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(54) **Method for determining the angular position of a sound source**

(57) The subject method relates to calculating the distance of a sound source in a sound system to a detection centre or to at least one sensor, or the location of such sound source relative to the detection centre or to at least one sensor, and to determining the angular position of the sound source by making use of such calculated distance or location information and the detected signal response provided in a pre-established database. Said database comprises detected signal response data acquired from previously conducted testing for a given sound source, the distance information used in said test-

ing process, and the angular position data of the sound source matching with such data. By using this method, the angular positions of sound sources composing a sound system are accurately determined. This method provides a basis for processes to be executed for enhancing the sound quality of a sound system, and by determining the angular position of the sound source according to the present invention, the actual directions of sound system components are detected so that a full control is provided for the sound system over the sound propagation area.

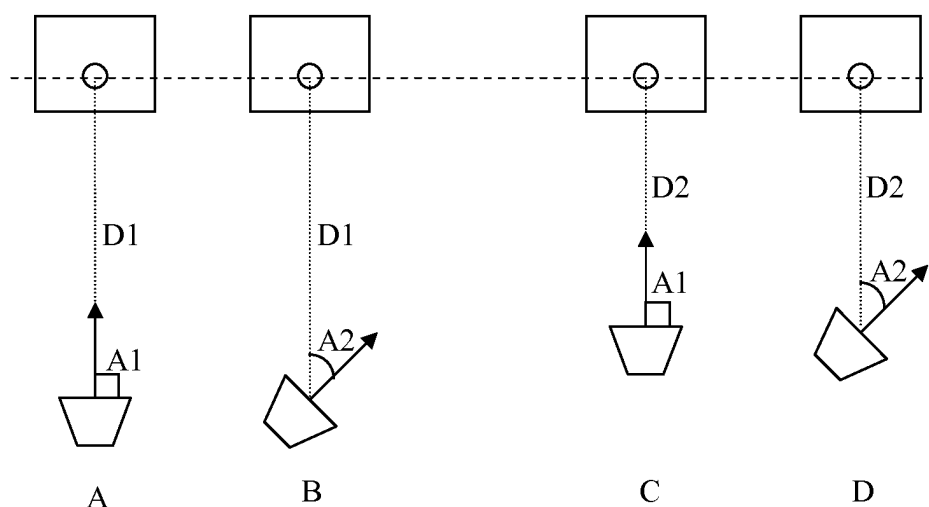


Figure – 2

Description

Technical Field

[0001] The present method relates to calculating the location of or the distance of a sound source in a sound system to a detection centre or to at least one sensor, or to determining the angular position of a sound source by making use of previously gathered distance or location information, the data in the database, and of detected signal response data.

Prior Art

[0002] The basic aim of determining the location and/or angular position of a sound source is to acquire reliable data for use in the processes of enhancing the sound quality of a sound system where a sound source is attached to.

[0003] Up to now, the methods which have been used for calculating a sound source's location were based on conducting distance measurements and on using such calculated distance information to determine the relative locations. The basic distance measurement principle used in such systems are as following: the difference is calculated between the arrival time of a sound originating from a sound source -of which the distance is to be measured- to a sensor provided in the system (typically a microphone) and the reference time created once the sound is originated from the sound source, then such sound arrival time obtained is multiplied with the speed of sound so as to give the distance. This widely used method is deemed inexpensive and reliable. Methods used for determining the location of a sound source are based on the principle of using the distance data between the sound source and each sensor and determining the relative location of the sound source, thanks to employing a plurality of sensors. In systems where the sound source is considered to be positioned in front of the detection centre, at least two sensors are employed for a two-dimensional (i.e. planar) location determination of the sound source, whereas at least three sensors are employed for a three-dimensional location determination. Concerning the systems where the sound source's relative location to the detection centre is considered to be unknown, at least three sensors are employed for the two-dimensional location determination of the sound source, whereas at least four sensors are employed for the three-dimensional location determination.

[0004] In the patent application US2004/0141418A1 is disclosed a method for detecting the distance of a sound source by making use of the signal level difference detected in a system comprising a plurality of microphones.

[0005] Likewise, the patent US6469732B1 discloses a system wherein the position of a speaking participant during a video conference is determined by making use of a microphone array consisting of a plurality of micro-

phones.

[0006] Among the methods which have been developed so far for the purpose of determining the location of a sound source, the method disclosed in the patent US71672043B2 emerges as the most developed one, in which a security camera is claimed to monitor the sound source through a video recorder in the system, by determining the location of the sound source in a three-dimensional space by means of 4 sensors.

[0007] In another method, all elements within a system are equipped with sensors. Thanks to the sensor setup, the relative location is determined more reliably. The patent EP1217661B1 discloses a similar method, wherein the location of devices incorporating their own electromagnetic communication subsystems, sound outputs, and sound receivers are determined. According to this method, the data acquired by detecting the relative distances between individual devices are combined so that the location of each device within the system is determined.

[0008] Said distance measurement and location detection methods vary among themselves according to how the sensors are arranged spatially. The most widely used method is based on placing sensor or sensors on the control panel or subwoofer, which is located at the center of other components of a sound system. Thereby, the relative locations of other sound sources of a sound system are determined.

[0009] Apart from these methods, such measurements can also be conducted according to at least one sensor positioned/carried by the user for user-location based detections. The basic objective here is to enhance the quality of sound delivered to the user, rather than localization, by means of processes conducted in reference to the sound characteristics determined by such sensors.

[0010] Processing by using a database for enhancing the quality of sound in sound systems is a known and implemented method. The data stored on available databases comprise instant impulse response data and the procedures have to be performed. In other words, the data stored in an available database are used in selecting the processes for enhancing the sound quality. The patent application US 2006/0062397A1 disclosing a technique developed for measuring the distance of a subwoofer describes a process making use of a database in sound systems. The database described in this patent application stores sound source characteristics, whereby the signal response detected by a sensor is compared to such sound characteristics so that the distance between the sound source and said sensor is determined.

[0011] No database used so far in sound systems has comprised any data for determining the angular position of a sound source according to the present invention, and no process has been mentioned towards determining the angular position.

[0012] Whilst the known methods and systems referred to hereinabove achieve the determination of relative locations of sound system components, none of such

methods has been oriented so far for determining the angular positions of sound sources within a sound system. Since such known location detection methods do determine the relative locations only, a full and real improvement process cannot be conducted on the sound provided by the sound system. This lack causes a great variation in sound quality with respect to location, since no full control is ensured by the system over the sound propagation area.

Objective of Invention

[0013] The objective of the subject method is to calculate the distance of a sound source in a sound system to a detection centre or to at least one sensor, or the location of such sound source relative to the detection centre or to at least one sensor, and to determine the angular position of the sound source by making use of such calculated distance or location information and the detected signal response provided in a pre-established database. This method provides a basis for processes to be executed for enhancing the sound quality of a sound system, and by determining the angular position of the sound source according to the present invention, the actual directions of sound system components are detected so that a full control is provided for the sound system over the sound propagation area.

Description of Figures

[0014] The subject method is illustrated in annexed figures briefly described hereunder.

Figure 1 is a database example comprising the distance and angle values along with detected results under the testing process for use in a preferred system embodiment according to the subject method. Figure 2 gives some exemplary steps under the testing process.

Figure 3 illustrates the possibility that sound sources with the same detected angular values may have many different locations and different angular positions. (The detected angle is the angle between the normal line of the sound source and the line passing through the sound source's center and the sensor) Figure 4 illustrates the expected locations and expected directions of sound sources in a sound system.

Figure 5 illustrates a method for determining the sound source's location and angular position by combining the different distance and angular values originating from two sensors.

Description of Invention

[0015] The subject method is based on calculating the distance of a sound source in a sound system to a detection centre or to at least one sensor, or the location of

such sound source to the detection centre or to at least one sensor, and on determining the angular position of the sound source by making use of such calculated distance or location information and the detected signal response provided in a pre-established database. Said database comprises detected signal response data obtained from previously conducted tests for a given sound source, the distances used in said test process, and the angular position data of the sound source matching to such information. Thanks to this method, the angular positions of sound sources included within said sound system are accurately determined.

[0016] This method provides a basis for processes to be executed for enhancing the sound quality of a sound system, and by determining the angular position of the sound source according to the present invention, the actual directions of sound system components are detected so that a full control is provided for the sound system over the sound propagation area.

[0017] An exemplary database comprising the distance and angle values along with detected results under the testing process for use in a preferred system embodiment according to the subject method is given in Figure 1.

[0018] The distance data (D1, D2, D3, D4, D5) in Figure 1 refers to the distance between the sensor and the sound source according to how such sources are positioned during the testing process; the angle data (A1, A2, A3, A4, A5) refers to the angle between the normal line of the sound source and the line passing through the sound source's center and the sensor; and the signal responses detected by the sensor (C1, C2, ..., C25) refer to the data to be used together with the distance data in angular position determining process according to the present invention.

[0019] These data may vary according to the detection method. Such data (C1, C2, ..., C25) are not limited to those disclosed, and may further comprise data on amplitude, frequency response, signal characteristics, the ratio between detected signal responses when more than one sound is used at different frequencies during the angular position determination, and the combination thereof. In order to calculate the ratio of the detected signal responses, distinct sounds with different frequencies (e.g. low frequency, high frequency, etc.) are output from the sound source so that the amplitudes of such different sounds as detected by the sensor are compared.

[0020] Said testing process is composed of the following steps as illustrated in Figure 2:

- 1- The sound source is positioned at a certain distance (D1) to the sensor. (Figure 2 - A)
- 2- The angle (A1) between the normal line of the sound source, and the line passing through the sound source's center and the sensor is determined. (Figure 2 - B)
- 3- The signal response (C1) detected by the sensor for the sound output from the sound source is deter-

mined.

4- The procedure is repeated for the distance and angular positions to be measured. (Figure 2-C, D)

[0021] The distance, angle, and detected signal response data obtained by such measurements are used to acquire the data to be stored in the database, which will then be used for determining the location and angular position of sound sources in a sound system.

[0022] The higher the number of measured distance and angular data in the testing process, the closer will be the location and angular position data to the real data of a sound source to be detected according to the subject method.

[0023] The data present in the database may not always provide one-to-one matches with the signal responses detected while the sound source's location and angular position is determined. This case may be eliminated by correlating the data in the database to the detected signal response through a mathematical function.

[0024] The database used in determining the angular position is composed of the distance, sound characteristics, and angular position information used in the testing process.

[0025] As obvious, the test measurement data of a sound source can be determined previously. Therefore such generated database shall be peculiar to such sound source on which the measurements were performed. Separate tests must be conducted for each individual element in the sound system and these data must be kept in special databases for sound sources on which relevant measurements are made.

[0026] Various methods can be used on said database, while the location and angular position is determined according to the present invention. The basic principle to be used in such methods is analogues to the procedure implemented during the testing process. Accordingly, the basic steps of a preferred method are outlined as following:

- 1- The starting time of the sound output is detected by making use of a reference as the sound source outputs the sound.
- 2- The arrival time of the sound as detected by the sensor is compared to the sound's output time so that the sound's arrival time is determined.
- 3- The distance between the sound source and the sensor is determined by making use of the sound's arrival time.
- 4- The angular value matching to this data within the database is detected by referring to the signal response detected by the sensor and to the distance information.

[0027] Concerning the above given processes, only one sensor and only one sound source are taken into account. The data to be acquired by said process is the distance between the sound source and the sensor, and

the angle between the normal line of the sound source and the line passing through the sound source's center and the sensor. As illustrated in Figure 3, the distance (D) and angle (A) data alone are not adequate for determining the location and angular position. There are many different locations and different angular positions present within the same distance with the same detected angular value.

[0028] In order to overcome said problem, either a process may be executed based on some assumptions, or the number of sensors may be increased.

[0029] If there are location and angular position assumptions available for the sound source, any detection to be conducted by means of a single sensor, and the calculations to be based on such detection shall suffice in determining the angular positions of sound sources.

[0030] Such assumptions may be in the form of the expected locations and expected angular positions of a sound source, as depicted in Figure 4.

[0031] In case the subject method is adapted to home cinema systems, said assumptions can conveniently be made. As is known, the aim in home cinema systems is to optimize the sound quality at a certain location by using a plurality of speakers. Previously determined locations such as the front-rear, right-left and the center are availed for this purpose. Nevertheless, it is a preference to face or to direct the speakers within such home cinema systems to the center of such location of optimization.

[0032] Two sensors are provided in an exemplary system according to the present invention. Thus, the distance and angular position data from a single sensor that would be inadequate in exactly determining the location and angle data are made adequate when the different values acquired from both sensors are combined.

[0033] As illustrated in Figure 5, the distance D and angle A detected by the first sensor are coincided with the distance D' and angle A' determined by the second sensor so that the location of the sound source and the angular position are determined.

[0034] As a different method according to the present invention, three or more sensors are utilized to determine the location and angular position of the sound source. In this manner, the location and angular position of a sound source as determined on a two-dimensional space by means of two sensors may be transferred to a three-dimension space. In a system employing three sensors, there shall be left two potential positions for a sound source measured at the three-dimensional space by combining the data obtained from and calculated for each separate sensor. These two positions may be reduced to a single and absolute position by means of an assumption.

[0035] A system employing four sensors, on the other hand, shall suffice in determining the single and real location and angular position of a sound source measured in the three-dimensional space, without necessitating any assumptions. Such an absolute location and angular position can also be determined by using the forth sensor

only for the direction parameter, in place of subjecting it to angular position and distance determination calculations.

[0036] Even if the preferred method according to the present invention system is developed to determine the angular positions of sound sources within sound systems for end users, the same method can also be employed for determining the angular position of any sound source. Such exemplary uses may include, but not restricted to determining the direction of the barrel projecting bullets, missiles etc., the direction of a moving vehicle etc..

[0037] When the sensors are properly selected within the subject method, the direction of signal sources radiating electromagnetic waves -beside the angular positions of sound sources- can also be detected.

Claims

1. A method for determining the angular position of a sound source wherein said method estimates or calculates the distance between a sound source and at least one sensor, and makes use of a database of the sound output from said sound source and detected by the sensor **characterized in that** said method comprising the steps of:

- storing the detected signal response information as data which are acquired in a testing procedure for said sound source, in said database and
- comparing said data in said database to the signal response of the sound output by the sound source and detected by the sensor for determining the angular position of said sound source.

2. The method according to Claim 1, wherein such data in said database comprises, the data on amplitude, frequency response, signal characteristics, the ratio between detected signal responses when more than one sound is used at different frequencies while the angular position is determined, and the combination thereof though not restricted to them.
3. The method according to Claim 1, wherein the data in said database are determined previously.
4. The method according to Claim 1, wherein said database is stored in a memory.
5. The method according to Claim 4, wherein said memory is a non-volatile memory.
6. The method according to Claim 4, wherein said database is pre-established.
7. The method according to Claim 1, wherein said test-

ing procedure is executed previously.

8. The method according to Claim 1, wherein more than one sensor are used and wherein the data associated with signal responses detected by different sensors are compared to determine the angular position of said sound source.
9. The method according to Claim 1, wherein said method is used by a sound system for determining the angular position of at least one sound source used in said sound system.
10. The method according to Claim 9, wherein said sound system comprises different databases for sound sources which have different characteristics.
11. A method for determining the angular position of a sound source wherein said method estimates or calculates the location of a sound source, and makes use of a database of the sound output from said sound source and detected by at least one sensor **characterized in that** said method comprising the steps of;
 - storing the detected signal response information as data which are acquired in a testing procedure for said sound source, in said database and
 - comparing said data in said database to the signal response of the sound output by the sound source and detected by the sensor for determining the angular position of said sound source.
12. The method according to Claim 11, wherein such data in said database comprises, the data on amplitude, frequency response, signal characteristics, the ratio between detected signal responses when more than one sound is used at different frequencies while the angular position is determined, and the combination thereof, though not restricted to them.
13. The method according to Claim 11, wherein the data in said database are determined previously.
14. The method according to Claim 11, wherein said database is stored in a memory.
15. The method according to Claim 14, wherein said memory is a non-volatile memory.
16. The method according to Claim 14, wherein said database is pre-established.
17. The method according to Claim 11, wherein said testing procedure is executed previously.

18. The method according to Claim 11, wherein more than one sensor are used and wherein the data associated with signal responses detected by different sensors are compared to determine the angular position of said sound source.
19. The method according to Claim 11, wherein said method is used by a sound system for determining the angular position of at least one sound source used in said sound system.
20. The method according to Claim 19, wherein said sound system comprises different databases for sound sources which have different characteristics.
21. A method for determining the angular position of a signal source wherein said method estimates or calculates the location of a signal source, and makes use of a database of the signal output from said signal source and detected by at least one sensor **characterized in that** said method comprising the steps of;
- storing the detected signal response information as data which are acquired in a testing procedure for said signal source in said database, and
 - comparing said data in said database to the signal response of the signal output by the signal source and detected by the sensor for determining the angular position of said signal source.
22. The method according to Claim 21, wherein such data in said database comprises, the data on amplitude, frequency response, signal characteristics, the ratio between detected signal responses when more than one signal is used at different frequencies while the angular position is determined, and the combination thereof, though not restricted to them.
23. The method according to Claim 21, wherein the data in said database are determined previously.
24. The method according to Claim 21, wherein said database is stored in a memory.
25. The method according to Claim 24, wherein said memory is a non-volatile memory.
26. The method according to Claim 24, wherein said database is pre-established.
27. The method according to Claim 21, wherein said testing procedure is executed previously.
28. The method according to Claim 21, wherein more than one sensor are used and wherein the data associated with signal responses detected by different sensors are compared to determine the angular position of said signal source.
29. The method according to Claim 21, wherein said system comprises different databases for signal sources which have different characteristics.
30. A method for determining the angular position of a signal source wherein said method estimates or calculates the distance between a signal source and at least one sensor, or estimating or calculating the location of said signal source, and makes use of a database of the signal output from said signal source and detected by at least one sensor **characterized in that** said method comprising the steps of;
- storing the detected signal response information as data which are acquired in a testing procedure for said signal source in said database, and
 - comparing said data in said database to the signal response of the signal output by the signal source and detected by the sensor for determining the angular position of said signal source.
31. The method according to Claim 30, wherein such data in said data base comprises, the data on amplitude, frequency response, signal characteristics, the ratio between detected signal responses when more than one sound signal is used at different frequencies while the angular position is determined, and the combination thereof, though not restricted to them.
32. The method according to Claim 30, wherein the data in said database are determined previously.
33. The method according to Claim 30, wherein said database is stored in a memory.
34. The method according to Claim 4, wherein said memory is a non-volatile memory.
35. The method according to Claim 33, wherein said database is pre-established.
36. The method according to Claim 30, wherein said testing procedure is executed previously.
37. The method according to Claim 30, wherein more than one sensor are used and wherein the data associated with signal responses detected by different sensors are compared to determine the angular position of said signal source.
38. The method according to Claim 30, wherein the angular position of at least one signal source used in a sound system is determined.

39. The method according to Claim 38, wherein said sound system comprises different databases for signal sources having different characteristics.

40. The method according to Claim 30, wherein said signal is a sound signal. 5

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		ANGLE INFORMATION				
		A1	A2	A3	A4	A5
DISTANCE	D1	C1	C2	C3	C4	C5
	D2	C6	C7	C8	C9	C10
	D3	C11	C12	C13	C14	C15
	D4	C16	C16	C18	C19	C20
	D5	C21	C22	C23	C24	C25

Figure – 1

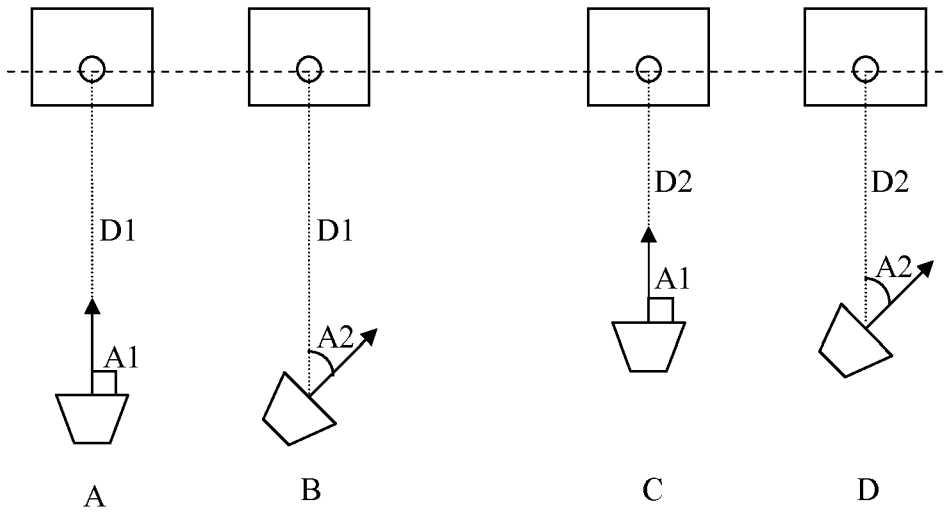


Figure – 2

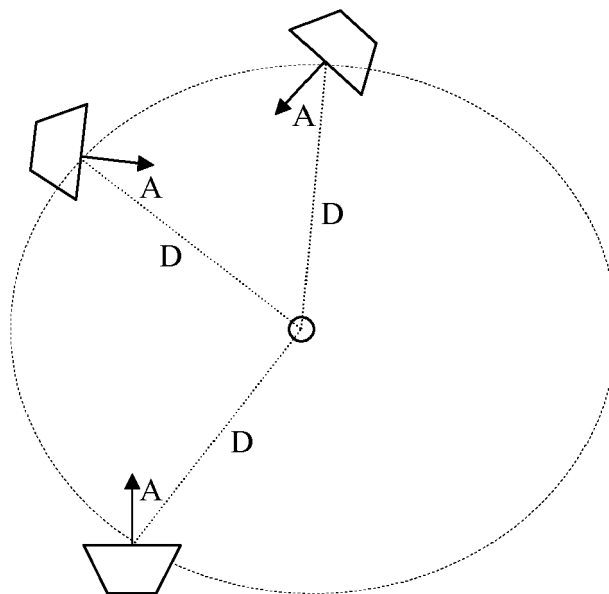


Figure – 3

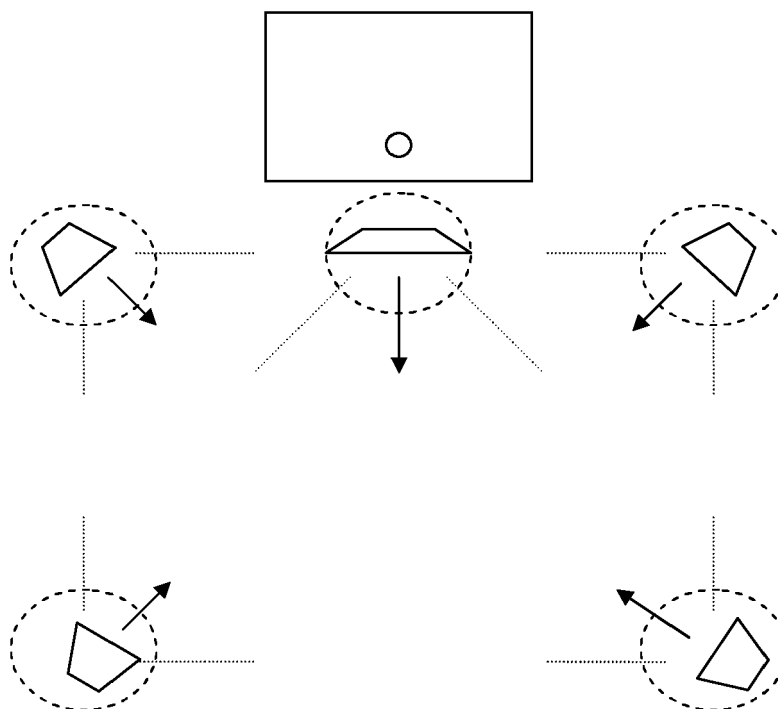


Figure – 4

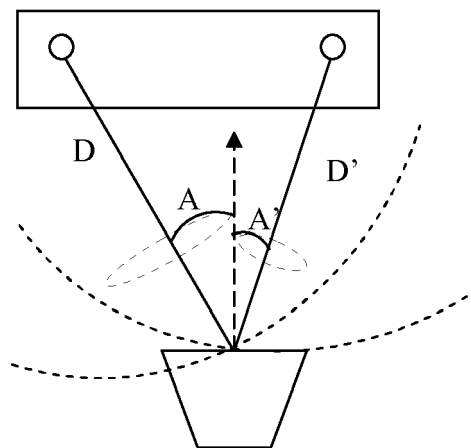


Figure – 5

REFERENCES CITED IN THE DESCRIPTION

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