Informe del Agente (Robot de Fútbol)

1. Datos experimentales

Distancia de prueba: $D = 1{,}1$ m
Tiempos experimentales registrados:

- Desplazamiento en pasto: $T_{pasto} = 2{,}52$ s
- Desplazamiento en piso de madera: $T_{madera} = 1{,}82$ s
- Desplazamiento en piso irregular: $T_{irregular} = 1{,}75$ s
- Quitar balón en gravilla: $T_{qg} = 37{,}61$ s
- Jugada en gravilla: $T_{jg} = 8{,}04$ s
- Quitar balón en piso liso: $T_{ql} = 4{,}07$ s
- Jugada en piso liso: $T_{jl} = 4{,}27$ s

Masa del robot: $m = 353$ g $= 0{,}353$ kg

2. Datos sin tratamiento

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scenario,sample_index,time_s
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CALCULATIONS
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desplazamiento_irregular,47,1.650261,0.666561,V = 1.1 / 1.650261 = 0.666561 m/s,-5.6993,pct =
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desplazamiento_irregular,51,1.485214,0.740634,V = 1.1 / 1.485214 = 0.740634 m/s,-15.1306,pct
desplazamiento_irregular,52,1.942751,0.566207,V = 1.1 / 1.942751 = 0.566207 m/s,11.0143,pct =
desplazamiento_irregular,53,2.195653,0.50099,V = 1.1 / 2.195653 = 0.500990 m/s,25.4659,pct =
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desplazamiento_irregular,56,1.648311,0.66735,V = 1.1 / 1.648311 = 0.667350 m/s,-5.8108,pct =
desplazamiento_irregular,57,2.016051,0.545621,V = 1.1 / 2.016051 = 0.545621 m/s,15.2029,pct =
desplazamiento_irregular,58,1.601389,0.686904,V = 1.1 / 1.601389 = 0.686904 m/s,-8.492,pct =
desplazamiento_irregular,59,1.843202,0.596788,V = 1.1 / 1.843202 = 0.596788 m/s,5.3258,pct =
desplazamiento_irregular,60,1.912673,0.575111,V = 1.1 / 1.912673 = 0.575111 m/s,9.2956,pct =
desplazamiento_irregular,61,1.555345,0.707239,V = 1.1 / 1.555345 = 0.707239 m/s,-11.1232,pct
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desplazamiento_irregular,64,1.534879,0.716669,V = 1.1 / 1.534879 = 0.716669 m/s,-12.2927,pct
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quitar_gravilla,2,30.236057,0.03638,V = 1.1 / 30.236057 = 0.036380 m/s,-19.6063,pct = (30.236
quitar_gravilla,3,47.446999,0.023184,V = 1.1 / 47.446999 = 0.023184 m/s,26.1553,pct = (47.446
quitar_gravilla,4,45.644609,0.024099,V = 1.1 / 45.644609 = 0.024099 m/s,21.363,pct = (45.6446
quitar_gravilla,5,37.334862,0.029463,V = 1.1 / 37.334862 = 0.029463 m/s,-0.7316,pct = (37.334
quitar_gravilla,6,39.154439,0.028094,V = 1.1 / 39.154439 = 0.028094 m/s,4.1065,pct = (39.1544
quitar_gravilla,7,54.428542,0.02021,V = 1.1 / 54.428542 = 0.020210 m/s,44.7183,pct = (54.4285
quitar_gravilla,8,29.82285,0.036884,V = 1.1 / 29.822850 = 0.036884 m/s,-20.705,pct = (29.8228
quitar_gravilla,9,44.811716,0.024547,V = 1.1 / 44.811716 = 0.024547 m/s,19.1484,pct = (44.811
quitar_gravilla,10,34.948437,0.031475,V = 1.1 / 34.948437 = 0.031475 m/s,-7.0767,pct = (34.94
quitar_gravilla,11,34.744553,0.03166,V = 1.1 / 34.744553 = 0.031660 m/s,-7.6188,pct = (34.744
quitar_gravilla,12,52.073749,0.021124,V = 1.1 / 52.073749 = 0.021124 m/s,38.4572,pct = (52.07
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quitar_gravilla,14,48.318634,0.022766,V = 1.1 / 48.318634 = 0.022766 m/s,28.4728,pct = (48.318
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quitar_gravilla,16,37.886484,0.029034,V = 1.1 / 37.886484 = 0.029034 m/s,0.7351,pct = (37.886
quitar_gravilla,17,46.586888,0.023612,V = 1.1 / 46.586888 = 0.023612 m/s,23.8684,pct = (46.58
quitar_gravilla,18,33.525804,0.032811,V = 1.1 / 33.525804 = 0.032811 m/s,-10.8593,pct = (33.5
quitar_gravilla,19,41.877164,0.026267,V = 1.1 / 41.877164 = 0.026267 m/s,11.3458,pct = (41.87
quitar_gravilla,20,35.896862,0.030643,V = 1.1 / 35.896862 = 0.030643 m/s,-4.555,pct = (35.896
quitar_gravilla,21,38.886806,0.028287,V = 1.1 / 38.886806 = 0.028287 m/s,3.3949,pct = (38.886
quitar_gravilla,22,45.44435,0.024205,V = 1.1 / 45.444350 = 0.024205 m/s,20.8305,pct = (45.444
quitar_gravilla,23,26.839352,0.040985,V = 1.1 / 26.839352 = 0.040985 m/s,-28.6377,pct = (26.8
quitar_gravilla,24,65.15314,0.016883,V = 1.1 / 65.153140 = 0.016883 m/s,73.2336,pct = (65.153
quitar_gravilla,25,24.36729,0.045142,V = 1.1 / 24.367290 = 0.045142 m/s,-35.2106,pct = (24.367
quitar_gravilla,26,21.627028,0.050862,V = 1.1 / 21.627028 = 0.050862 m/s,-42.4966,pct = (21.6
quitar_gravilla,27,52.854792,0.020812,V = 1.1 / 52.854792 = 0.020812 m/s,40.5339,pct = (52.854
quitar_gravilla,28,48.031052,0.022902,V = 1.1 / 48.031052 = 0.022902 m/s,27.7082,pct = (48.03
quitar_gravilla,29,45.825601,0.024004,V = 1.1 / 45.825601 = 0.024004 m/s,21.8442,pct = (45.82
quitar_gravilla,30,45.881226,0.023975,V = 1.1 / 45.881226 = 0.023975 m/s,21.9921,pct = (45.88
quitar_gravilla,31,37.44879,0.029373,V = 1.1 / 37.448790 = 0.029373 m/s,-0.4286,pct = (37.448
quitar_gravilla,32,25.798992,0.042637,V = 1.1 / 25.798992 = 0.042637 m/s,-31.4039,pct = (25.7
quitar_gravilla,33,38.607853,0.028492,V = 1.1 / 38.607853 = 0.028492 m/s,2.6532,pct = (38.607
quitar_gravilla,34,28.696182,0.038333,V = 1.1 / 28.696182 = 0.038333 m/s,-23.7007,pct = (28.6
quitar_gravilla,35,50.445989,0.021805,V = 1.1 / 50.445989 = 0.021805 m/s,34.1292,pct = (50.44
quitar_gravilla,36,35.67421,0.030835,V = 1.1 / 35.674210 = 0.030835 m/s,-5.147,pct = (35.6742
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quitar_gravilla,38,33.379437,0.032954,V = 1.1 / 33.379437 = 0.032954 m/s,-11.2485,pct = (33.3
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quitar_gravilla,40,30.189412,0.036437,V = 1.1 / 30.189412 = 0.036437 m/s,-19.7304,pct = (30.1
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quitar_gravilla,43,40.834617,0.026938,V = 1.1 / 40.834617 = 0.026938 m/s,8.5738,pct = (40.834
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quitar_gravilla,45,31.409487,0.035021,V = 1.1 / 31.409487 = 0.035021 m/s,-16.4863,pct = (31.4
quitar_gravilla,46,40.664589,0.027051,V = 1.1 / 40.664589 = 0.027051 m/s,8.1217,pct = (40.664
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quitar_gravilla,49,28.152759,0.039073,V = 1.1 / 28.152759 = 0.039073 m/s,-25.1455,pct = (28.1
quitar_gravilla,50,34.800288,0.031609,V = 1.1 / 34.800288 = 0.031609 m/s,-7.4707,pct = (34.80
quitar_gravilla,51,41.702632,0.026377,V = 1.1 / 41.702632 = 0.026377 m/s,10.8818,pct = (41.70
quitar_gravilla,52,57.030852,0.019288,V = 1.1 / 57.030852 = 0.019288 m/s,51.6375,pct = (57.03
quitar_gravilla,53,48.899802,0.022495,V = 1.1 / 48.899802 = 0.022495 m/s,30.0181,pct = (48.89
quitar_gravilla,54,35.504649,0.030982,V = 1.1 / 35.504649 = 0.030982 m/s,-5.5978,pct = (35.50
quitar_gravilla,55,37.35968,0.029444,V = 1.1 / 37.359680 = 0.029444 m/s,-0.6656,pct = (37.359
quitar_gravilla,56,24.413205,0.045058,V = 1.1 / 24.413205 = 0.045058 m/s,-35.0885,pct = (24.4
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quitar_gravilla,62,57.786209,0.019036,V = 1.1 / 57.786209 = 0.019036 m/s,53.6459,pct = (57.78
quitar_gravilla,63,36.178336,0.030405,V = 1.1 / 36.178336 = 0.030405 m/s,-3.8066,pct = (36.17
quitar_gravilla,64,42.897932,0.025642,V = 1.1 / 42.897932 = 0.025642 m/s,14.0599,pct = (42.89
quitar_gravilla,65,46.69471,0.023557,V = 1.1 / 46.694710 = 0.023557 m/s,24.155,pct = (46.6947
quitar_gravilla,66,32.328534,0.034026,V = 1.1 / 32.328534 = 0.034026 m/s,-14.0427,pct = (32.3
quitar_gravilla,67,40.559841,0.02712,V = 1.1 / 40.559841 = 0.027120 m/s,7.8432,pct = (40.5598
quitar_gravilla,68,37.77576,0.029119,V = 1.1 / 37.775760 = 0.029119 m/s,0.4407,pct = (37.7757
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quitar_gravilla,70,27.434486,0.040096,V = 1.1 / 27.434486 = 0.040096 m/s,-27.0553,pct = (27.4
quitar_gravilla,71,37.93264,0.028999,V = 1.1 / 37.932640 = 0.028999 m/s,0.8579,pct = (37.9326
quitar_gravilla,72,44.165401,0.024906,V = 1.1 / 44.165401 = 0.024906 m/s,17.4299,pct = (44.16
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quitar_gravilla,76,27.50902,0.039987,V = 1.1 / 27.509020 = 0.039987 m/s,-26.8572,pct = (27.50
quitar_gravilla,77,49.092793,0.022407,V = 1.1 / 49.092793 = 0.022407 m/s,30.5312,pct = (49.09
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quitar_gravilla,79,66.435471,0.016557,V = 1.1 / 66.435471 = 0.016557 m/s,76.6431,pct = (66.43
quitar_gravilla,80,26.969966,0.040786,V = 1.1 / 26.969966 = 0.040786 m/s,-28.2904,pct = (26.9
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quitar_gravilla,82,29.719895,0.037012,V = 1.1 / 29.719895 = 0.037012 m/s,-20.9787,pct = (29.7
quitar_gravilla,83,9.652099,0.113965,V = 1.1 / 9.652099 = 0.113965 m/s,-74.3364,pct = (9.6520
quitar_gravilla,84,30.689224,0.035843,V = 1.1 / 30.689224 = 0.035843 m/s,-18.4014,pct = (30.6
quitar_gravilla,85,27.617157,0.03983,V = 1.1 / 27.617157 = 0.039830 m/s,-26.5696,pct = (27.61
quitar_gravilla,86,39.589709,0.027785,V = 1.1 / 39.589709 = 0.027785 m/s,5.2638,pct = (39.589
quitar_gravilla,87,42.108705,0.026123,V = 1.1 / 42.108705 = 0.026123 m/s,11.9615,pct = (42.10
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quitar_gravilla,92,44.085378,0.024952,V = 1.1 / 44.085378 = 0.024952 m/s,17.2172,pct = (44.08
quitar_gravilla,93,20.23111,0.054372,V = 1.1 / 20.231110 = 0.054372 m/s,-46.2082,pct = (20.23
quitar_gravilla,94,61.718407,0.017823,V = 1.1 / 61.718407 = 0.017823 m/s,64.1011,pct = (61.71
quitar_gravilla,95,53.13556,0.020702,V = 1.1 / 53.135560 = 0.020702 m/s,41.2804,pct = (53.135
quitar_gravilla,96,31.434006,0.034994,V = 1.1 / 31.434006 = 0.034994 m/s,-16.4211,pct = (31.4
quitar_gravilla,97,15.059154,0.073045,V = 1.1 / 15.059154 = 0.073045 m/s,-59.9597,pct = (15.0
quitar_gravilla,98,55.431699,0.019844,V = 1.1 / 55.431699 = 0.019844 m/s,47.3855,pct = (55.43
quitar_gravilla,99,36.102255,0.030469,V = 1.1 / 36.102255 = 0.030469 m/s,-4.0089,pct = (36.10
quitar_gravilla,100,53.903995,0.020407,V = 1.1 / 53.903995 = 0.020407 m/s,43.3236,pct = (53.9
jugada_gravilla,1,5.47616,0.200871,V = 1.1 / 5.476160 = 0.200871 m/s,-31.8886,pct = (5.476160
jugada_gravilla,2,7.076205,0.155451,V = 1.1 / 7.076205 = 0.155451 m/s,-11.9875,pct = (7.07620
jugada_gravilla,3,8.048432,0.136673,V = 1.1 / 8.048432 = 0.136673 m/s,0.1049,pct = (8.048432
jugada_gravilla,4,8.115545,0.135542,V = 1.1 / 8.115545 = 0.135542 m/s,0.9396,pct = (8.115545
jugada_gravilla,5,7.316295,0.150349,V = 1.1 / 7.316295 = 0.150349 m/s,-9.0013,pct = (7.316295
jugada_gravilla,6,9.041543,0.121661,V = 1.1 / 9.041543 = 0.121661 m/s,12.457,pct = (9.041543
jugada_gravilla,7,6.323266,0.173961,V = 1.1 / 6.323266 = 0.173961 m/s,-21.3524,pct = (6.32326
jugada_gravilla,8,7.811054,0.140826,V = 1.1 / 7.811054 = 0.140826 m/s,-2.8476,pct = (7.811054
jugada_gravilla,9,8.233435,0.133602,V = 1.1 / 8.233435 = 0.133602 m/s,2.4059,pct = (8.233435
jugada_gravilla,10,8.867218,0.124052,V = 1.1 / 8.867218 = 0.124052 m/s,10.2888,pct = (8.86721
jugada_gravilla,11,9.184277,0.11977,V = 1.1 / 9.184277 = 0.119770 m/s,14.2323,pct = (9.184277
jugada_gravilla,12,6.231576,0.17652,V = 1.1 / 6.231576 = 0.176520 m/s,-22.4928,pct = (6.23157
jugada_gravilla,13,5.573144,0.197375,V = 1.1 / 5.573144 = 0.197375 m/s,-30.6823,pct = (5.5731
jugada_gravilla,14,10.094504,0.10897,V = 1.1 / 10.094504 = 0.108970 m/s,25.5535,pct = (10.094
jugada_gravilla,15,8.574361,0.128289,V = 1.1 / 8.574361 = 0.128289 m/s,6.6463,pct = (8.574361
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jugada_gravilla,17,10.534252,0.104421,V = 1.1 / 10.534252 = 0.104421 m/s,31.023,pct = (10.534
jugada_gravilla,18,8.226005,0.133722,V = 1.1 / 8.226005 = 0.133722 m/s,2.3135,pct = (8.226005
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jugada_gravilla,29,9.741947,0.112914,V = 1.1 / 9.741947 = 0.112914 m/s,21.1685,pct = (9.74194
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jugada_gravilla,31,6.13732,0.179231,V = 1.1 / 6.137320 = 0.179231 m/s,-23.6652,pct = (6.13732
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jugada_gravilla,36,8.159144,0.134818,V = 1.1 / 8.159144 = 0.134818 m/s,1.4819,pct = (8.159144
jugada_gravilla,37,10.658814,0.103201,V = 1.1 / 10.658814 = 0.103201 m/s,32.5723,pct = (10.65
jugada_gravilla,38,5.820797,0.188978,V = 1.1 / 5.820797 = 0.188978 m/s,-27.602,pct = (5.82079
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jugada_gravilla,47,8.62949,0.12747,V = 1.1 / 8.629490 = 0.127470 m/s,7.332,pct = (8.629490 - 
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jugada_gravilla,49,7.213702,0.152488,V = 1.1 / 7.213702 = 0.152488 m/s,-10.2773,pct = (7.2137
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jugada_gravilla,62,8.096704,0.135858,V = 1.1 / 8.096704 = 0.135858 m/s,0.7053,pct = (8.096704
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jugada_gravilla,70,7.114084,0.154623,V = 1.1 / 7.114084 = 0.154623 m/s,-11.5164,pct = (7.1140
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quitar_liso,47,4.422303,0.248739,V = 1.1 / 4.422303 = 0.248739 m/s,8.6561,pct = (4.422303 - 4
quitar_liso,48,3.946041,0.27876,V = 1.1 / 3.946041 = 0.278760 m/s,-3.0457,pct = (3.946041 - 4
quitar_liso,49,4.296585,0.256017,V = 1.1 / 4.296585 = 0.256017 m/s,5.5672,pct = (4.296585 - 4
quitar_liso,50,3.701267,0.297196,V = 1.1 / 3.701267 = 0.297196 m/s,-9.0598,pct = (3.701267 -
quitar_liso,51,4.122863,0.266805,V = 1.1 / 4.122863 = 0.266805 m/s,1.2988,pct = (4.122863 - 4
quitar_liso,52,3.974959,0.276732,V = 1.1 / 3.974959 = 0.276732 m/s,-2.3352,pct = (3.974959 -
quitar_liso,53,4.782931,0.229985,V = 1.1 / 4.782931 = 0.229985 m/s,17.5167,pct = (4.782931 -
quitar_liso,54,4.225324,0.260335,V = 1.1 / 4.225324 = 0.260335 m/s,3.8163,pct = (4.225324 - 4
quitar_liso,55,4.276106,0.257243,V = 1.1 / 4.276106 = 0.257243 m/s,5.064,pct = (4.276106 - 4.
quitar_liso,56,3.818549,0.288068,V = 1.1 / 3.818549 = 0.288068 m/s,-6.1782,pct = (3.818549 -
quitar_liso,57,3.772316,0.291598,V = 1.1 / 3.772316 = 0.291598 m/s,-7.3141,pct = (3.772316 -
quitar_liso,58,3.805923,0.289023,V = 1.1 / 3.805923 = 0.289023 m/s,-6.4884,pct = (3.805923 -
quitar_liso,59,4.310813,0.255172,V = 1.1 / 4.310813 = 0.255172 m/s,5.9168,pct = (4.310813 - 4
quitar_liso,60,3.812989,0.288488,V = 1.1 / 3.812989 = 0.288488 m/s,-6.3148,pct = (3.812989 -
quitar_liso,61,4.246908,0.259012,V = 1.1 / 4.246908 = 0.259012 m/s,4.3466,pct = (4.246908 - 4
quitar_liso,62,5.337032,0.206107,V = 1.1 / 5.337032 = 0.206107 m/s,31.131,pct = (5.337032 - 4
quitar_liso,63,4.601822,0.239036,V = 1.1 / 4.601822 = 0.239036 m/s,13.0669,pct = (4.601822 -
quitar_liso,64,3.870963,0.284167,V = 1.1 / 3.870963 = 0.284167 m/s,-4.8904,pct = (3.870963 -
quitar_liso,65,4.803341,0.229007,V = 1.1 / 4.803341 = 0.229007 m/s,18.0182,pct = (4.803341 -
quitar_liso,66,3.82087,0.287893,V = 1.1 / 3.820870 = 0.287893 m/s,-6.1211,pct = (3.820870 - 4
quitar_liso,67,2.825725,0.389281,V = 1.1 / 2.825725 = 0.389281 m/s,-30.5719,pct = (2.825725 -
quitar_liso,68,3.454563,0.318419,V = 1.1 / 3.454563 = 0.318419 m/s,-15.1213,pct = (3.454563 -
quitar_liso,69,2.927882,0.375698,V = 1.1 / 2.927882 = 0.375698 m/s,-28.0619,pct = (2.927882 -
quitar_liso,70,3.855401,0.285314,V = 1.1 / 3.855401 = 0.285314 m/s,-5.2727,pct = (3.855401 -
quitar_liso,71,4.081244,0.269526,V = 1.1 / 4.081244 = 0.269526 m/s,0.2763,pct = (4.081244 - 4
quitar_liso,72,5.093465,0.215963,V = 1.1 / 5.093465 = 0.215963 m/s,25.1466,pct = (5.093465 -
quitar_liso,73,4.269589,0.257636,V = 1.1 / 4.269589 = 0.257636 m/s,4.9039,pct = (4.269589 - 4
quitar_liso,74,3.936239,0.279455,V = 1.1 / 3.936239 = 0.279455 m/s,-3.2865,pct = (3.936239 -
quitar_liso,75,4.576352,0.240366,V = 1.1 / 4.576352 = 0.240366 m/s,12.4411,pct = (4.576352 -
quitar_liso,76,2.720102,0.404397,V = 1.1 / 2.720102 = 0.404397 m/s,-33.167,pct = (2.720102 -
quitar_liso,77,4.213843,0.261044,V = 1.1 / 4.213843 = 0.261044 m/s,3.5342,pct = (4.213843 - 4
quitar_liso,78,4.540613,0.242258,V = 1.1 / 4.540613 = 0.242258 m/s,11.563,pct = (4.540613 - 4
quitar_liso,79,3.167323,0.347296,V = 1.1 / 3.167323 = 0.347296 m/s,-22.1788,pct = (3.167323 -
quitar_liso,80,4.768262,0.230692,V = 1.1 / 4.768262 = 0.230692 m/s,17.1563,pct = (4.768262 -
quitar_liso,81,4.276652,0.257211,V = 1.1 / 4.276652 = 0.257211 m/s,5.0774,pct = (4.276652 - 4
quitar_liso,82,3.816467,0.288225,V = 1.1 / 3.816467 = 0.288225 m/s,-6.2293,pct = (3.816467 -
quitar_liso,83,4.456313,0.246841,V = 1.1 / 4.456313 = 0.246841 m/s,9.4917,pct = (4.456313 - 4
quitar_liso,84,5.456258,0.201603,V = 1.1 / 5.456258 = 0.201603 m/s,34.0604,pct = (5.456258 -
quitar_liso,85,4.181029,0.263093,V = 1.1 / 4.181029 = 0.263093 m/s,2.728,pct = (4.181029 - 4.
quitar_liso,86,4.221539,0.260569,V = 1.1 / 4.221539 = 0.260569 m/s,3.7233,pct = (4.221539 - 4
quitar_liso,87,3.78956,0.290271,V = 1.1 / 3.789560 = 0.290271 m/s,-6.8904,pct = (3.789560 - 4
quitar_liso,88,3.55117,0.309757,V = 1.1 / 3.551170 = 0.309757 m/s,-12.7477,pct = (3.551170 -
quitar_liso,89,4.57692,0.240336,V = 1.1 / 4.576920 = 0.240336 m/s,12.455,pct = (4.576920 - 4.
quitar_liso,90,3.547361,0.31009,V = 1.1 / 3.547361 = 0.310090 m/s,-12.8413,pct = (3.547361 -
quitar_liso,91,4.113691,0.2674,V = 1.1 / 4.113691 = 0.267400 m/s,1.0735,pct = (4.113691 - 4.0
quitar_liso,92,3.77839,0.291129,V = 1.1 / 3.778390 = 0.291129 m/s,-7.1649,pct = (3.778390 - 4
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quitar_liso,93,4.362417,0.252154,V = 1.1 / 4.362417 = 0.252154 m/s,7.1847,pct = (4.362417 - 4
quitar_liso,94,4.273701,0.257388,V = 1.1 / 4.273701 = 0.257388 m/s,5.0049,pct = (4.273701 - 4
quitar_liso,95,4.703418,0.233872,V = 1.1 / 4.703418 = 0.233872 m/s,15.5631,pct = (4.703418 - 
quitar_liso,96,3.758635,0.292659,V = 1.1 / 3.758635 = 0.292659 m/s,-7.6502,pct = (3.758635 - 
quitar_liso,97,3.905241,0.281673,V = 1.1 / 3.905241 = 0.281673 m/s,-4.0481,pct = (3.905241 - 
quitar_liso,98,3.472465,0.316778,V = 1.1 / 3.472465 = 0.316778 m/s,-14.6815,pct = (3.472465 -
quitar_liso,99,3.798759,0.289568,V = 1.1 / 3.798759 = 0.289568 m/s,-6.6644,pct = (3.798759 - 
quitar_liso,100,4.300342,0.255794,V = 1.1 / 4.300342 = 0.255794 m/s,5.6595,pct = (4.300342 - 
jugada_liso,1,4.657881,0.236159,V = 1.1 / 4.657881 = 0.236159 m/s,9.0839,pct = (4.657881 - 4.1
jugada_liso,2,3.797482,0.289666,V = 1.1 / 3.797482 = 0.289666 m/s,-11.066,pct = (3.797482 - 4
jugada_liso,3,4.715586,0.233269,V = 1.1 / 4.715586 = 0.233269 m/s,10.4353,pct = (4.715586 - 4
jugada_liso,4,4.964629,0.221567,V = 1.1 / 4.964629 = 0.221567 m/s,16.2677,pct = (4.964629 - 4
jugada_liso,5,4.481844,0.245435,V = 1.1 / 4.481844 = 0.245435 m/s,4.9612,pct = (4.481844 - 4.1
jugada_liso,6,5.23167,0.210258,V = 1.1 / 5.231670 = 0.210258 m/s,22.5215,pct = (5.231670 - 4.1
jugada_liso,7,3.87351,0.28398,V = 1.1 / 3.873510 = 0.283980 m/s,-9.2855,pct = (3.873510 - 4.27
jugada_liso,8,3.632239,0.302844,V = 1.1 / 3.632239 = 0.302844 m/s,-14.9359,pct = (3.632239 - 
jugada_liso,9,3.358584,0.327519,V = 1.1 / 3.358584 = 0.327519 m/s,-21.3446,pct = (3.358584 - 
jugada_liso,10,5.036573,0.218402,V = 1.1 / 5.036573 = 0.218402 m/s,17.9525,pct = (5.036573 - 
jugada_liso,11,4.605297,0.238855,V = 1.1 / 4.605297 = 0.238855 m/s,7.8524,pct = (4.605297 - 4
jugada_liso,12,4.241518,0.259341,V = 1.1 / 4.241518 = 0.259341 m/s,-0.667,pct = (4.241518 - 4
jugada_liso,13,4.413456,0.249238,V = 1.1 / 4.413456 = 0.249238 m/s,3.3596,pct = (4.413456 - 4
jugada_liso,14,3.693299,0.297837,V = 1.1 / 3.693299 = 0.297837 m/s,-13.5059,pct = (3.693299 -
jugada_liso,15,5.523203,0.19916,V = 1.1 / 5.523203 = 0.199160 m/s,29.349,pct = (5.523203 - 4.1
jugada_liso,16,4.336213,0.253678,V = 1.1 / 4.336213 = 0.253678 m/s,1.5507,pct = (4.336213 - 4
jugada_liso,17,4.326054,0.254273,V = 1.1 / 4.326054 = 0.254273 m/s,1.3127,pct = (4.326054 - 4
jugada_liso,18,4.641883,0.236973,V = 1.1 / 4.641883 = 0.236973 m/s,8.7092,pct = (4.641883 - 4
jugada_liso,19,4.516469,0.243553,V = 1.1 / 4.516469 = 0.243553 m/s,5.7721,pct = (4.516469 - 4
jugada_liso,20,4.384718,0.250871,V = 1.1 / 4.384718 = 0.250871 m/s,2.6866,pct = (4.384718 - 4
jugada_liso,21,3.864961,0.284608,V = 1.1 / 3.864961 = 0.284608 m/s,-9.4857,pct = (3.864961 - 
jugada_liso,22,4.51158,0.243817,V = 1.1 / 4.511580 = 0.243817 m/s,5.6576,pct = (4.511580 - 4.1
jugada_liso,23,5.234349,0.21015,V = 1.1 / 5.234349 = 0.210150 m/s,22.5843,pct = (5.234349 - 4
jugada_liso,24,4.959393,0.221801,V = 1.1 / 4.959393 = 0.221801 m/s,16.145,pct = (4.959393 - 4
jugada_liso,25,5.086349,0.216265,V = 1.1 / 5.086349 = 0.216265 m/s,19.1182,pct = (5.086349 - 
jugada_liso,26,4.008053,0.274447,V = 1.1 / 4.008053 = 0.274447 m/s,-6.1346,pct = (4.008053 - 
jugada_liso,27,3.762926,0.292326,V = 1.1 / 3.762926 = 0.292326 m/s,-11.8753,pct = (3.762926 -
jugada_liso,28,4.205547,0.261559,V = 1.1 / 4.205547 = 0.261559 m/s,-1.5094,pct = (4.205547 - 
jugada_liso,29,4.298553,0.2559,V = 1.1 / 4.298553 = 0.255900 m/s,0.6687,pct = (4.298553 - 4.27
jugada_liso,30,4.830664,0.227712,V = 1.1 / 4.830664 = 0.227712 m/s,13.1303,pct = (4.830664 - 
jugada_liso,31,3.402781,0.323265,V = 1.1 / 3.402781 = 0.323265 m/s,-20.3096,pct = (3.402781 -
jugada_liso,32,5.053742,0.217661,V = 1.1 / 5.053742 = 0.217661 m/s,18.3546,pct = (5.053742 - 
jugada_liso,33,4.189037,0.26259,V = 1.1 / 4.189037 = 0.262590 m/s,-1.8961,pct = (4.189037 - 4
jugada_liso,34,4.051266,0.27152,V = 1.1 / 4.051266 = 0.271520 m/s,-5.1226,pct = (4.051266 - 4
jugada_liso,35,3.751398,0.293224,V = 1.1 / 3.751398 = 0.293224 m/s,-12.1453,pct = (3.751398 -
jugada_liso,36,3.422051,0.321445,V = 1.1 / 3.422051 = 0.321445 m/s,-19.8583,pct = (3.422051 -
jugada_liso,37,4.691793,0.234452,V = 1.1 / 4.691793 = 0.234452 m/s,9.878,pct = (4.691793 - 4.1
jugada_liso,38,4.307568,0.255365,V = 1.1 / 4.307568 = 0.255365 m/s,0.8798,pct = (4.307568 - 4
jugada_liso,39,3.609024,0.304792,V = 1.1 / 3.609024 = 0.304792 m/s,-15.4795,pct = (3.609024 -
jugada_liso,40,3.606402,0.305013,V = 1.1 / 3.606402 = 0.305013 m/s,-15.5409,pct = (3.606402 -
jugada_liso,41,4.097944,0.268427,V = 1.1 / 4.097944 = 0.268427 m/s,-4.0294,pct = (4.097944 - 
jugada_liso,42,5.125207,0.214625,V = 1.1 / 5.125207 = 0.214625 m/s,20.0283,pct = (5.125207 - 
jugada_liso,43,4.136985,0.265894,V = 1.1 / 4.136985 = 0.265894 m/s,-3.1151,pct = (4.136985 - 
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jugada_liso,44,3.49979,0.314305,V = 1.1 / 3.499790 = 0.314305 m/s,-18.0377,pct = (3.499790 -
jugada_liso,45,4.144081,0.265439,V = 1.1 / 4.144081 = 0.265439 m/s,-2.9489,pct = (4.144081 -
jugada_liso,46,4.130256,0.266327,V = 1.1 / 4.130256 = 0.266327 m/s,-3.2727,pct = (4.130256 -
jugada_liso,47,2.888115,0.380871,V = 1.1 / 2.888115 = 0.380871 m/s,-32.3626,pct = (2.888115 -
jugada_liso,48,4.242179,0.259301,V = 1.1 / 4.242179 = 0.259301 m/s,-0.6515,pct = (4.242179 -
jugada_liso,49,4.151669,0.264954,V = 1.1 / 4.151669 = 0.264954 m/s,-2.7712,pct = (4.151669 -
jugada_liso,50,4.626736,0.237749,V = 1.1 / 4.626736 = 0.237749 m/s,8.3545,pct = (4.626736 - 4
jugada_liso,51,5.217405,0.210833,V = 1.1 / 5.217405 = 0.210833 m/s,22.1875,pct = (5.217405 -
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jugada_liso,55,5.58859,0.19683,V = 1.1 / 5.588590 = 0.196830 m/s,30.8803,pct = (5.588590 - 4.
jugada_liso,56,4.300344,0.255794,V = 1.1 / 4.300344 = 0.255794 m/s,0.7106,pct = (4.300344 - 4
jugada_liso,57,4.277137,0.257181,V = 1.1 / 4.277137 = 0.257181 m/s,0.1672,pct = (4.277137 - 4
jugada_liso,58,4.257638,0.258359,V = 1.1 / 4.257638 = 0.258359 m/s,-0.2895,pct = (4.257638 -
jugada_liso,59,4.371499,0.25163,V = 1.1 / 4.371499 = 0.251630 m/s,2.377,pct = (4.371499 - 4.2
jugada_liso,60,4.19603,0.262153,V = 1.1 / 4.196030 = 0.262153 m/s,-1.7323,pct = (4.196030 - 4
jugada_liso,61,3.976056,0.276656,V = 1.1 / 3.976056 = 0.276656 m/s,-6.8839,pct = (3.976056 -
jugada_liso,62,3.989789,0.275704,V = 1.1 / 3.989789 = 0.275704 m/s,-6.5623,pct = (3.989789 -
jugada_liso,63,4.253217,0.258628,V = 1.1 / 4.253217 = 0.258628 m/s,-0.393,pct = (4.253217 - 4
jugada_liso,64,3.991549,0.275582,V = 1.1 / 3.991549 = 0.275582 m/s,-6.5211,pct = (3.991549 -
jugada_liso,65,3.904738,0.281709,V = 1.1 / 3.904738 = 0.281709 m/s,-8.5541,pct = (3.904738 -
jugada_liso,66,4.324535,0.254363,V = 1.1 / 4.324535 = 0.254363 m/s,1.2772,pct = (4.324535 - 4
jugada_liso,67,4.13935,0.265742,V = 1.1 / 4.139350 = 0.265742 m/s,-3.0597,pct = (4.139350 - 4
jugada_liso,68,5.040646,0.218226,V = 1.1 / 5.040646 = 0.218226 m/s,18.0479,pct = (5.040646 -
jugada_liso,69,2.911643,0.377794,V = 1.1 / 2.911643 = 0.377794 m/s,-31.8116,pct = (2.911643 -
jugada_liso,70,4.829288,0.227777,V = 1.1 / 4.829288 = 0.227777 m/s,13.0981,pct = (4.829288 -
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jugada_liso,72,3.207595,0.342936,V = 1.1 / 3.207595 = 0.342936 m/s,-24.8807,pct = (3.207595 -
jugada_liso,73,4.094407,0.268659,V = 1.1 / 4.094407 = 0.268659 m/s,-4.1123,pct = (4.094407 -
jugada_liso,74,4.079674,0.269629,V = 1.1 / 4.079674 = 0.269629 m/s,-4.4573,pct = (4.079674 -
jugada_liso,75,3.548791,0.309965,V = 1.1 / 3.548791 = 0.309965 m/s,-16.8901,pct = (3.548791 -
jugada_liso,76,3.871447,0.284132,V = 1.1 / 3.871447 = 0.284132 m/s,-9.3338,pct = (3.871447 -
jugada_liso,77,3.700941,0.297222,V = 1.1 / 3.700941 = 0.297222 m/s,-13.3269,pct = (3.700941 -
jugada_liso,78,5.167863,0.212854,V = 1.1 / 5.167863 = 0.212854 m/s,21.0272,pct = (5.167863 -
jugada_liso,79,4.749442,0.231606,V = 1.1 / 4.749442 = 0.231606 m/s,11.2281,pct = (4.749442 -
jugada_liso,80,4.921545,0.223507,V = 1.1 / 4.921545 = 0.223507 m/s,15.2587,pct = (4.921545 -
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jugada_liso,82,3.691474,0.297984,V = 1.1 / 3.691474 = 0.297984 m/s,-13.5486,pct = (3.691474 -
jugada_liso,83,4.001236,0.274915,V = 1.1 / 4.001236 = 0.274915 m/s,-6.2942,pct = (4.001236 -
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jugada_liso,87,4.146857,0.265261,V = 1.1 / 4.146857 = 0.265261 m/s,-2.8839,pct = (4.146857 -
jugada_liso,88,4.077942,0.269744,V = 1.1 / 4.077942 = 0.269744 m/s,-4.4978,pct = (4.077942 -
jugada_liso,89,4.634296,0.237361,V = 1.1 / 4.634296 = 0.237361 m/s,8.5315,pct = (4.634296 - 4
jugada_liso,90,4.497641,0.244573,V = 1.1 / 4.497641 = 0.244573 m/s,5.3312,pct = (4.497641 - 4
jugada_liso,91,4.085041,0.269275,V = 1.1 / 4.085041 = 0.269275 m/s,-4.3316,pct = (4.085041 -
jugada_liso,92,4.864041,0.226149,V = 1.1 / 4.864041 = 0.226149 m/s,13.912,pct = (4.864041 - 4
jugada_liso,93,3.716063,0.296012,V = 1.1 / 3.716063 = 0.296012 m/s,-12.9728,pct = (3.716063 -
jugada_liso,94,4.585605,0.239881,V = 1.1 / 4.585605 = 0.239881 m/s,7.3912,pct = (4.585605 - 4
```

```
jugada_liso,95,4.573905,0.240495,V = 1.1 / 4.573905 = 0.240495 m/s,7.1172,pct = (4.573905 - 4
jugada_liso,96,4.111388,0.26755,V = 1.1 / 4.111388 = 0.267550 m/s,-3.7146,pct = (4.111388 - 4
jugada_liso,97,4.437111,0.247909,V = 1.1 / 4.437111 = 0.247909 m/s,3.9136,pct = (4.437111 - 4
jugada_liso,98,3.628929,0.30312,V = 1.1 / 3.628929 = 0.303120 m/s,-15.0134,pct = (3.628929 -
jugada_liso,99,4.743471,0.231898,V = 1.1 / 4.743471 = 0.231898 m/s,11.0883,pct = (4.743471 -
jugada_liso,100,4.175256,0.263457,V = 1.1 / 4.175256 = 0.263457 m/s,-2.2188,pct = (4.175256 -

FORMULAS_AND_EXAMPLES
Formula_V = V = D / T  (D = distancia en metros, T = tiempo en segundos)
Formula_D = D = V * T
Formula_T = T = D / V

Examples using experimental times (demostración de sustitución):
Scenario: desplazamiento_pasto | T_exp = 2.52 s | V = 1.1 / 2.52 = 0.436508 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 2.895516 s | pct = (2.895516 - 2.52)/2.
   Interpretacion: muestra mas lenta que el tiempo experimental.
Scenario: desplazamiento_madera | T_exp = 1.82 s | V = 1.1 / 1.82 = 0.604396 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 1.613922 s | pct = (1.613922 - 1.82)/1.
   Interpretacion: muestra mas rapida que el tiempo experimental.
Scenario: desplazamiento_irregular | T_exp = 1.75 s | V = 1.1 / 1.75 = 0.628571 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 1.825135 s | pct = (1.825135 - 1.75)/1.
   Interpretacion: muestra mas lenta que el tiempo experimental.
Scenario: quitar_gravilla | T_exp = 37.61 s | V = 1.1 / 37.61 = 0.029248 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 26.697524 s | pct = (26.697524 - 37.61)
   Interpretacion: muestra mas rapida que el tiempo experimental.
Scenario: jugada_gravilla | T_exp = 8.04 s | V = 1.1 / 8.04 = 0.136816 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 5.47616 s | pct = (5.47616 - 8.04)/8.04
   Interpretacion: muestra mas rapida que el tiempo experimental.
Scenario: quitar_liso | T_exp = 4.07 s | V = 1.1 / 4.07 = 0.270270 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 4.635431 s | pct = (4.635431 - 4.07)/4.
   Interpretacion: muestra mas lenta que el tiempo experimental.
Scenario: jugada_liso | T_exp = 4.27 s | V = 1.1 / 4.27 = 0.257611 m/s
  Ejemplo sustitucion con primera muestra: T_sample = 4.657881 s | pct = (4.657881 - 4.27)/4.
   Interpretacion: muestra mas lenta que el tiempo experimental.
```

3. Datos con analisis

En esta sección se presentan los datos ya tratados (resumen estadístico a partir de las 100 simulaciones por escenario), junto con las fórmulas utilizadas para obtener cada columna y ejemplos de sustitución numérica.

3.1. Fórmulas utilizadas

Se emplearon las fórmulas básicas del movimiento y métricas estadísticas:

- Velocidad media (para desplazamientos):

$$V = \frac{D}{T}$$

  donde D es la distancia (1.1 m) y T es el tiempo de la muestra (s).

- Diferencia porcentual entre una muestra y el tiempo experimental:

$$\text{PctDiff} = \frac{T_{\text{muestra}} - T_{\text{exp}}}{T_{\text{exp}}} \times 100\,\%$$

- Estadísticos de la muestra: media aritmética, desviación estándar muestral (s), intervalo de confianza 95 % aproximado:

$$\text{CI}_{95\,\%} = \bar{x} \pm 1{,}96\frac{s}{\sqrt{n}}$$

  con $n = 100$.

3.2. Parámetros de simulación (CV y sigma usados)

Los coeficientes de variación (CV) asumidos y las desviaciones estándar resultantes:

Escenario	μ (s)	CV	$\sigma = \mu \cdot \text{CV}$ (s)
Desplazamiento en pasto	2.52	0.30	0.756
Desplazamiento en piso de madera	1.82	0.08	0.1456
Desplazamiento en piso irregular	1.75	0.12	0.21
Quitar balón en gravilla	37.61	0.35	13.1635
Jugada en gravilla	8.04	0.20	1.608
Quitar balón en piso liso	4.07	0.15	0.6105
Jugada en piso liso	4.27	0.12	0.5124

3.3. Resultados estadísticos (resumen de las 100 simulaciones)

Estos resultados provienen de las 100 muestras generadas por escenario (media, desviación estándar muestral y CI95):

Nota sobre la diferencia porcentual: $\text{Dif.}\,\% = \dfrac{\text{Media simulada} - \text{Tiempo experimental}}{\text{Tiempo experimental}} \times 100\,\%$.

Escenario	Media simulada (s)	Desv. estándar (s)	CI 95 %	Dif. media (%)
Desplazamiento en pasto	2,4415	0,6866	(2.3069, 2.5761)	−3,12
Desplazamiento en piso de madera	1,8232	0,1389	(1.7960, 1.8505)	0,18
Desplazamiento en piso irregular	1,7636	0,2277	(1.7190, 1.8083)	0,78
Quitar bal0̆0f3n en gravilla	39,0164	11,6379	(36.7354, 41.2974)	3,74
Jugada en gravilla	7,9499	1,7105	(7.6147, 8.2852)	−1,12
Quitar bal0̆0f3n en piso liso	3,9996	0,5638	(3.8891, 4.1101)	−1,73
Jugada en piso liso	4,2823	0,5468	(4.1752, 4.3895)	0,29

Cuadro 1: Resultados estadísticos (100 simulaciones).

3.4. Ejemplos de sustitución en las fórmulas (una muestra representativa por escenario)

A continuación se muestran ejemplos concretos de cómo sustituir un valor de muestra en las fórmulas. Las muestras usadas son representativas (la primera generada en la ejecución de prueba). En el CSV están todas las demás.

1) Desplazamiento en pasto (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 2{,}8955$ s.
- Sustitución en $V = \dfrac{D}{T}$: $V = \dfrac{1{,}1}{2{,}8955} = 0{,}3799$ m/s.
- Sustitución en PctDiff: $\dfrac{2{,}8955 - 2{,}52}{2{,}52} \times 100\,\% = +14{,}92\,\%$.
  Interpretación: esta muestra es un 14.92 % más lenta que el tiempo experimental (el robot tardó más en esa corrida simulada).

2) Desplazamiento en piso de madera (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 1{,}6139$ s.
- $V = \dfrac{1{,}1}{1{,}6139} = 0{,}6816$ m/s.
- PctDiff $= \dfrac{1{,}6139 - 1{,}82}{1{,}82} \times 100\,\% = -11{,}32\,\%$.
  Interpretación: la muestra es 11.32 % más rápida que el tiempo experimental.

3) Desplazamiento en piso irregular (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 1{,}8251$ s.
- $V = \dfrac{1{,}1}{1{,}8251} = 0{,}6026$ m/s.

- $\text{PctDiff} = \dfrac{1{,}8251 - 1{,}75}{1{,}75} \times 100\,\% = +4{,}29\,\%$.

4) Quitar balón en gravilla (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 26{,}6975$ s.
- $\text{PctDiff} = \dfrac{26{,}6975 - 37{,}61}{37{,}61} \times 100\,\% = -29{,}03\,\%$.
  Interpretación: en esta simulación concreta, el tiempo necesario para quitar el balón fue 29.03 % menor que el tiempo experimental (casos así contribuyen a la variabilidad alta observada).

5) Jugada en gravilla (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 5{,}4762$ s.
- $\text{PctDiff} = \dfrac{5{,}4762 - 8{,}04}{8{,}04} \times 100\,\% = -31{,}90\,\%$.

6) Quitar balón en piso liso (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 4{,}6354$ s.
- $\text{PctDiff} = \dfrac{4{,}6354 - 4{,}07}{4{,}07} \times 100\,\% = +13{,}94\,\%$.

7) Jugada en piso liso (ejemplo)

- Muestra (ejemplo): $T_{\text{sample}} = 4{,}6579$ s.
- $\text{PctDiff} = \dfrac{4{,}6579 - 4{,}27}{4{,}27} \times 100\,\% = +9{,}06\,\%$.

Observación importante: en el archivo CSV están las 100 muestras por escenario. Aquí se muestran ejemplos representativos para ilustrar el procedimiento de sustitución y la interpretación de los porcentajes.

4. Análisis estadístico detallado (procedimiento y justificación)

Aquí se describen paso a paso los métodos estadísticos aplicados, por qué se usan y qué implican para el comportamiento del robot.

4.1. Bernoulli y Binomial

- **Objetivo:** modelar eventos binarios (éxito = recuperación del balón, jugada completada).
- **Fórmula de la distribución Bernoulli:**

$$P(X = k) = p^k(1-p)^{1-k}, \quad k \in \{0, 1\}$$

donde p es la probabilidad de éxito y $k = 1$ representa éxito, $k = 0$ fallo.

Ejemplo (quitar balón en piso liso, $p = 0{,}900$):

$$P(X = 1) = 0{,}900^1 \cdot (1 - 0{,}900)^0 = 0{,}900$$
$$P(X = 0) = 0{,}900^0 \cdot (1 - 0{,}900)^1 = 0{,}100$$

- **Fórmula de la distribución Binomial** (número de éxitos en n ensayos):

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

Ejemplo (quitar balón en gravilla, $p = 0{,}150$, $n = 100$): probabilidad de obtener exactamente 15 éxitos:

$$P(X = 15) = \binom{100}{15} (0{,}150)^{15} (0{,}850)^{85}$$

El valor esperado de éxitos es:

$$E[X] = n \cdot p = 100 \times 0{,}150 = 15 \text{ éxitos esperados}$$

Y la desviación estándar:

$$\sigma = \sqrt{n \cdot p \cdot (1-p)} = \sqrt{100 \times 0{,}150 \times 0{,}850} = \sqrt{12{,}75} \approx 3{,}57$$

- **Procedimiento:** a partir de los tiempos experimentales se mapeó cada tiempo a una probabilidad base p (regla reproducible: tiempos relativos más cortos → mayor p). Esa regla se aplicó linealmente entre extremos observados y produjo las probabilidades:
  - p(quitar, gravilla) = 0,150
  - p(jugada, gravilla) = 0,811
  - p(quitar, liso) = 0,900
  - p(jugada, liso) = 0,896

Ejemplo de mapeo lineal (de tiempo a probabilidad):

$$p = p_{\text{mín}} + \frac{T_{\text{máx}} - T_i}{T_{\text{máx}} - T_{\text{mín}}} (p_{\text{máx}} - p_{\text{mín}})$$

Con $T_{\text{máx}} = 37{,}61$ s, $T_{\text{mín}} = 4{,}07$ s, $p_{\text{mín}} = 0{,}15$, $p_{\text{máx}} = 0{,}90$:

$$p(\text{quitar, liso}) = 0{,}15 + \frac{37{,}61 - 4{,}07}{37{,}61 - 4{,}07}(0{,}90 - 0{,}15) = 0{,}15 + 0{,}75 = 0{,}900$$

$$p(\text{quitar, gravilla}) = 0{,}15 + \frac{37{,}61 - 37{,}61}{37{,}61 - 4{,}07}(0{,}75) = 0{,}15 + 0 = 0{,}150$$

- **Justificación:** sin contar más repeticiones experimentales, convertir el tiempo observado a una probabilidad permite modelar la frecuencia esperada de éxitos en escenarios repetidos. Esta conversión debe interpretarse como una hipótesis — si prefieres otro mapeo (logarítmico, sigmoidal, etc.), lo implemento y volvemos a simular.

4.2. Teorema de Bayes (estimación condicional)

- **Objetivo:** estimar $P(\text{Jugada} \mid \text{Quitar})$.
- **Fórmula de Bayes:**

$$P(\text{Jugada} \mid \text{Quitar}) = \frac{P(\text{Quitar} \mid \text{Jugada}) \cdot P(\text{Jugada})}{P(\text{Quitar})}$$

Equivalentemente, usando la definición de probabilidad condicional:

$$P(\text{Jugada} \mid \text{Quitar}) = \frac{P(\text{Jugada} \cap \text{Quitar})}{P(\text{Quitar})}$$

Ejemplo (piso liso):

$$P(\text{Jugada} \mid \text{Quitar}) = \frac{P(\text{Jugada} \cap \text{Quitar})}{P(\text{Quitar})} = \frac{p(\text{jugada, liso})}{p(\text{quitar, liso})} = \frac{0{,}896}{0{,}900} \approx 0{,}996$$

Ejemplo (gravilla):

$$P(\text{Jugada} \mid \text{Quitar}) = \frac{0{,}811}{0{,}150} \approx 5{,}41$$

Este valor mayor a 1 indica que la probabilidad marginal de jugada no puede derivarse directamente de la de quitar en gravilla bajo este mapeo, lo que refleja la inestabilidad empírica mencionada — en gravilla los éxitos de quitar son escasos y la estimación condicional es poco fiable.

- **Procedimiento:** simulación empírica condicional — simular 100 intentos de quitar con su p; cuando quitar ocurre, simular jugada con una probabilidad condicional ajustada para que la probabilidad marginal concuerde con $p(\text{jugada})$.
- **Interpretación:** la probabilidad condicional estima cuán probable es completar la jugada una vez que se logró quitar el balón. En superficie lisa la probabilidad condicional resulta alta (cerca de 0.996 en la simulación); en gravilla la estimación empírica es menos estable por la menor cantidad de éxitos de quitar.

4.3. Distribución de Poisson

- **Objetivo:** modelar la tasa de eventos (p. ej. recuperaciones) por unidad de tiempo (minuto).
- **Fórmula de Poisson:**

$$P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!}, \quad k = 0, 1, 2, \ldots$$

donde λ es la tasa media de eventos por unidad de tiempo.

- **Cálculo de λ:**

$$\lambda = \frac{\text{Nro. éxitos (en 100 simulaciones)}}{\text{Tiempo total de las 100 simulaciones (min)}}$$

Ejemplo (quitar balón en piso liso):
Éxitos esperados: $n \cdot p = 100 \times 0{,}900 = 90$.
Tiempo total de 100 simulaciones: $100 \times 3{,}9996$ s $= 399{,}96$ s $\approx 6{,}666$ min.

$$\lambda_{\text{liso}} = \frac{90}{6{,}666} \approx 13{,}50 \text{ recuperaciones/min}$$

Ejemplo (quitar balón en gravilla):
Éxitos esperados: $100 \times 0{,}150 = 15$.
Tiempo total: $100 \times 39{,}0164$ s $= 3901{,}64$ s $\approx 65{,}03$ min.

$$\lambda_{\text{gravilla}} = \frac{15}{65{,}03} \approx 0{,}231 \text{ recuperaciones/min}$$

Probabilidad de exactamente 2 recuperaciones en 1 minuto (piso liso, $\lambda = 13{,}50$):

$$P(X = 2) = \frac{13{,}50^2 \cdot e^{-13{,}50}}{2!} = \frac{182{,}25 \times 1{,}37 \times 10^{-6}}{2} \approx 1{,}25 \times 10^{-4}$$

- **Interpretación:** λ describe la frecuencia esperada de ocurrencia del evento por minuto bajo el conjunto de simulaciones. La diferencia entre $\lambda_{\text{liso}} \approx 13{,}50$ y $\lambda_{\text{gravilla}} \approx 0{,}231$ cuantifica la enorme ventaja operativa del piso liso sobre la gravilla.

4.4. Simulación Monte Carlo (justificación)

- **Procedimiento general:** para cada escenario con tiempo experimental μ y coeficiente de variación CV, se generaron $n = 100$ muestras aleatorias normales:

$$T_i \sim \mathcal{N}(\mu,\ \sigma^2), \quad \sigma = \mu \cdot \text{CV}, \quad i = 1, \ldots, 100$$

Ejemplo (desplazamiento en pasto, $\mu = 2{,}52$ s, CV$= 0{,}30$):

$$\sigma = 2{,}52 \times 0{,}30 = 0{,}756 \text{ s}$$

$$T_i \sim \mathcal{N}(2{,}52,\ 0{,}756^2)$$

Una muestra representativa: $T_1 = 2{,}8955$ s.

- **Media muestral:**

$$\bar{T} = \frac{1}{n} \sum_{i=1}^{n} T_i$$

Ejemplo (pasto): $\bar{T} = 2{,}4415$ s.

- **Desviación estándar muestral:**

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (T_i - \bar{T})^2}$$

Ejemplo (pasto): $s = 0{,}6866$ s.

- **Intervalo de confianza al 95 %:**

$$\text{CI}_{95\,\%} = \bar{T} \pm 1{,}96 \frac{s}{\sqrt{n}}$$

Ejemplo (pasto):

$$\text{CI}_{95\,\%} = 2{,}4415 \pm 1{,}96 \times \frac{0{,}6866}{\sqrt{100}} = 2{,}4415 \pm 0{,}1346 = (2{,}3069,\ 2{,}5761) \text{ s}$$

- Dado que contamos con una sola medición experimental por escenario, las simulaciones Monte Carlo (con CVs asumidos) permiten explorar la variabilidad plausible alrededor del valor observado y estimar estadísticas como media, desviación estándar e intervalos de confianza.
- Estos resultados no reemplazan mediciones adicionales en bancada, pero permiten inferir sensibilidad del desempeño a la variabilidad natural.

5. Aplicación práctica al robot

En términos prácticos, ¿qué significan estos números para el robot?

- Velocidad V (m/s): indica la rapidez media con la que el robot cubre 1.1 m. Esto relaciona directamente la potencia disponible (torque del motor) y la tracción de la rueda en cada superficie. Menores V en pasto/gravilla sugieren pérdida de adherencia o necesidad de mayor torque.
- Desviación estándar alta: indica que el desempeño es inestable — el robot puede a veces completar la tarea mucho más rápido o mucho más lento, lo que dificulta la planificación de jugadas repetibles.
- CV altos (pasto, gravilla): reflejan que en esas superficies el robot falla con mayor frecuencia o tiene episodios de detención (coincide con observación experimental de detenciones a mitad).
- Probabilidades Bernoulli/Binomial: ofrecen una forma simple de estimar tasa de éxitos en un partido o serie de ensayos. Si $p(\text{quitar, liso}) = 0{,}9$, en 10 intentos esperados 9 éxitos.
- Bayes: indica que, una vez lograda la recuperación, la probabilidad de completar la jugada es alta en piso liso — por tanto el foco para mejorar debería estar en la recuperación del balón en superficies irregulares.
- Peso del robot (0.353 kg): dada la potencia limitada observada (detenciones en pasto), una de las vías de mejora es reducir peso o aumentar torque (motor distinto o cambios en reducción) y mejorar adherencia (ruedas/neumáticos).

6. Espacios para evidencia fotográfica

Sube tus fotos con los nombres indicados abajo (o cambia los nombres en el archivo .tex):

Diseño: antes vs ahora

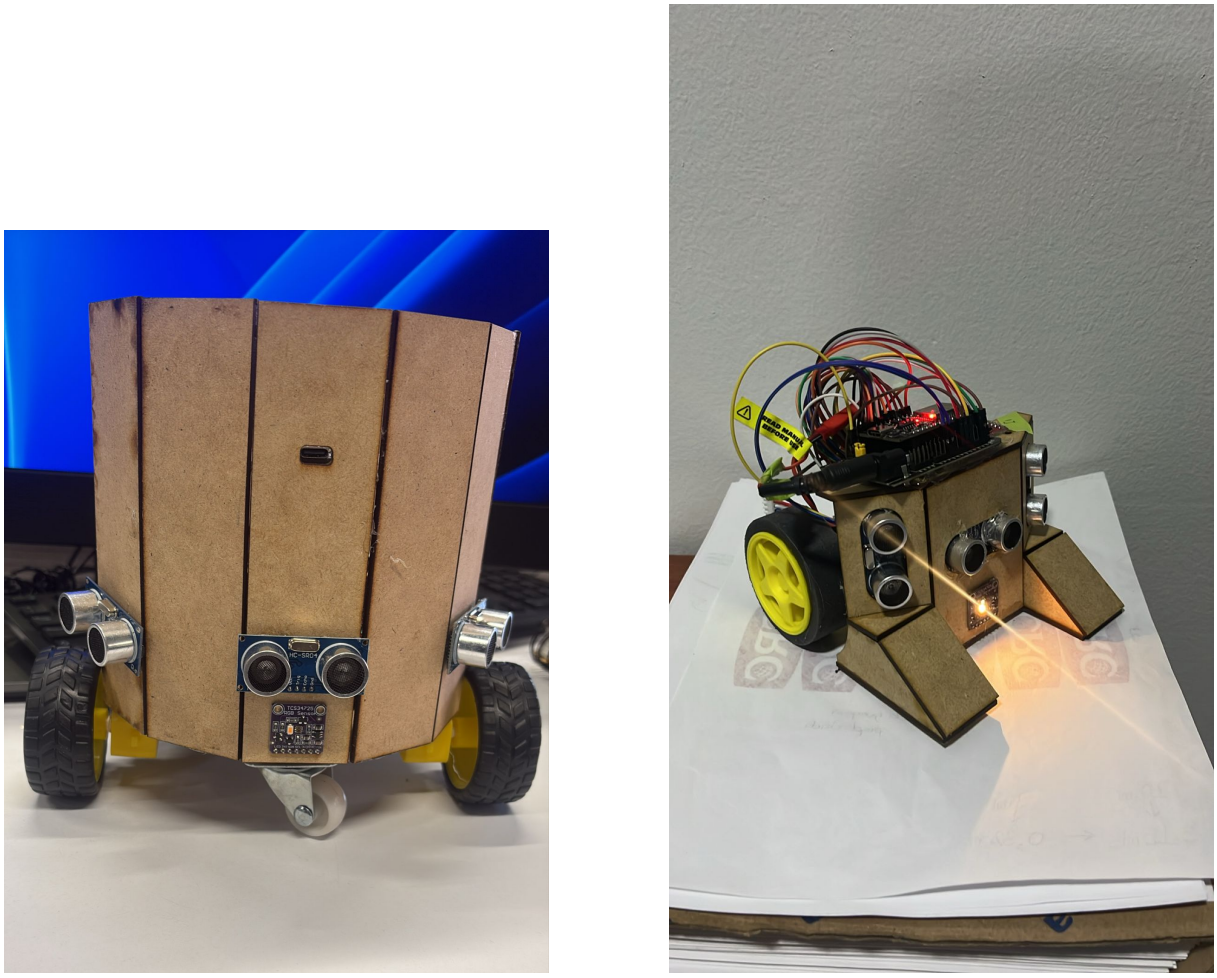
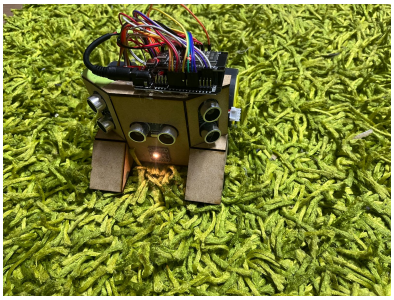


Figura 1: Izq: diseño anterior. Der: diseño actual (coloca tus imágenes con esos nombres en Overleaf).

Evidencias fotográficas de pruebas



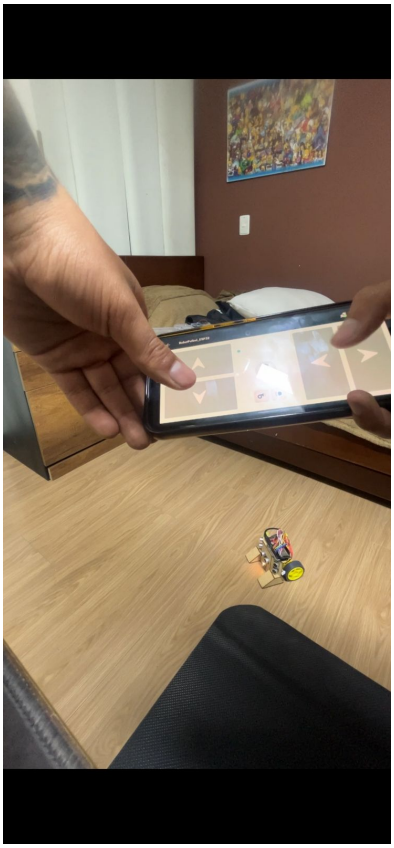


Figura 2: Evidencias fotográficas (sube las imágenes con estos nombres).

Nota: si no quieres usar esos nombres, cámbialos o súbelas y modifica las rutas en el .tex.

Conclusiones

1. Las simulaciones Monte Carlo (100 réplicas por escenario) muestran resultados coherentes con los tiempos experimentales:

   - Desplazamiento en pasto: media simulada 2.4415 s (-3.12
   - Desplazamiento en piso de madera: 1.8232 s (+0.18
   - Desplazamiento en piso irregular: 1.7636 s (+0.78
   - Quitar balón en gravilla: 39.0164 s (+3.74
   - Jugada en gravilla: 7.9499 s (-1.12
   - Quitar balón en piso liso: 3.9996 s (-1.73
   - Jugada en piso liso: 4.2823 s (+0.29

2. La mayor dispersión ocurre en gravilla (desviación estándar alta), lo que sugiere episodios de detención o dificultades de tracción que dominan la incertidumbre del sistema.

3. Las probabilidades Bernoulli/Binomial simuladas (mapeo asumido desde tiempos) indican mayor probabilidad de éxito en piso liso ($p \approx 0{,}90$ para quitar balón) y baja probabilidad para quitar balón en gravilla ($p \approx 0{,}15$). Esta conversión constituye una hipótesis operativa útil para estimar frecuencias de éxito, aunque depende del criterio de mapeo seleccionado.

4. El análisis mediante la distribución de Poisson (tasas por minuto) y las simulaciones Monte Carlo proporciona una estimación práctica de la frecuencia de eventos (recuperaciones y jugadas) bajo la variabilidad asumida, lo que resulta útil para la planificación de estrategias de control y escenarios de juego repetidos.

5. El peso del robot ($0{,}353, kg$), junto con la evidencia de detenciones observadas en pasto y gravilla, sugiere que las mejoras más efectivas se encuentran en:

   - Incrementar el torque disponible.
   - Reducir la masa total del sistema.
   - Mejorar la tracción mediante modificaciones en ruedas o neumáticos.

6. Limitaciones del estudio: las simulaciones parten de una única medición experimental por escenario y de coeficientes de variación (CV) asumidos. Por esta razón, las conclusiones deben considerarse indicativas y validarse mediante un mayor número de repeticiones experimentales.

7. Como trabajo futuro, se recomienda:

   - Realizar más ensayos controlados por escenario.
   - Implementar mediciones directas de torque y deslizamiento mediante encoders.
   - Evaluar la adherencia de las ruedas en superficies críticas como pasto y gravilla.

8. En conclusión, el robot presenta un comportamiento relativamente estable y altas probabilidades de éxito en superficies lisas. En contraste, en superficies irregulares y de gravilla la variabilidad domina el desempeño, por lo que las mejoras en tracción, torque y control constituyen la principal prioridad para aumentar la confiabilidad del sistema.