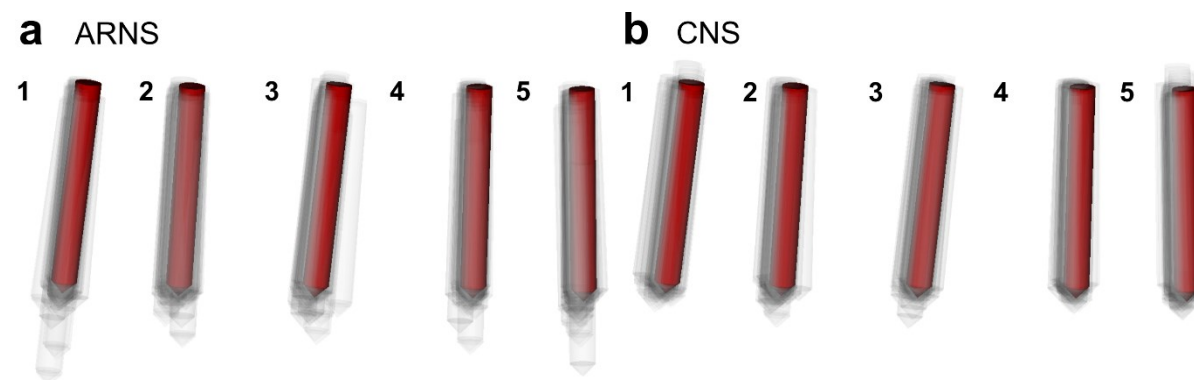


Supplementary Information

Figures

Supplementary Figure 1 – Visualization of drilling accuracy by method



Supplementary Figure 1. (a-b) Comparison of conducted trajectories 1 to 5 in red of Augmented Reality Navigation System (ARNS) (a) and Conventional Navigation System (CNS) (b) with planning trajectories (grey transparent).

Movies

Supplementary Movie 1 – Demonstration of both systems

This movie begins with an introduction to the general experimental setup, followed by a presentation of the setup and guidance function of the Augmented Reality Navigation System (ARNS). This is followed by a demonstration of ARNS guidance during the drilling process, showing a virtual twin guiding the drilling. The video then switches to the Conventional Navigation System (CNS), showing first the setup and then the guidance function of the CNS. It then shows the CNS screen during guided drilling.

Tables

Supplementary Table 1 – Sub-analysis of surgeons

		Sub-analysis of the surgeons								
		Previous Experience in CNS		Surgical Experience (Median)						
		Yes (n = 90/9)	No (n = 30/3)	Higher (n = 60/6)	Lower (n = 60/6)	Surgeons (n = 120/12)	Students (n = 120/12)	Engineers (n = 120/12)	Total (n = 360/36)	p value*
Maximum Projected Translational Deviation (mm)	Mean (SD)	0.96 (0.49)	0.97 (0.34)	0.98 (0.40)	0.96 (0.45)	0.96 (0.45)	1.05 (0.46)	1.21 (0.48)	1.07 (0.48)	0.319 / 0.004
Projected Translational Deviation at the Entry Points (mm)	Mean (SD)	0.82 (0.39)	0.85 (0.33)	0.86 (0.32)	0.82 (0.38)	0.82 (0.38)	0.93 (0.44)	1.09 (0.44)	0.95 (0.43)	0.203 / 0.002
Projected Translational Deviation at the Endpoints (mm)	Mean (SD)	0.87 (0.53)	0.89 (0.39)	0.88 (0.45)	0.87 (0.50)	0.87 (0.50)	0.93 (0.51)	1.07 (0.52)	0.96 (0.51)	0.513 / 0.039
Translational Deviation in 3D Euclidean Distance at Entry Points (mm)	Mean (SD)	0.83 (0.40)	0.86 (0.34)	0.87 (0.33)	0.84 (0.38)	0.84 (0.38)	0.94 (0.45)	1.11 (0.44)	0.96 (0.44)	0.205 / 0.002
Angular Deviation (°)	Mean (SD)	0.88 (0.57)	0.81 (0.52)	0.79 (0.43)	0.87 (0.55)	0.87 (0.55)	0.95 (0.60)	0.94 (0.44)	0.92 (0.54)	0.435 / 0.523
Depth Deviation (mm)	Mean (SD)	1.29 (1.51)	0.97 (1.00)	0.99 (0.77)	1.21 (1.40)	1.21 (1.40)	0.59 (0.87)	0.90 (1.52)	0.90 (1.32)	0.024 / 0.0256
NASA-TLX	ARNS	47.1 (20.5)	43.2 (8.8)	56.3 (16.4)	36.0 (14.0)	46.1 (18.0)	55.7 (16.6)	47.2 (11.5)	49.7 (15.8)	0.275
	CNS	57.1 (16.6)	34.8 (2.4)	52.0 (13.4)	51.0 (22.1)	51.5 (17.4)	63.8 (11.2)	50.9 (12.6)	55.4 (14.9)	0.051
SUS	ARNS	81.1 (12.4)	61.7 (16.1)	71.2 (13.1)	81.2 (16.9)	76.2 (15.4)	73.1 (15.7)	83.5 (15.7)	77.6 (15.8)	0.259
	CNS	65.8 (23.3)	79.2 (10.4)	74.2 (12.5)	64.2 (27.8)	69.2 (21.2)	56.0 (19.1)	68.8 (15.2)	64.7 (19.2)	0.164
Previous Experience with CNS	no	7 (77.8%)	2 (66.7%)	2 (33.3%)	1 (16.7%)	3 (25.0%)	12 (100.0%)	9 (75.0%)	24 (66.7%)	< 0.001
	yes	2 (22.2%)	1 (33.3%)	4 (66.7%)	5 (83.3%)	9 (75.0%)	0 (0.0%)	3 (25.0%)	12 (33.3%)	
Previous Experience with AR	no	0 (0%)	3 (100%)	4 (66.7%)	5 (83.3%)	9 (75.0%)	10 (83.3%)	6 (50.0%)	25 (69.4%)	0.182
	yes	9 (100%)	0 (0%)	2 (33.3%)	1 (16.7%)	3 (25.0%)	2 (16.7%)	6 (50.0%)	11 (30.6%)	
Preferred Navigation System	ARNS	7 (77.8%)	0 (0.0%)	3 (50.0%)	4 (66.7%)	7 (58.3%)	10 (83.3%)	10 (83.3%)	27 (75.0%)	0.264
	CNS	2 (22.2%)	3 (100.0%)	3 (50.0%)	2 (33.3%)	5 (41.7%)	2 (16.7%)	2 (16.7%)	9 (25.0%)	

n = number of trajectories drilled / number of participants; * = if two p-values, first for students, second for engineers, reference surgeons.

Supplementary Table 2 – Likert Questionnaire

#	Likert questions	ARNS				CNS				Total (n=72)	p*
		Surgeon (n=12)	Student (n=12)	Engineer (n=12)	ARNS Total (n=36)	Surgeon (n=12)	Student (n=12)	Engineer (n=12)	CNS Total (n=36)		
1.	The (AR-based conventional) navigation system interfered with my drilling trajectory.	1.5 (0.8)	1.6 (0.7)	1.4 (0.7)	1.5 (0.7)	1.9 (1.2)	2.1 (0.7)	1.3 (0.7)	1.8 (0.9)	1.6 (0.8)	0.065
2.	With the (AR-based conventional) navigation system, it is easy to find the starting point.	3.2 (0.8)	3.4 (0.7)	3.5 (0.7)	3.4 (0.7)	2.8 (1.3)	2.5 (0.8)	3.0 (1.0)	2.8 (1.0)	3.1 (0.9)	0.473
3.	With the (AR-based conventional) navigation system, it is easy to set the orientation.	3.3 (0.8)	3.5 (0.7)	3.4 (0.9)	3.4 (0.8)	2.8 (0.9)	2.8 (0.9)	3.2 (0.6)	2.9 (0.8)	3.2 (0.8)	0.57
4.	The (AR-based conventional) navigation system is easy to use.	3.4 (1.0)	3.3 (0.7)	3.6 (0.7)	3.4 (0.8)	3.0 (1.2)	2.7 (1.0)	3.2 (0.6)	2.9 (1.0)	3.2 (0.9)	0.316
5.	I felt safe using the (AR-based conventional) navigation system.	3.2 (0.7)	2.9 (0.5)	3.5 (0.7)	3.2 (0.7)	3.2 (0.9)	2.4 (0.8)	2.9 (0.9)	2.8 (0.9)	3.0 (0.8)	0.04
6.	The (AR-based conventional) navigation system is good for drilling trajectories.	3.6 (0.7)	3.6 (0.7)	3.2 (0.8)	3.5 (0.7)	2.9 (1.1)	2.8 (0.4)	3.1 (0.5)	2.9 (0.7)	3.2 (0.7)	0.623
7.	I find the (AR-based conventional) navigation system unnecessarily complex.	1.8 (0.8)	1.4 (0.7)	1.7 (0.8)	1.6 (0.8)	2.2 (1.2)	2.1 (0.8)	1.5 (0.5)	1.9 (0.9)	1.8 (0.8)	0.398
8.	I think I would need the assistance of a technical person to use the (AR-based conventional) navigation system.	2.0 (1.0)	2.5 (0.9)	1.8 (0.6)	2.1 (0.9)	1.8 (1.1)	2.6 (1.0)	1.9 (0.8)	2.1 (1.0)	2.1 (0.9)	0.015
9.	I think that the various functions in the (AR-based conventional) navigation system were well integrated.	3.2 (1.0)	3.3 (0.7)	3.5 (0.8)	3.4 (0.8)	2.8 (0.8)	2.8 (0.5)	2.8 (1.0)	2.8 (0.8)	3.1 (0.8)	0.629
10.	I still have a lot to learn before I could use the (AR-based conventional) navigation system.	2.0 (0.9)	2.4 (0.7)	1.6 (0.7)	2.0 (0.8)	2.2 (1.0)	2.9 (0.9)	1.9 (1.1)	2.4 (1.0)	2.2 (0.9)	0.002
11.	I found the (AR-based conventional) navigation system intuitive.	3.2 (1.0)	3.5 (0.7)	3.6 (0.5)	3.4 (0.7)	2.9 (1.1)	2.7 (0.7)	2.8 (0.8)	2.8 (0.9)	3.1 (0.9)	0.818
12.	I drilled the trajectories accurately with the (AR-based conventional) navigation system.	2.8 (0.6)	2.8 (0.5)	3.1 (0.9)	2.9 (0.7)	2.9 (1.0)	2.2 (0.6)	2.5 (0.8)	2.5 (0.8)	2.7 (0.8)	0.118

* Kruskal-Wallis test comparing total responses of surgeons, students, and engineers. Only questions 5, 8 and 10 showed significant differences between the professions.