CLAIMS

I/We Claim:

1. A system (100) for navigating an entity (200) through a time-varying indoor navigation space, said system (100) comprising:

a position sensing unit (102) comprising a plurality of positioning sensors (202A-H) positioned in a preset manner;

an absolute position unit (104) configured to provide an instantaneous absolute position of the entity (200) based on location information received from the position sensing unit (102);

an absolute orientation unit (106) to provide an absolute orientation of the entity (200) based on an output from the position sensing unit (102);

a navigation guidance unit (108) to provide a plurality of attributes based on a navigable layout identified in a navigation area for navigating the entity (200) towards a desired target position;

a navigation control unit (110) to control navigation of the entity (200) between any two points in the time-varying indoor navigation space autonomously based on the instantaneous absolute position of the entity (200) provided by the absolute position unit (104), the absolute orientation of the entity (200) provided by the absolute orientation unit (106) and the plurality of attributes provided by the navigation guidance unit (108);

a drive wheel control unit (112) communicatively coupled to the navigation control unit (110) and configured to control a plurality of drive wheels of the entity (200) by applying an instantaneous angular correction to the entity (200), and wherein the instantaneous angular correction to be applied to the entity (200) is obtained from the navigation control unit (110) and translated into instantaneous differential speeds that drive the plurality of drive wheels of the entity (200) based on drive wheel parameters, and wherein the drive wheel control unit (112) is configured for controlling a speed of the plurality of drive wheels during the navigation of the entity (200), including during ramping-up the speed of the entity (200) and ramping-down the speed of the entity (200);

said system (100) **characterized in that**:

the navigation control unit (110) computes an instantaneous angular correction and triggers the drive wheel control unit (112) to apply the instantaneous angular correction to the entity (200) iteratively at predetermined periodic intervals to achieve a smooth and perfect alignment of the entity (200) along a predetermined path (311), and wherein the instantaneous angular correction is computed based on a weighted combination of a plurality of parameters including:

(1) an angular position of the entity (200) from a starting point with respect to the predetermined path (311);

(2) the angular position of the entity (200) from an end point with respect to the predetermined path (311);

(3) an instantaneous orientation of the entity (200);

(4) the instantaneous absolute position of the entity (200); and

(5) a deviation of the entity (200) represented by a perpendicular distance of the entity (200) from the predetermined path (311);

the drive wheel control unit (112) performs a course-correction for the entity (200) by applying the instantaneous angular correction to change a course of the entity (200) to bring the entity (200) towards the predetermined path (311), and wherein the instantaneous angular correction is implemented by the drive wheel control unit (112) by translating the instantaneous angular correction to the instantaneous differential speeds that drive the plurality of the drive wheels of the entity (200).

2. The system (100) as claimed in claim 1, wherein the position sensing unit (102) comprises a plurality of positioning sensors (202A-H) installed on a plurality of pre-defined points in a multi-dimensional space on the entity (200) in the preset manner, thereby enabling a geometrical inference of the entity (200) based on the location information provided by each of the position sensors (202A-H) embodied in the position sensing unit (102).

3. The system (100) as claimed in claim 1 or 2, wherein the absolute position unit (104) is configured to provide the instantaneous absolute position of the entity (200) based on the location information received from the position sensing unit (102) and a predefined geometrical relationship between the plurality of positioning sensors (202A-H), and wherein the location information indicates a location of the plurality of pre-defined points in the multi-dimensional space on the entity (200), and wherein the location of each of the pre-

defined points is transformed into a known point representing an ideal absolute point of the entity (200) using a translation vector representing a pre-defined position of each of the positioning sensors (202A-H) and an ideal absolute point of the entity (200), and wherein the instantaneous absolute position representing the ideal absolute point of the entity (200) is obtained by averaging translated positions of each of the plurality of positioning sensors (202A-H).

4. The system (100) as claimed in claim 1 or 3, wherein the absolute orientation unit (106) is configured to provide a refined representation of the absolute orientation of the entity (200), and wherein the refined representation of the absolute orientation of the entity (200) is derived based on the location of each of the pre-defined points, an absolute orientation of a set of unique vectors constructed using a combination of the pre-defined points and a relationship of the pre-defined points with the absolute orientation of the entity (200), and wherein the set of unique vectors embodies a known angular relationship with a given axis (354, 356) of the entity (200), and wherein the set of unique vectors is constructed using a time-averaged location information of the pre-defined points in the entity (200), and wherein the time-averaged location information is obtained using the position sensing unit (102), and wherein the set of unique vectors represents at least one of a direction and the absolute orientation of the entity (200), with a known angular offset, and wherein each of the unique vectors is constructed by connecting any two of said pre-defined points, and wherein each of the unique vectors' absolute orientation along with the direction provides a measure of a desired absolute orientation of the entity (200) with the known angular offset, and wherein the known angular offset is applied to each of the unique vectors' absolute orientations to provide a unique representation of the absolute orientation of the entity (200), and wherein a weighted averaging of the known angular offset applied to each of the unique vectors' absolute orientations provides a refined representation of the absolute orientation of the entity (200).

5. The system (100) as claimed in claim 1 or 4, wherein the navigation guidance unit (108) extracts the plurality of attributes from the navigable layout identified in the indoor navigation space to enable the navigation control unit (110) to relate with a context of the navigable layout, and wherein one or more of the attributes are updated dynamically based on a feedback obtained from a navigation history of the entity (200), and wherein the navigable layout is divided into a plurality of navigable line segments connected by nodes whose absolute coordinates are recorded on a map, and wherein the plurality of navigable

line segments form a part of a set of valid paths leading to a network of valid paths, and wherein the attributes correspond to the network of valid paths and are recorded on the map, and wherein the attributes are selected from a group consisting of cost, path width, speed limit, intermediate node transition angles, node angular offset, and node flags, and wherein an optimal path for navigation between any two points in the indoor navigation space is determined in real-time based on a minimum total cost, a distance between the entity (200) and a nearest node, and a penal cost for every intermediate node visited, and wherein the minimum total cost indicates the cost for traversing a combination of the nodes to reach the desired target position, and wherein a measurement error in said absolute orientation of the entity (200) at a particular node is estimated by the navigation control unit (110) during a course of the navigation starting from said particular node, and wherein estimated measurement error is recorded on the map as the known angular offset at each node while orienting towards a target node, and wherein recorded known angular offset is applied to the absolute orientation of the entity (200) during subsequent navigations from a same starting node to a same target node, and wherein the recorded known angular offset is applied to the absolute orientation of the entity (200) during the navigation of each of the line segments, and wherein the recorded known angular offset for a given pair of the starting node and the target node is continuously refined and dynamically updated in the map.

6. The system (100) as claimed in claim 1 or 5, wherein the navigation control unit (110) is configured to perform the navigation of the entity (200) between the any two points in the indoor navigation space based on a strategy guided by the navigation guidance unit (108) to reach the desired target position, and wherein the navigation of the entity (200) is divided based on the line segments involved in reaching the desired target position optimally, and wherein each of the line segments is navigated by the navigation control unit (110) to maintain the navigation of the entity (200) along the predetermined path (311) defined by each of the line segments, and wherein the navigation control unit (110) is configured to orient the entity (200) initially towards a destination point in one of the line segments within a predetermined deviation limit, based on the absolute orientation provided by the absolute orientation unit (106), and wherein the navigation control unit (110) cooperates with the drive control unit (112) to:

    ramp-up the speed of the entity (200);

perform the course-correction on the entity (200) to orient the entity (200) along the predetermined path (311) and compensating for a residual angle, upon the entity (200) reaching a desired maximum speed;

perform stabilization of the navigation of the entity (200) for aligning the entity (200) within the predetermined deviation limit from the predetermined path (311); and

ramp down said speed of the entity (200) and stop the navigation upon a distance of the entity (200) from the destination point in the one of the line segments reaching the predetermined deviation limit from the desired target position.

7. The system (100) as claimed in claim 1 or 5 or 6, wherein the drive wheel control unit (112) ramps-up the speed of the entity (200) by estimating an improved representation of an orientation of the entity (200) and by averaging slopes of each of the line segments connecting positions of the entity (200) with the starting point iteratively at predetermined periodic intervals to determine the residual angle introduced in the absolute orientation of the entity (200) due to multi-path reflections, and wherein the residual angle is determined by subtracting an averaged slope value from the absolute orientation of the entity (200) obtained from the absolute orientation unit (106) during an initiation of the navigation of the entity (200), and wherein the residual angle is attributed to the starting node when oriented towards a specific target node, and wherein the residual angle is dynamically updated in the navigation guidance unit (108) as node angular offset to be accounted for subsequent and new navigations before ramping-up the speed of the entity (200), and wherein estimated residual angle is used in the instantaneous angular correction of the said entity (200), and wherein ramping-up the speed of the entity (200) is continued in a straight-line until the desired maximum speed is reached or when the deviation of the entity (200) from an ideal path exceeds the predetermined deviation limit, and wherein the instantaneous angular correction of said entity (200) is continued to minimize the deviation of the entity (200) from the ideal path, when the desired maximum speed is not reached.

8. The system (100) as claimed in claim 1 or 6 or 7, wherein the drive wheel control unit (112) applies a reverse correction to move the entity (200) to align with a trajectory of the predetermined path (311) and to avoid crossover of the entity (200) to another side of the predetermined path (311) during the course-correction of the entity (200), thereby stabilizing the entity (200) gradually to arrive at the destination point in the one of the line segments, and wherein a trajectory of the entity (200) is tracked and a sign of the instantaneous angular

correction is changed to maintain the entity (200) within the predetermined deviation limit on either side of the predetermined path (311), and wherein the course-correction is repeated on the entity (200) to rectify the deviation of the entity (200) and the stabilization of the navigation of the entity (200) is continued, when a position of the entity (200) has deviated from the predetermined path (311) beyond an acceptable threshold level during the stabilization of the entity (200) due to floor imperfections, mechanical imperfections, or measurement inaccuracies.

9. The system (100) as claimed in claim 1 or 7 or 8, wherein the drive wheel control unit (112) ramps down the speed of the entity (200) and maintains the orientation of the entity (200) until the entity (200) reaches a point within the predetermined deviation limit from the destination point in the one of the line segments, and wherein the speed of the plurality of drive wheels is gradually ramped-down along with the instantaneous angular correction until the entity (200) arrives near the desired target position within the predetermined deviation limit.

10. The system (100) as claimed in claim 1 or 8 or 9, wherein the navigation control unit (110) is configured to:

derive the instantaneous orientation of the entity (200) by tracking an angle of one of the line segments connecting the drive wheels of the entity (200), said one of the line segments having a fixed angular offset with the orientation of the entity (200), and wherein a starting angle of said one of the line segments is derived from the absolute orientation of the entity (200) provided by the absolute orientation unit (106) at a start of the navigation, and wherein an instantaneous orientation of said one of the line segments is derived during the navigation of the entity (200) by using an absolute position of the drive wheels provided by the drive wheel control unit (112), and wherein the instantaneous orientation of the entity (200) is derived by applying the fixed angular offset to the instantaneous orientation of said one of the line segments; and

continuously monitor the instantaneous absolute position and the trajectory of the entity (200) iteratively at predetermined periodic intervals and dynamically decide a navigation strategy that includes continuing with an ongoing course of the navigation or performing an orientation correction for the entity (200), followed by a new navigation cycle for navigating a predetermined line segment, and wherein the deviation of the entity (200) beyond the predetermined deviation limit, due to uneven

floor surfaces leading to wheel slippages and multipath reflections leading to signal degradation, triggers the orientation correction and initiation of the new navigation cycle, and wherein the orientation correction and the initiation of the new navigation cycle is triggered by considering a future trajectory of the entity (200) even when the deviation is within the predetermined deviation limit, and wherein, when the entity (200) starts the new navigation cycle with the orientation having a large residual angle not reported appropriately by the absolute orientation unit (104) due to the multipath reflections, thereby leading the entity (200) to stray away from a desired path and move towards obstacles, including walls adjacent to the predetermined path (311), and wherein the navigation control unit (110) judges that a current path taken by the entity (200) is invalid and initiates the navigation through a next best optimal path, when the entity (200) is obstructed in the current path beyond a predetermined time limit and the course-correction does not facilitate the initiation of the new navigation cycle.

11. The system (100) as claimed in claim 1 or 10, wherein the drive wheel control unit (112) is configured to translate the instantaneous angular correction provided by the navigation control unit (110) to the instantaneous differential speeds using a plurality of parameters derived based on predetermined physical properties of the entity (200) to physically achieve the instantaneous angular correction of the entity (200), and wherein the drive wheel control unit (112) monitors absolute positions of the drive wheels throughout the navigation of the entity (200) and feeds monitored absolute positions of the drive wheels to the navigation control unit (110) which provides the instantaneous angular correction to the drive wheel control unit (112) and triggers the drive wheel control unit (112) to derive the instantaneous differential speeds for a next iteration, and wherein the absolute positions of the drive wheels are derived at the start of the navigation from the instantaneous absolute position of the entity (200) provided by the absolute position unit (104) and the absolute orientation of the entity (200) provided by the absolute orientation unit (106), and wherein the absolute positions of the drive wheels during the navigation of the entity (200) are determined based on current absolute drive wheel positions, a current maximum speed of the entity (200), duration of an iteration, width of the entity (200), and the instantaneous angular correction to be achieved during the iteration, and wherein the instantaneous differential speeds are derived from a difference in an estimated angular displacement between two drive wheels of the entity (200) when the entity (200) moves from a current position to an estimated position, and wherein an outer wheel of the entity (200) is applied with the current

maximum speed while an inner wheel of the entity (200) is applied a speed lesser than the current maximum speed by a factor of the difference in the estimated angular displacement between the two drive wheels, depending on a direction of rotation of the entity (200), and wherein the drive wheel control unit (112) controls the two drive wheels by time slicing the instantaneous differential speeds to be applied to the two drive wheels of the entity (200) and thereby eliminates an undesired shaky movement of the entity (200) due to a sudden jump in a speed difference between the two drive wheels, to effectively apply the instantaneous angular correction to the entity (200) before an arrival of a next iteration signal from the navigation control unit (110).

12. A method of navigating an entity (200) through a time-varying indoor navigation space, said method comprising the steps of:

    determining (402), by an absolute position unit (104), an instantaneous absolute position and an absolute orientation of said entity (200);

    identifying (403), by a navigation guidance unit (108), line segments to be navigated by the entity (200), based on a navigation strategy;

    performing (404) a navigation of said entity (200) for each of the line segments based on said instantaneous absolute position and said absolute orientation of said entity (200), wherein said navigation comprises:

        a) initiating (404a) the navigation of the entity (200) and ramping up a speed of the entity (200);

        b) performing (404b) a course-correction on the entity (200) to orient the entity (200) along a predetermined path (311) and compensating for a residual angle, upon said entity (200) reaching a desired maximum speed;

        c) performing (404c) stabilization of the navigation of the entity (200) for aligning the entity (200) within a predetermined deviation limit from the predetermined path (311);

        d) ramping-down (404d) said speed of the entity (200) and stopping the navigation upon a distance of the entity (200) being within the predetermined deviation limit from a destination point in an identified line segment; and

e) repeating steps (404a to 404d) for each of the identified line segments until all the identified line segments are navigated and the entity (200) reaches a desired target position;

said method **characterized by steps of:**

computing and applying an instantaneous angular correction to the entity (200) iteratively at predetermined periodic intervals and achieving a smooth and perfect alignment of the entity (200) along a predetermined path (311);

computing the instantaneous angular correction based on a weighted combination of a plurality of parameters including:

(1) an angular position of the entity (200) from a starting point with respect to the predetermined path (311);

(2) the angular position of the entity (200) from an end point with respect to the predetermined path (311);

(3) an instantaneous orientation of the entity (200);

(4) the instantaneous absolute position of the entity (200); and

(5) a deviation of the entity (200) represented by a perpendicular distance of the entity (200) from the predetermined path (311);

performing a course-correction by a drive wheel control unit (112), by applying an instantaneous angular correction to change a course of the entity (200) to bring the entity (200) towards the predetermined path (311), and wherein the instantaneous angular correction is implemented by the drive wheel control unit (112) by translating the instantaneous angular correction to the instantaneous differential speeds that drive the plurality of the drive wheels of the entity (200).

13. The method as claimed in claim 12, wherein said step of initiating (404a) said navigation comprises:

upon initiating the navigation of the entity (200), determining and fine-tuning an orientation of the entity (200) such that the orientation of the entity (200) is aligned to the destination point in the identified line segment within a predetermined error margin, based on said absolute orientation of the entity (200);

ramping up said speed of the entity (200) and applying the instantaneous angular correction to the entity (200) by the residual angle, upon the deviation of the entity

(200) from the predetermined path (311) not being within the predetermined deviation limit; and

ramping up said speed of the entity (200) without applying said instantaneous angular correction upon the deviation of the entity (200) from the predetermined path (311) being within the predetermined deviation limit.

14. The method as claimed in claim 12, wherein performing (404b) said course-correction comprises:

determining if the entity (200) has reached a maximum ramp-up speed;

applying the instantaneous angular correction to change the course of the entity (200) to bring the entity (200) towards the predetermined path (311) representing the identified line segment;

continuing to apply the instantaneous angular correction in a same direction as long as a first exit condition is not met.

15. The method as claimed in claim 12 or 14, wherein performing (404c) said stabilization comprises:

determining if the first exit condition is met, and wherein the first exit condition is defined as a specific point at which $\Theta 2 < k\,\Theta 1$, wherein k is a predetermined factor that decides an exact transition point, and wherein $\Theta 1$ is an initial angle of the entity (200) from the starting point with respect to the identified line segment, and $\Theta 2$ is an angle of the entity (200) from the starting point with respect to the identified line segment that keeps varying during the course-correction as the entity (200) moves towards the predetermined path (311) representing the identified line segment; and

performing said stabilization upon said first exit condition being met, and wherein said stabilization further comprises:

reversing said course-correction while aligning the entity (200) parallel to said predetermined path (311) and within the predetermined deviation limit;

determining if the deviation of the entity (200) from said predetermined path (311) is within the predetermined deviation limit;

aligning the entity (200) along said predetermined path (311) and within said predetermined deviation limit from said predetermined path (311); and

repeating the course-correction upon the first exit condition not being met.

16. The method as claimed in claim 12 or 13 or 14, wherein ramping-down (404d) the speed of the entity (200) comprises:

determining if the deviation of the entity (200) from the predetermined path (311) is within the predetermined deviation limit;

determining if a second exit condition is met, upon said deviation being within said predetermined deviation limit, and repeating the course-correction upon said deviation exceeding said predetermined deviation limit, and wherein the second exit condition is defined as a point at which a remaining distance to the destination point in the identified line segment is within the predetermined deviation limit;

ramping-down the speed of the entity (200) along with said instantaneous angular correction to keep said entity (200) along said predetermined path (311) upon said second exit condition being met, and repeating said stabilization upon said second exit condition not being met;

determining if the distance of said entity (200) to said destination point in the identified line segment is within the predetermined deviation limit based on said instantaneous absolute position of the entity (200);

repetitively ramping-down the speed of the entity (200) upon said distance of said entity (200) from said desired target position not being within the predetermined deviation limit; and

stopping the navigation of said entity (200) upon said distance of said entity (200) from said destination point in the identified line segment reaching said predetermined deviation limit.