Journal of Scientific & Industrial Research
Vol. 78, December 2019, pp. 879-884

Positioning of Two-Wheeled Mobile Robot to Control Wheelslip by Using the Wheel Rotate Planning Technique

D Vidhyaprakash[1], S Karthikeyan[2]*, M Periyasamy[3], K Kalaimurugan[4] and S Navaneethasanthakumar[5]

[1] Department of Mechanical Engineering, Mahat Amma Institute of Engineering and Technology, Pudukottai, India
[2,4] Department of Mechanical engineering, Syed Ammal Engineering College, Ramanathapuram, India
[3]Department of Electronics and Communication Engineering, Syed Ammal Engineering College, Ramanathapuram
[5] MLR Institute of Technology, Hyderabad, India

Received 11 September 2018; revised 15 April 2019; accepted 22 October 2019

The prediction of proper position x, y coordinate points of two-wheeled mobile robot wheel axle basically depends on the number of wheels rotating. The accurate wheel rotation gives the appropriate pose for a wheeled mobile robot. It is mostly used for simple and inexpensive implementation for determining the precise x, y coordinates to reach the angularity based target (45˚, 135˚, 225˚, 315˚) within time and also control the four main affecting factors such as wheel slip, deviation from passage, target reaching time, loss of energy etc., The aim of the research is preventive control position of wheeled mobile robot to be focus on the reaching target. Mostly the straight line movement gives controlling the affecting factors like wheel slip, odometry, vibrations are comparing with elliptical path movement. The wheel rotate planning technique gives the position of robot. The wheel rotate planning techniques is considering one wheel fixed and one wheel rotating methodology is used in target reaching. This research considers the influencing parameters of navigation such as number of left side wheel rotations, number of right side wheel rotations, both wheels (opposite) rotations. These research results were obtained based on the analysis of centripetal force law contributions for predicting the robot's suitable wheel axle position and is to generate a robot to reach the target with minimum wheel slip.

Keywords: Wheel slip, Odometry, Navigation, Positioning, Wheel rotate planning

Introduction

The movement is an essential ability factor for all wheeled mobile robots, and the highlight of a robot's movements depends upon both factors position and path planning. The localization helps to find out the robot position in its working layout and local sensorial data. The pose prediction of a robot is one of the fundamental problems. Always the WMR's wheel slip is more in the turning movement. The entire pathways are related to the robot's wheel contact[1]. In this occasion, change in total momentum of a body or system equal to the sum of external forces (motor power) on the body of the system. In this paper, wheel axle points are predicted for the without wheel slip navigation for the two-wheeled mobile robot has been developed based on the centripetal law using One wheel fixed & One Wheel rotating methodology and wheel rotate planning Technique[2].

Main affecting factor-wheel slip

The tire is slipping relative to the road; the coefficient of friction for dynamic contact is lower and has less traction. The slip is generally given as percentage of the difference between rotational speed (wheel speed) of the wheel and vehicle speed.

- $W = (\omega * r - v)/v$ … 1

Where (ω– Rotational speed of the wheel, r – Wheel radius, v – Vehicle Speed)

The wheel slip will be generating another three affecting factors such as loss of energy, deviate from the passage, increasing target distance. These are the affecting factors that reduced the WMR's performance during the real time[3].

The wheel rotates planning for various reaching paths

Generally, whenever want to reach the angularity based target, the WMR should want to turn and move towards the target. If not turn the body of WMR, it is possible to reach a target. Both of the planning is must to reach a target that is path planning and wheel rotate planning. Most of the researchers are concentrating on the path planning on robot trajectory, but very few researchers have been concentrating on the wheel rotate planning of robot for only movements of all wheels to straight away with the particular speed

*Author for Correspondence
E-mail: viddravid@gmail.com

limit. Here the very first time using the wheel rotate planning for the controlling wheel slip within inexpensive contribution, the path planning has been decided only on the travel on a pre-planned trajectory, but the wheel rotating has only concentrated on the turning movement, and speed wheeled mobile robots[4]. The wheel rotating is directly relating to the motor's energy consuming. The turning movement of WMR is directly associated with the diameter of wheel and which side of the wheel rolling. The particular degrees of wheel rolling gives a specific turning movement, and also after turning the WMR has positioning for another straight line movement. All of the wheel axle position has to represent the x, y coordinates. The above showing types of paths has been consuming the both wheel rotations, which always gives the use of more motor energy and produce the wheel slips hence want to choose the economical path with necessary and the exact wheel rotations towards the targets[5].

Experimental techniques and methodology

The experiments were based on centripetal force law it is a force that makes a body follows a curved path. Its direction is always orthogonal to the motion of the body and towards the fixed point of the instantaneous centre of curvature of the path the model of two-wheeled LEGO NXT mobile robot. The WMR's wheel diameter is 56mm (175.84mm circumference), self-load 0.375kg, and 110 mm length of wheel axle; power consuming 1.5 voltage. It has one caster wheel (without motor) for supporting wheel[6]. The LEGO NXT ROBOT Locating on smooth surface work layout is shown in figure 1. In the wheel rotation planning techniques is very simplest and inexpensive. This is allowed for the movement for WMR within limits. The wheel rotation is controlled by the robot's motor torque. The number of rotations is desired with respect needs to a travelling distance of robot, as well as can determine the XY coordinates of wheel axle. The wheel rotation planning is more helpful to control the

Fig. 1 — LEGO NXT ROBOT Locating on smooth surface work layout

WMR navigation and save energy and time. It has been obtained from the OWF, and OWR methods give makes a turning of robot[7]. The angularity based target reaching real time experiments has been completed on kadappa floor surface; the kadappa surface is one of the smoothest surface and lowest roughness. This working layout has formed as a four quadrants with 45˚, 135˚, 225˚, 315˚as per the below diagram, in this layout with some constraints it can be applied on the military utilities at the time of prediction of enemies war champ. Every 45˚degrees target has the bomb caution area near the navigation passage, so want to avoid the bomb hiding area by using the robots axle length calculation, this scenario of layout has been defined below. All the experiments had been conducted in the model of two wheeled LEGO NXT mobile robot. The WMR’s wheel diameter is 56mm (175.84mm circumference), self-load 0.375kg, and 110 mm length of wheel axle; power consuming 1.5 voltage. It has one caster wheel (without motor) for supporting wheel. At the real time experiment can be attaching a LEGO NXT robot with the mind storms software. By the use of the mind storm software, one can operate a robot movement. Can all input data's and commands are interface with this software.

New aspects on real time experiment

In this experiment, occasion have planned to use only the wheel related parameters, such as the wheel rotation from 56mm diameter of the wheel by any one side of the wheel. It is suitable for obtaining a turning movement. It is essential to be preventive counting and controlling for 45°left and right side turning[8]. As per the above wheel rotate planning techniques: it can obtain U shape curvature path, at the end of U shape curvature were considered as a wheel axle position point. It is suitable for making straight line navigation up to 1 meter target; hence the end of U shape should be perpendicular towards the angularity target. After that navigation path will be shown as a hook path shape as per the given figure, in this new aspect give some extra pushing force acted on the WMR body to help robot’s movements toward the target the extra push force has obtained from robot’s one side rotating wheel motor[9]. This is one of the inexpensive solutions for the turning of wheeled mobile robots are avoiding elliptical path movement. The experimental data are shown in Table 1 and Table 2.

Recommended parameters

From this experiment, data represents economic based contributions of WMR's performance. The

Table 1 — Experimental data

	45°					135°			
S. No	Left side wheel-fixed	Right side wheel-rotating CW in %	X-axis	Y-axis	S.NO	Left side wheel-rotating CCW in %	Right side wheel-fixed	X-axis	Y-axis
1	0	0.1	32	18	1	-0.1	0	-27	16
2	0	0.25	42	28	2	-0.25	0	-43	32
3	0	0.35	60	32	3	-0.35	0	-53	27
4	0	0.5	75	45	4	-0.5	0	-68	43
5	0	0.65	124	35	5	-0.65	0	-83	56
6	0	0.75	134	45	6	-0.75	0	-132	41
7	0	0.85	104	145	7	-0.85	0	-139	62
8	0	1	115	160	8	-1	0	-104	152

Table 2 — Experimental data

	225°					315°			
S.NO	Left side wheel-fixed	Right side wheel-rotating CW in %	X-axis	Y-axis	S.NO	Left side wheel-rotating CCW in %	Right side wheel-fixed	X-axis	Y-axis
1	0	0.1	-33	-13	1	-0.1	0	28	-18
2	0	0.25	-36	-23	2	-0.25	0	43	-33
3	0	0.35	-54	-27	3	-0.35	0	52	-39
4	0	0.5	-63	-39	4	-0.5	0	66	-42
5	0	0.65	-114	-37	5	-0.65	0	81	-53
6	0	0.75	-123	-44	6	-0.75	0	133	-40
7	0	0.85	-102	-132	7	-0.85	0	137	-63
8	0	1	-112	-148	8	-1	0	104	-152

performance is related to the meaning of controlling any one of the wheels or both wheel opposite rotations (CW-CW or CCW-CCW) at the time of robot's turning operation. Only can consuming from two parameters, only out of all three parameters.

A number of left side wheel rotation CW (using for left turn 45° and 225°).

Number of right side wheel rotation cw (using for left turn 45° and 225°).-recommended parameter

Number of left side wheel rotation ccw (using for right turn 135° and 315°) -.recommended parameter

Number of right side wheel rotation CCW (using for right turn 135 °and 315°). Both the wheels are rotating in opposite directions using the left side wheel CW and right side CW (using for left turn 45° and 225°). The both wheel rotate planning parameters are also using to take for experiments to turning of both turn direction of WMR. But both wheels are rolling which allows the wheel slip and other related affecting factors. Hence have not need to considerable for angularity based target reaching. Entire XY coordinates with wheel rotation degrees in LABVIEW SOFTWARE is shown in figure 2.

Calculation (for wheel rotation)

$$C = \prod \times d \qquad \text{... 2}$$

Circumference of robot's wheel
=∏ × d (3.14*diameter of wheel) = 3.14*56mm = 175.84mm

No. of wheel rotations = distance travel / one wheel rotation -------------- Equation-3

For 45°

U-shape distance (0, 0 to (42, 28)) 118/ 175.84=0.6wheel rotations (use one side wheel rotation)

After U shape distance (perpendicular line with target) path (42, 28) up 1 meter target 923/175.84=5.2*2 (both wheel rotations) =10.4 wheel rotations

Ellipse distance (0, 0 to 1 meter target) 1066/175.84=6.06*2=12.12 (both wheel rotations) =12.12 wheel rotations.

Rotation for ellipse –Rotation for Hook path with U shape) 12.12-11 (including one wheel rotations in U Shape movement) = 1.12 Wheel Rotations.
Without wheel slip possible for 1.12 rotations in 45°target reaching quadrants.

For 135°

U-shape distance (0, 0 to (-43, 32))126/ 175.84=0.71 wheel rotations (use one side wheel rotation)

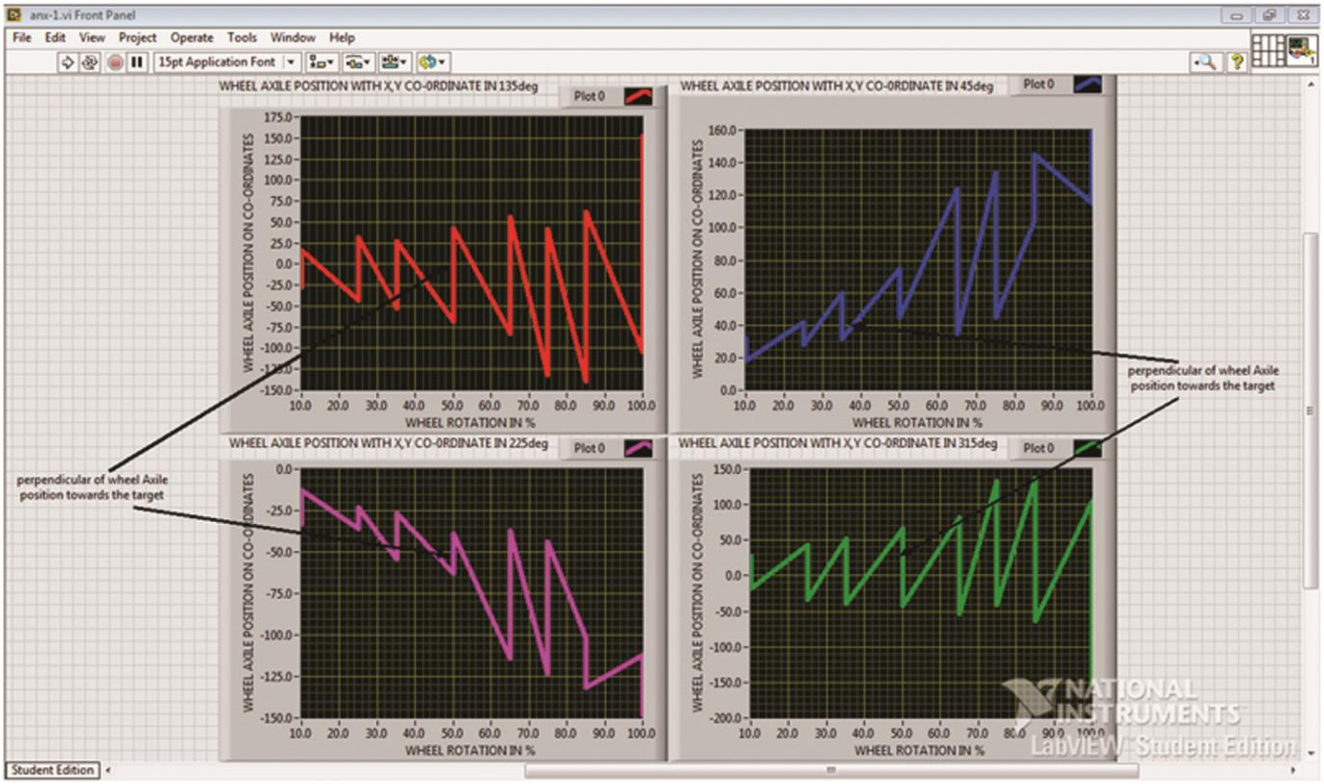

Fig. 2 — Entire XY coordinates with wheel rotation degrees in LABVIEW SOFTWARE Fig. 3 - Comparison distance between ellipse path and hook path navigation for wheel rotate planning techniques

After U shape distance (perpendicular line with target) path (-43, 32) up to 1 meter target 924/175.84=5.2*2 =10.4 (both wheel rotations) wheel rotations

Ellipse distance (0, 0 to 1 meter target) 1066/175.84=6.06*2=12.12 (both wheel rotations) =12.12 wheel rotations.

Rotation for ellipse –Rotation for Hook path (with U shape) 12.12-11.11=1.01wheel rotations.

Without wheel slip possible for 1.01 rotations in 135°target reaching quadrants

For 225°

U-shape distance (0, 0) to (-36, -23) 117/175.84 = 0.6 wheel rotations (use one side wheel rotation)

After U shape distance (perpendicular line with target) path (-36,-23) up to 1 meter target 919/175.84=5.2*2 (both wheel rotations) =10.4 wheel rotations

Ellipse distance (0, 0 to 1 meter target) 1066/175.84=6.06*2=12.12 (both wheel rotations) =12.12 wheel rotations.

Rotation for ellipse –Rotation for Hook path (with U shape) 12.12-11.05=1.12 wheel rotations

Without wheel slip possible for 1.12 rotations in 225°target reaching quadrants

For 315°

U-shape distance (0, 0 to (43, -33)119/175.84=0.6 wheel rotations (use one side wheel rotation)

After U shape distance (perpendicular line with target) path (43,-33) up to 1 meter target 917/175.84=5.21*2 (both wheel rotations) =10.4 wheel rotations

Ellipse distance (0, 0 to 1 meter target) 1066/175.84=6.06*2=12.12 (both wheel rotations) =12.12 wheel rotations. Rotation for ellipse –Rotation for Hook path (with U shape) 12.12-11=1.12 wheel rotations.

Without wheel slip possible for 1.12 rotations in 315^0 target reaching quadrant.

Comparison with wheel rotation for ellipse path navigation vs. wheel rotation for hook path navigation

The ellipse is only comparable path with other types of paths for the economic contribution because of its most irrelativeness straight line robot movements distance10. Whenever the wheeled mobile robot wants to travel on the ellipse path the robot must be using its both wheel rotations with some related turning angle of

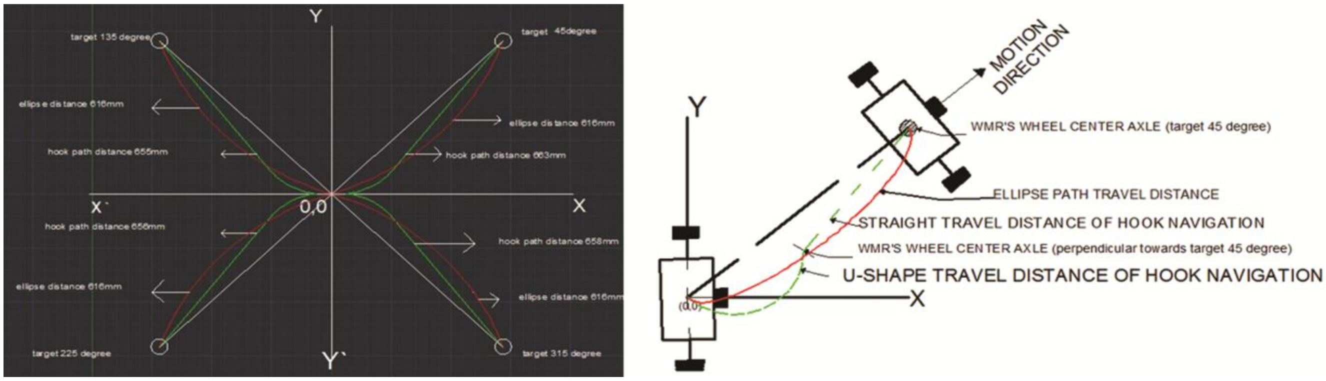

Fig. 3 — Comparison distance between ellipse path and hook path navigation for wheel rotate planning techniques

wheel. In this duration wheel rotating plan for both wheels with wheel steering angle, hence it will give more wheel slip up to the end of the target. Here after U turn in this hook path navigation is only need to consuming the both wheel rotation & without wheel steering angle[11]. Comparison distance between ellipse path navigation for wheel rotate planning techniques are shown in figure 3.

Result and Discussions

By the contribution of the three types of parameters had been used in this research and getting results that represent is the robot want to make U path navigation. In this U path navigation forming one segment of curvature travelled by using the one wheel rotate planning. After U shape path created, it should be focus towards the target. In case is not perpendicular towards a target, it is not suitable to reach in the (45°) any distance target[12]. Hence it needs to be predicted, which is the most perpendicular wheel axial position points(X, Y coordinates). The above said points are recommended to the left side or right side movements of WMR related with four quadrants. The entire robot movements in terms of wheel axial points are graphically represented manually[13]. It is recommended that the four directional wheel position in XY coordinates at 45 (42, 28) and saved1.12 wheel rotation, at 135 (-43, 32) and saved1.01 wheel rotations, at 225 (-36, -23) and saved 1.12 wheel rotations, at 315 (43,-33) and saved1.12 wheel rotations are more reliable to reach the desired target[14]. The above described coordinates are only obtained based on left side wheel fixed & right side wheel rotation (CW) for 45˚&225˚and right side wheel fixed & left side wheel rotation (CCW) for 135˚&315˚. In these results are only obtained by the OWF, and OWR methodology and wheel rotate planning techniques[15]. The accurate wheel rotate planning occurs the accurate XY coordinate of wheel axle position points. The four different factors like wheel slip, deviate from the passage, increasing target reaching time, loss of energy are controlled since the wheel rotate planning.

Conclusion

In this work, the experiments were conducted based on certain percentage of wheel rotation by the principle of centripetal force law[16]. The proper x, y (position point) coordinates which are responsible for the straight line movement of the two-wheeled mobile robot were predicted to reach the target by using the OWF & OWR methodology &wheel rotate planning techniques. It is observed that results are obtained from the Hook path U shape. The accurate x, y coordinate was found by centripetal force[17].

Left side wheel fixed & right side wheel rotation (CW) for 45˚&225˚

Right side wheel fixed & left side wheel rotation (CCW) for 135˚&315˚

As per non centripetal force values are not consider the angularity target reaching that is below For the 45˚ target the left wheel CW &right wheel fixed, for the 135˚ target the left wheel fixed & right wheel CCW, for the 225˚ target the left wheel CW& right wheel fixed, for the 315˚ target the left wheel fixed& right wheel CCW, and also both side wheel rotation (CW-CW&CCW-CCW). Is not considered because it has both opposite rotation (forward, reverse) in the turning movements of wheeled mobile robot on the experimental surface. In this time it may give more wheel slippage possibilities.

The control of the robot's wheel rotations is done in four different quadrants 45º

At 135º the1.01 of wheel rotation are controlled

At 225ºthe1.12 of wheel, rotation are controlled

At 315ºthe 1.12 of wheel, rotation are controlled

Hence in that 4.37numbers of wheel rotations were not given the wheel slip.

The above results show that the experimental values were taken using LEGONXT by keeping the payload constant. The experiment can be repeated in the same LEGONXT robot by varying the payload in the future work.

References

1 Erfani S, Jafari A & Hajiahmad A, Comparison of two data fusion methods for localization of wheeled mobile robot in farm conditions, *Artificial Intelligence in Agriculture*, (2019),

2 Alipour K, Robat A B, & Tarvirdizadeh B, Dynamics modeling and sliding mode control of tractor-trailer wheeled mobile robots subject to wheels slip. *Mech Mach Theory*, **138** (2019) 16–37.

3 Guo J, Gao H, Ding L, Guo T, & Deng Z, Linear normal stress under a wheel in skid for wheeled mobile robots running on sandy terrain, *J Terramechanics*, **70** (2017) 49–57.

4 Kundu A S, Mazumder O, Lenka P K, & Bhaumik S, Design and Performance Evaluation of 4 Wheeled Omni Wheelchair with Reduced Slip and Vibration. *Procedia Comput Sci*, **105** (2017) 289–295.

5 Li Y, Ding L, Zheng Z, Yang Q, Zhao X, & Liu G, A multi - mode real-time terrain parameter estimation method for wheeled motion control of mobile robots. *Mech Syst Signal Pr*, **104** (2017) 758–775.

6 Luo Z, Shang J, Wei G, & Ren L, A reconfigurable hybrid wheel-track mobile robot based on Watt II six-bar linkage. *Mech Mach Theory*, **128** (2018) 16–32.

7 Seo I S, & Han S I, Dual closed-loop sliding mode control for a decoupled three-link wheeled mobile manipulator. *ISA T*, (2018).

8 Trojnacki, Maciej, Dabek, Przemysław, Studies of dynamics of a lightweight wheeled mobile robot during longitudinal motion on soft ground. *Mech Res Commun* (2016).

9 Klančar G, Zdešar A, Blažič S, & Škrjanc I, Motion Modeling for Mobile Robots. *Wheeled Mobile Robotics*, (2017) 13–59.

10 Sorour M, Cherubini A & Khelloufi A, Complementary-route based ICR control for steerable wheeled mobile robots, Robot Auton Syst (2019).

11 Peña Fernández C A, Cerqueira J J F & Lima A M N, Nonlinear trajectory tracking controller for wheeled mobile robots by using a flexible auxiliary law based on slipping and skidding variations. Robot Auton Syst. (2019).

12 Ding L, Yang H, Gao H Li N, Deng Z, Guo J, & Li N Terramechanics-based modeling of sinkage and moment for in-situ steering wheels of mobile robots on deformable terrain. Mech Mach Theory, **116** (2017) 14–33.

13 Jaskot, Anna, Posiadała, Bogdan, Spiewak, Szczepan, Dynamics modelling of the four-wheeled mobile platform. Mech Res Commun **17** (2017).

14 Kassaeiyan P, Tarvirdizadeh B, & Alipour K, Control of tractor-trailer wheeled robots considering self-collision effect and actuator saturation limitations. Mech Syst Signal Pr, **127** (2019) 388–411.

15 Shu Li , Liang Ding , Haibo Gao , Chao Chen , Zhen Liu , Zongquan Deng , Adaptive Neural Network Tracking Control-Based Reinforcement Learning for Wheeled Mobile Robots with Skidding and Slipping, Neurocomputing, **17** (2017).

16 Qiu Q, Fan Z, Meng Z, Zhang Q, Cong Y, Li B, and Zhao C, Extended Ackerman Steering Principle for the coordinated movement control of a four wheel drive agricultural mobile robot. Comput Electron Agr, **152** (2018) 40–50.

17 Salgado I, Cruz-Ortiz D, Camacho O, & Chairez I, Output feedback control of a skid-steered mobile robot based on the super-twisting algorithm. Control Eng Pract, **58** (2017) 193–203.