CLAIMS

I/We Claim:

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

a position sensing unit (102), having a plurality of positioning sensors placed in a preset manner;

an absolute position unit (104) to provide an instantaneous absolute position of the entity (200) based on an output 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 unique attributes based on a desired navigable layout identified in a navigation area for navigating the entity (200) towards a desired target position;

a navigation control unit (110) to control/regulate navigation of the entity (200) between any two points in a 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 a plurality of navigation 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, 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 to the drive the plurality of wheels based

on drive wheel parameters and wherein the drive wheel control unit (112) is configured for controlling the speed of the drive wheels during complete navigation including ramp-up and ramp-down; and

characterized in that:

wherein the navigation control unit (110) computes and applies angular correction to the entity (200) iteratively at predetermined periodic intervals during every stage of a multi-stage navigation to achieve a smooth and perfect alignment of the entity (200) along the pre-determined path, and wherein the angular correction is computed based on weighted combination of various parameters including (1) the angular position of the entity from the start point with respect to the pre-defined navigation path (2) the angular position of the entity from the end point with respect to the pre-defined navigation path (3) the instantaneous orientation of the entity (4) the instantaneous absolute position of the entity (5) the deviation of the entity represented by the perpendicular distance of the entity (200) from the pre-defined navigation path, and wherein the angular correction factor applied at each stage of the multi-stage navigation limit is derived or estimated based on the weighted combination of the parameters;

wherein the drive wheel control unit performs a course-correction stage/process by applying an angular correction to change a course of the entity so as to bring the entity towards the pre-defined path representing the said line-segment, and wherein the angular correction is acted up on or implemented by the drive wheel control unit (112) which in turn translates the angular correction to differential drive wheels speeds.

2. The system as claimed in claim 1, wherein the position sensing unit (102) comprises a plurality of positioning sensors installed on a plurality of pre-defined

points in a multi-dimensional space on the entity (200) in preset manner thereby enabling a geometrical inference of the entity (200) based on a location information provided by each sensor in the position sensing unit (102).

3. The system as claimed in claim 1, wherein the absolute position unit (104) is configured to provide a refined instantaneous absolute position of the entity (200) based on the inputs received from the position sensing unit (102) and a pre-defined geometrical relationship between the plurality of sensors in the position sensing unit (102), and wherein the location information of a plurality of pre-defined points in the entity (200) is obtained/determined from the position sensing unit (102) and wherein the obtained/determined each such location is transformed into a known point representing an ideal absolute point of the entity (200) using a translation vector representing the pre-defined position of each such sensor and an ideal absolute point of the entity (200), and wherein the absolute position representing the ideal absolute point of the entity is then obtained by averaging the translated positions after applying a statistical correction.

4. The system as claimed in claim 1, wherein the absolute orientation unit (106) is configured to provide a refined representation of the absolute orientation of the entity (200), and wherein refined representation of the absolute orientation of the entity (200) is derived using the individual location of the pre-defined points provided by the position sensing unit (102), based on the absolute orientation of a set of unique vectors constructed using a combination of the pre-defined points and their know relationship with the absolute orientation of the entity (200), and wherein the unique set of vectors with known angular relationship with a given axis of the entity (200) are constructed using a time-averaged location information of the said pre-defined points in the entity (200), and wherein the

time-averaged location information of the said pre-defined points in the entity (200) is obtained using the position sensing unit (102), and wherein the unique set of vectors with the known angular relationship with a given axis of the entity (200) represent a direction or the absolute orientation of the entity with a known angular offset, and wherein each such vector is constructed by connecting any two said pre-defined points or any two points representing a combination of such pre-defined points, and wherein each such vector's absolute orientation along with a direction provides a measure of a desired absolute orientation of the entity (200) with a known angular offset, and wherein the respective known offset is applied to each such vector's orientation to provide a unique representation of the absolute orientation of the entity (200), and wherein a weighted averaging of all such angles provides a refined representation of the absolute orientation of the entity (200).

5. The system as claimed in claim 1, wherein the navigation guidance unit (108) is configured to provide unique attributes, and wherein the plurality of unique attributes is extracted from the desired navigable layout identified in the indoor navigation space to enable the navigation control unit (110) to relate with the context of the navigation layout, and wherein one or more of the attributes are updated dynamically as a learning/feedback obtained from the navigation history of the entity (200), and wherein an entire navigation layout is split/divided into a plurality of navigable line segments that are connected by nodes whose absolute coordinates are recorded in a map, and wherein the plurality of navigable line segments form part of a set of valid paths leading to a network of valid paths, and wherein the attributes of a network of valid paths are recorded in the map, and wherein the attributes are selected from the group consisting of cost, path width, speed limit, intermediate node transition angles, node angular offset, and node

flags for special purposes, and wherein an optimal path for a given navigation between any two points, is arrived at in real-time based on a minimum total cost which includes a cost to traverse through a combination of nodes to reach the desired target, distance between the entity (200) and one such nearest node, and a penal cost for every intermediate node visited, and wherein any measurement error in the said absolute orientation of the entity (200) at a particular node is estimated by the navigation control unit (110) during the course of the navigation starting from the said node, and wherein the estimated error is recorded in the map as a known angle offset at each such node while orienting towards the respective target node, and wherein the recorded known angle offset is applied to the absolute orientation of the entity (200) during subsequent navigations from the same starting node to the same target node, and wherein this process is repeated during a navigation process of each line segment and the angle offset for a given pair of start and end nodes is continuously refined and dynamically updated in the map, and wherein the navigation guidance unit (108) is configured to record any other key parameter of interest related to the layout, and help in enhancing a navigation experience.

6. The system as claimed in claim 1, wherein the navigation control unit (110) is configured to perform a navigation of the entity (200) between any two points in the navigation space based on a strategy guided by the navigation guidance unit (108) so as to reach the desired target, and wherein the navigation process is split/divided in to a plurality of steps based on a number of line segments involved in reaching the desired target optimally, and wherein each such line segment is navigated using a multi-stage navigation mechanism in order to maintain the navigation of the entity (200) along the path defined by the line segment, and wherein the multi-stage navigation mechanism comprises orienting

the entity initially towards the destination point in the line segment within an acceptable limit, based on the absolute orientation provided by the absolute orientation unit (106), followed by navigation of the entity through a plurality of stages/sub-processes, and wherein the plurality of stages/sub-processes comprises ramping- up a speed of the entity (200), performing a course correction on the entity (200) to orient the entity (200) along a predetermined path and compensating for a residual angle, upon reaching said maximum speed; performing stabilization of navigation of the entity (200) for aligning the entity (200) within a deviation limit form the predetermined path; and ramping-down said speed of the entity (200) and stopping navigation upon a distance of the entity (200) from a destination point in the line segment reaching a predetermined limit from said target location.

7. The system as claimed in claim 1, wherein the drive wheel control unit is configured to perform the Ramp-up stage/process by estimating a better representation of the orientation of the entity (200) in addition to ramping-up the speed of the entity by averaging the slopes of the lines connecting the bot positions with the starting point iteratively at predetermined periodic intervals to determine a residual angle introduced in the absolute orientation of the entity, due to multi-path reflections, and wherein the residual angle is determined by subtracting the averaged slope value from the absolute orientation of the entity (200) obtained from the absolute orientation unit (106) during initiation of navigation, and wherein the said residual angle is attributed to a given start 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/new navigation processes before ramp-up and wherein the estimated residual angle is used in angular correction of the said

entity (200) in subsequent stages, and wherein the Ramping-up of speed of the entity is continued in a straight-line until the desired maximum speed is reached or when a deviation from the ideal path exceeds an acceptable limit, whichever is earlier, and wherein the remaining ramp-up processes along with required angular corrections is continued to minimize deviation, when the desired maximum speed is not reached.

8. The system as claimed in claim 1, wherein the drive wheel control unit is configured to perform the Stabilization stage/process by applying reverse correction to force/move the entity to align with a trajectory of the pre-defined path and to avoid crossover of the entity (200) to other side of the pre-defined path with continuation of the course-correction process, thereby stabilizing the entity gradually to arrive at the destination point in the line segment, and wherein the trajectory trend of the entity (200) is tracked/monitored during the stabilization processes, and change the sign of the angle correction factor so as to maintain the entity within a deviation limit on either side of the predetermined path, and wherein the course-correction process is repeated to rectify a deviation and the stabilization process is continued, when a position of the entity is deviated from the predetermined path (311) beyond an acceptable threshold level during the stabilization processes due to any uncontrollable non-linear factors comprising floor imperfections, mechanical imperfections, measurement inaccuracies.

9. The system as claimed in claim 1, wherein the drive wheel control unit is configured to perform the Ramping-down stage/process by ramping down the speed and maintaining the orientation of the entity until the entity reaches a point which is within a pre-determined limit from the destination point in the

line segment, wherein the drive wheel speeds are gradually ramped-down along with required corrections during the ramping down process until the entity arrives near the target within an acceptable error limit.

10. The system as claimed in claim 1, wherein the navigation control unit (110) is configured to derive the instantaneous orientation of the entity (200) by tracking or monitoring the angle of a line segment connecting the drive wheels of the entity (200) that has a fixed angular offset with the orientation of the entity (200), and wherein the starting angle of the said line segment is derived from the absolute orientation of the entity at the start of the navigation provided by the absolute orientation unit (106),and wherein the instantaneous orientation of the line segment is derived/estimated during the course of the navigation using the absolute position of the drive wheels provided by the drive wheel control unit (112), and wherein the instantaneous orientation of the entity is obtained/estimated by applying the fixed angular offset to the instantaneous orientation of the said line segment.

11. The system (100) as claimed in claim 1, wherein the navigation control unit (110) is configured to continuously monitor the instantaneous absolute position and trajectory of the said entity iteratively at a predetermined periodic intervals and dynamically decide the navigation strategy by either continuing with the ongoing course of navigation or performing an orientation correction followed by a new cycle of multi-stage navigation for the given line segment, and wherein any deviation of the entity (200) beyond acceptable limits, due to uneven floor surfaces leading to wheel slippages, multi-path reflections leading to signal degradation, triggers an orientation correction and initiation of new cycle of multi-stage navigation, and wherein the said orientation correction and

initiation of new cycle of multi-stage navigation is triggered as a precautionary measure, by considering the future trajectory even when the actual deviation is within acceptable limits, while the entity (200) starts a navigation cycle with an orientation with large residual angle which is not reported appropriately by the absolute orientation unit (104) due to multipath reflections, thereby leading to stray away from the desired path and move towards obstacles including walls adjacent to the navigation path, and wherein the navigation control unit (110) judges that the given path is invalid and initiates navigation through the next best optimal path, when the entity (200) is obstructed/stopped in the given path beyond a reasonable time and course correction does not provide/yield sufficient clearance to initiate a new navigation cycle.

12. The system as claimed in claim 1, wherein the drive wheel control unit (112) is configured to translate or convert the instantaneous angular correction provided by the navigation control unit (110) to instantaneous differential drive wheel speeds using a plurality of parameters based on the physical properties of the entity (200) to achieve the angular correction of the entity (200) physically, and wherein the drive wheel control unit (112) monitors the absolute positions of the drive wheels throughout the navigation process and feeds the monitored absolute positions of the drive wheels to the navigation control unit (110) which in turn provides the instantaneous angular correction for the drive wheel control unit (112) to derive the differential drive wheel speeds for the 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 provided by the absolute position unit (104) and the absolute orientation of the entity provided by the absolute orientation unit (106), and wherein the absolute positions of the drive wheels during the course of navigation are estimated or

determined based on current absolute drive wheel positions, current maximum speed of the entity, duration of an iteration, width of the entity (200) and the angular correction to achieve during the iteration, and wherein the differential wheel speeds are derived or estimated from the difference in estimated angular displacement between the two drive wheels when the entity moves from the current position to an estimated position, and wherein the outer wheel is applied with the current maximum speed while the inner wheel is applied a speed which is lesser than the current maximum speed by a factor of the difference in predicted angular displacement between the two drive wheels, depending up on the direction of rotation of the entity, and wherein the drive wheel control unit (112) controls the wheels by time slicing the differential speed to be applied and applying the difference in steps across the wheels to avoid any undesired shaky movement of the vehicle due to a sudden jump in speed difference between the two wheels, so as to achieve smooth transition and effectively apply the desired angular correction to the entity (200) before the arrival of the next iteration signal from the navigation control unit (110).

13. A method of navigating an entity (200) through a navigation space, said method comprises steps of:

determining (402), using an absolute portion unit (104), at least one of an instantaneous absolute position and an absolute orientation of said entity (200);

identifying (403), using a navigation guidance unit (108), the line segments to navigate from start to end based on the strategy provided by the navigation guidance unit (108);

performing (404) a multi-stage navigation of said entity for each such line segment based on said instantaneous absolute position and said absolute

orientation of said entity (200), wherein said multi-stage navigation comprises:

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

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

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

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

e) repeating steps 404a to 404d for each line segment identified in 403 until all line segments are navigated and the target is reached;

characterized in that:

wherein the angular correction is computed and applied to the entity (200) iteratively at predetermined periodic intervals during every stage of a multi-stage navigation using the navigation control unit (110) to achieve a smooth and perfect alignment of the entity (200) along the pre-determined path, and wherein the angular correction is computed based on weighted combination of various parameters including (1) the angular position of the entity from the start point with respect to the pre-defined navigation path (2) the angular position of the entity from the end point with respect to the pre-defined navigation path (3) the instantaneous orientation of the entity (4) the instantaneous absolute position of the entity (5) the deviation of the entity represented by the perpendicular distance of the entity (200) from the pre-defined navigation path, and wherein the angular correction factor applied at each stage of the multi-stage navigation limit is derived or estimated based on the weighted

combination of the parameters; and

wherein unique attributes are provided based on a desired navigable layout identified in a navigation area for navigating the entity (200) towards a desired target position using a navigation guidance unit (108);

wherein a course-correction stage/process is performed by the drive wheel control unit by applying an angular correction to change a course of the entity so as to bring the entity towards the pre-defined path representing the said line-segment, and wherein the angular correction is acted up on or implemented by the drive wheel control unit (112) which in turn translates the angular correction to differential drive wheels speeds.

14. The method as claimed in claim 13, wherein said step of initiating said navigation comprises:

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

performing ramping up said speed of the entity (200) and applying a deviation correction to the entity (200) by a residual angle upon a deviation of the entity (200) from a predetermined path (311) not being within a predetermined deviation limit, or ramping up said speed of the entity (200) without applying said deviation correction upon a deviation of the entity (200) from a predetermined path (311) being within a predetermined deviation limit.

15. The method as claimed in claim 13, wherein performing said course-correction comprises:

determining if maximum ramp-up speed is reached;

applying angular correction to change a course of the entity so as to bring the entity towards the pre-defined path representing the said line-segment;

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

16. The method as claimed in claim 13, wherein performing said stabilization comprises:

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

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

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

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

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

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

17. The method as claimed in claim 13, wherein the step of performing ramping-down comprises:

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

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

performing a ramping down process of the speed of the entity (200) along with deviation correction to keep said entity (200) along said predetermined path (311) upon said second exit condition being met;

or repeating said stabilization upon said second exit condition not being met;

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

repeating ramping-down upon said distance of said entity (200) from said target location not being within a predetermined limit; and

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