signal is multipath, and is_not_multipath indicates the signal is not multipath.

When the above steps are executed, 17 states (7+8+2 probabilities) characterizing the GNSS received signals for a particular second can be obtained. This may serve as the input for the computational model.

In a possible design, the method is performed by only one of: a GNSS receiver, an application processor such as of a mobile phone, a software application, a GNSS receiver and an application processor of a mobile phone, a GNSS receiver and a software application.

The method may be performed without using input from additional hardware. In particular, the method may be performed without using any additional sensory hardware.

For example, the method may be performed without using sensors or input from image analysis. Sensors may include: transducers, cameras, light sensors, inertial sensors (e.g., gyroscopes, accelerometers), barometers and thermometers. The method may also be performed with input from additional sensory hardware, such as said sensors if available, but comparatively greater weight may be placed on the characteristic features of the received GNSS signals in making the determination of environmental context.

The method may be performed by the GNSS receiver in conjunction with the application processor.

The method may be performed by using the received and processed GNSS signals only.

In the case of the application processor such as a CPU, the relevant GNSS-related information (the relevant information comprising the set of characteristic features comprising e.g. statistical information corresponding to satellite angle, satellite signal strength and multipath indicator) is supplied to the CPU.

The relevant GNSS-related information may be reported to an operating system e.g. Android platform, in which case the method can also be performed by App/Apk such as Maps, navigation apps in the platform instructing relevant hardware.

In embodiments, the method of the invention has been experimentally validated to have a detection accuracy for three outdoor contexts of over 95%.

In a possible design, the method further comprises:

Performing an optimization action according to the specific environmental context of the GNSS receiver, wherein the optimization action comprises one or more of: performing satellite acquisition, performing baseband resource allocation, switching to an energy-saving mode, switching

to a higher energy mode, activating multipath-detection module, determining GNSS receiver location, determining a route plan in a navigation application.

In a possible design, the method further comprises:

Re-determining or predicting, according to the specific environmental context of the GNSS, a location of the GNSS receiver.

According to one aspect, the present disclosure provides a Global Navigation Satellite System (GNSS) receiver, comprising a GNSS receiver configured to perform any or all steps of the methods. The GNSS receiver may perform these steps by itself.

The GNSS receiver may be a physical hardware module, unit or chip comprising circuitry. The GNSS receiver may be located inside or providing output to a mobile device or a module, unit or chip inside the mobile device, such as an application processor or navigation module.

In the several embodiments provided in the present disclosure, it should be understood that the disclosed apparatuses and methods may be implemented in other manners. For example, the described apparatus embodiments are merely an example. For example, the unit division is merely logical function division and may be other division in actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be omitted or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be indirect couplings or communication connections between some interfaces, apparatuses, and units, or may be implemented in electronic, mechanical, or other forms.

The units described as separate parts may or may not be physically separate, and parts displayed as units may or may not be physical units, may be located in one position, or may be distributed. Some or all of the units may be selected according to actual requirements to achieve the objectives of the solutions of the embodiments.

In addition, functional units in the embodiments of the present invention may be integrated into one processing unit, or each of the units may exist alone physically, or two or more units may be integrated into one unit. The integrated unit may be

implemented in a form of hardware, or may be implemented in a form of hardware in addition to a software functional unit.

When the foregoing integrated unit is implemented in a form of a software functional unit, the integrated unit may be stored in a computer-readable storage medium. The software functional unit is stored in a storage medium and includes several instructions for instructing a computer device (which may be a personal computer, a server, a network device, or the like) or a processor to perform some of the steps of the methods described in the embodiments of the present invention. The foregoing storage medium includes any medium that can store program code, such as a USB flash drive, a removable hard disk, a read-only memory (Read-Only Memory, ROM), a random access memory (Random Access Memory, RAM), a magnetic disk, or an optical disc.

It may be clearly understood by persons skilled in the art that, for the purpose of convenient and brief description, division of the foregoing function modules is taken as an example for illustration. In actual application, the foregoing functions can be allocated to different function modules and implemented according to a requirement, that is, an inner structure of an apparatus is divided into different function modules to implement all or part of the functions described above. For a detailed working process of the foregoing apparatus, refer to a corresponding process in the foregoing method embodiments, and details are not described herein again.

Finally, it should be noted that the foregoing embodiments are merely intended to describe the technical solutions of the present invention, but not to limit the present invention. Although the present invention is described in detail with reference to the foregoing embodiments, persons of ordinary skill in the art should understand that they may still make modifications to the technical solutions described in the foregoing embodiments or make equivalent replacements to some or all technical features thereof, without departing from the scope of the technical solutions of the embodiments of the present invention.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a flowchart of a method of detecting environmental context.

FIG. 2 is a block diagram of a GNSS receiver configured to detect environmental context.

FIG. 3 is an illustration of a neural network used in the method of detecting environmental context.

DESCRIPTION OF EMBODIMENTS

To make objectives, technical solutions, and advantages of embodiments of the present invention clearer, the following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to accompanying drawings in the embodiments of the present invention. It will be understood that the described embodiments are some but not all of the embodiments of the present invention. All other embodiments obtained by a person of ordinary skill in the art based on the embodiments of the present invention without creative efforts shall fall within the protection scope of the present invention.

Figure 1 illustrates a method in which the environmental context can be calculated.

First, in step 100, received GNSS signals are processed to obtain a set of characteristic features of the received GNSS signals.

When GNSS signals are received on the user end, the characteristics of the signals can be retrieved. Such information typically includes signal-to-noise ratio (SNR, or carrier-to-noise ratio, C/N0), number of satellites received, geometry distribution of each satellite (e.g., elevation and azimuth), pseudorange and Doppler measurements, multipath indicators (e.g., extracted from correlation peak shape). In different environments, the characteristics can be significantly different.

As described in the Summary, the GNSS signals are processed to obtain statistical information.

In this embodiment (others may differ), the processing comprises:

i. For each second, given the N satellites in tracking, compute the probability of distribution for C/N0, elevation angle and multipath indicator
ii. For C/N0, the possible C/N0 range is divided into 7 categories i.e. spaced bins: [0 10; 10 18; 18 23; 23 28; 28 33; 33 38; 38 50]. The normalized probability

of each category is computed for the current second

iii. For elevation angles, the possible range (0-90 degrees) is divided into 8 categories of degrees: [0 14;14 24;24 34;34 44;44 54;54 64;64 74;74 90]. The normalized probability of each category is computed for the current second

iv. For multipath indicators, two categories are used: is_multipath and is_not_multipath. The probability for each category is computed.
Given N satellites with M of them affected by multipath, the probability will be M/N

When the above steps are executed, 17 states (7+8+2 probabilities) characterizing the GNSS received signals for a particular second can be obtained. This serves as the input for the classification model described below.

Then, in step 200, the the set of characteristic features of the received GNSS signals are provided to a computational model.

The computational model then determines 300 a specific environmental context of the GNSS receiver according to the set of characteristic features of the received GNSS signals.

Using the abovementioned states, the computational model is a classifier which aims to determine the environmental context: whether the user is in open sky, urban areas (e.g., dense urban) or blockage area (e.g., under-flyover). Such classification is achieved by making use of an artificial neural network. A generic neural network 600 with 2 hidden layer suitable for this embodiment is shown in Figure 3.

Each input node is connected to every node in the first hidden layer by multiplying a weight and a bias. From perspectives of nodes from the hidden layer, it takes the aggregated weighted sum of previous nodes, i.e., $f_0(X) = W_0 X + b_0$, where X is the input and W_0 and b_0 are both vectors representing the weights and biases.

Followed by this linear mapping, an activation function featuring the non-linearity of the neural network is applied. In the proposed invention, a ReLu (Rectified Linear

Unit) activation function is used, which takes the form of $R(z) = max(0, z)$.

After the activation functions, nodes in hidden layer acts as a new input for the next round of propagation. This continues until the output layer. In output layer, a normalized exponential function is used, which maps the M values to M probabilities that add up to 1. The context category that is associated with the largest probability will be chosen the correct environmental contexts.

For an effective neural network implementation, that the weights and biases should be trained and tuned properly. In this embodiment, this training process was started by collecting representative samples of GNSS signals with known contexts to form a proprietary training dataset. Such training data is collected by operating a GNSS receiver across different cities with different modes (e.g., driving/walking) in different environments to ensure the data are reliable. The GNSS-related information is logged (i.e., such information forms the data). The data such as CN0 and elevation are available in any GNSS receiver. The skilled person can readily collect similar data to form the training dataset by using either a GNSS receiver or software/application that has access to GNSS-related data (e.g., Google maps) and perform the same operations as described above. With known inputs and outputs, the training of network is completed by basic backward propagation using Gradient descent.

Figure 2 illustrates how the GNSS receiver 400 may obtain the GNSS satellite signals and via statistical analysis convert them into characteristic features. These are then input into machine learning to obtain recognition results which accurately determine the context. This is performed in the GNSS receiver 400.

The results may then be used in the GNSS receiver 400 to optimize satellite acquisition strategy or baseband resource allocation.

In addition or alternatively, the results may be provided to an application processor 500 to optimize position using a navigation module.

The results may be used in other ways as described herein.

Table 1 illustrates classification results in Shanghai in an embodiment of the invention. The figures are percentages.

Number		classification		
		CBD	open sky	under viaduct
actual	CBD	13535	40	3
	open sky	61	4377	18
	under viaduct	247	52	6548

TABLE 1

Table 2 illustrates the number of tests on from which the data in Table 1 calculated.

Number		Classification		
		CBD	Open sky	under viaduct
Actual	CBD	99.68	0.29	0.03
	Open sky	1.37	98.23	0.40
	Under viaduct	3.61	0.76	95.63

TABLE 2

The foregoing disclosure merely discloses exemplary embodiments, and is not intended to limit the protection scope of the present invention. It will be appreciated by those skilled in the art that the foregoing embodiments and all or some of other embodiments and modifications which may be derived based on the scope of claims of the present disclosure will of course fall within the scope of the present disclosure.

CLAIMS

We claim:

1. A method of determining environmental context for a Global Navigation Satellite System (GNSS) receiver, comprising:
    - providing a set of characteristic features of received Global Navigation Satellite System (GNSS) signals to a computational model; and
    - determining, by the computational model, a specific environmental context of the GNSS receiver according to the set of characteristic features of the received GNSS signals

    wherein said determining comprises selecting the specific environmental context to correspond to an output of the computational model having a higher probability compared to other outputs of the computational model.

2. The method according to claim 1, wherein the computational model determines the specific environmental context from a group of environmental contexts comprising: a first outdoor context, a second outdoor context, and a third outdoor context.

3. The method according to claim 2, wherein the group of environmental contexts further comprises: a first indoor context.

4. The method according to claim 3, wherein the group of environmental contexts further comprises: a second indoor context.

5. The method according to any preceding claim, wherein the said characteristic features are obtained by statistically extracting three features of received GNSS signals to form three characteristic feature for received GNSS signals.

6. The method according to any preceding claim, wherein the set of characteristic features comprises statistical information corresponding to satellite angle, satellite signal strength and multipath indicator.

7. The method according to claim 6, wherein the set of characteristic features further comprises one or more of statistical information comprising number of satellite constellations.

8. The method according to claim 6 or 7, wherein the satellite angle comprises azimuth angle or elevation angle.

9. The method according to any of claims 6-8, wherein the satellite signal strength comprises signal to noise ratio (SNR) and/or or carrier to noise ratio (C/NO).

10. The method according to any of claims 6-9, wherein the set of characteristic features are obtained by:

obtaining statistical information characterizing the satellite angle or the satellite signal strength, comprising

obtaining a plurality of states having an associated probability for each of the satellite angle and the satellite signal strength.

11. The method according to claim 10, wherein obtaining the statistical information comprises

obtaining a probability distribution for the received GNSS signals, and

obtaining an indicator for each received GNSS signal to determine the presence of multipath.

12. The method according to claim 9 when dependent on claim 8 or any of claims 10-11 when dependent on claim 8 and claim 9, comprising:

for each time unit, given a number N of satellites which are sources of received GNSS signals, obtaining the probability of distribution for C/NO, the elevation angle and the multipath indicator.

13. The method according to claim 12, wherein for C/NO and for elevation angles, probability distribution of each is divided into probability bins.

14. The method according to claim 13, wherein there are seven probability bins for each of the probability distributions.

15. The method according to claim 14, wherein

for C/NO, the C/NO range is divided into said 7 bins being: [0 10; 10 18; 18 23; 23 28; 28 33; 33 38; 38 50];

for elevation angles, the range of 0-90 degrees is divided into 8 bins being: [0 14;14 24;24 34;34 44;44 54;54 64;64 74;74 90].

16. The method according to any of claims 12-15, wherein for multipath indicators, two bins are used which indicate multipath and not multipath respectively.

17. The method according to any preceding claim, wherein the method is performed by only one of : a GNSS receiver, an application processor of a mobile phone, a software application, a GNSS receiver and an application processor of a mobile phone, a GNSS receiver and a software application.

18. The method according to any preceding claim, further comprising:

performing an optimization action according to the specific environmental context of the GNSS receiver, wherein the optimization action comprises one or more of: performing satellite acquisition, performing baseband resource allocation, switching to an energy-saving mode, switching to a higher energy mode, activating multipath-detection module, determining GNSS receiver location, determining a route plan in a navigation application.

19. The method according to any preceding claim, further comprising:

re-determining or predicting, according to the specific environmental context of the GNSS, a location of the GNSS receiver.

20. A Global Navigation Satellite System (GNSS) receiver, comprising a GNSS receiver configured to perform any one of the methods of claims 1-19.