

# Needle Guidance using Handheld Stereo Vision and Projection for Ultrasound-based Interventions

Philipp J Stolka<sup>1</sup>, Pezhman Foroughi<sup>1</sup>, Matthew Rendina<sup>1</sup>, Clifford Weiss<sup>2</sup>, Gregory D Hager<sup>1,3</sup>, Emad M Bector<sup>1,2,3</sup>  
<sup>1</sup> Clear Guide Medical, <sup>2</sup> Johns Hopkins Medicine / Radiology, <sup>3</sup> Johns Hopkins University / Computer Science (Baltimore MD, USA)

## Motivation

**Interventional ultrasound (US) guidance** is one of the most flexible, cost-effective, and simple-to-use intraoperative imaging modalities, but **requires significant skill** to control US imaging, the US probe, and the interventional instrument - i.e. **to keep targets and needles aligned** at all times.

This **limits efficacy, safety, and applicability** for e.g. biopsies, nerve blocks, tumor ablations, tissue sclerotizations, injections, drainages etc. and makes extensive training necessary.

	visual tracking: Clear Guide	electromagnetic (EM) freehand tracking	optical freehand tracking	magnetic freehand tracking (e.g. eZono 4000)	magnetic constrained tracking (e.g. Soma AxiTrack)	mechanical constraints (e.g. CIVICO needle guide)
external tracking base	none	required	required	none	none	none
track instruments anywhere	up to half a meter within tracking area	only close to transmitter	only within line of sight	only close to probe	only along one line	no
track instruments at any time	immediately	after sensor attachment and calibration	after sensor attachment and calibration	after needle preparation	after probe assembly	after bracket installation
track more than one instrument	yes	yes	yes	no	no	no
track any instrument	any needle-like instrument, immediately	only with attached sensors	only with attached markers	only certain metallic, short, needle-like instruments; after preparation	only certain syringe needles	no
track from any probe	SuperPROBE head fits any probe	n/a	n/a	probes with attached tracking unit	only one probe model	probes with attached mechanical guide
track instruments in- and out-of-plane	within +/-45deg	yes	yes	yes	no	no
tracks instrument tip	with Clear Guide flexible version of your preferred instrument	yes	yes	yes	yes, after configuration of compatible instrument	no
registration/definition of instrument	not needed	necessary: sensor attachment, calibration	necessary: marker attachment, calibration	necessary: preparation, definition	necessary: sensor attachment, needle length definition	necessary: insertion angle definition

## State of the Art

Existing electromagnetic (EM), optical, magnetic, or mechanical guidance solutions are **cumbersome, expensive, or require special instruments** or setups (cf. table). **Local guidance approaches** include probe-mounted cameras, optical or magnetic sensors, and overlay- or projection-based alignment, but are not in widespread use.

## Approach

What is needed is an instrument-guidance solution that is **non-intrusive, inexpensive, simple, always-on, intuitive, integrates with any US system**, and is **available as a product**.

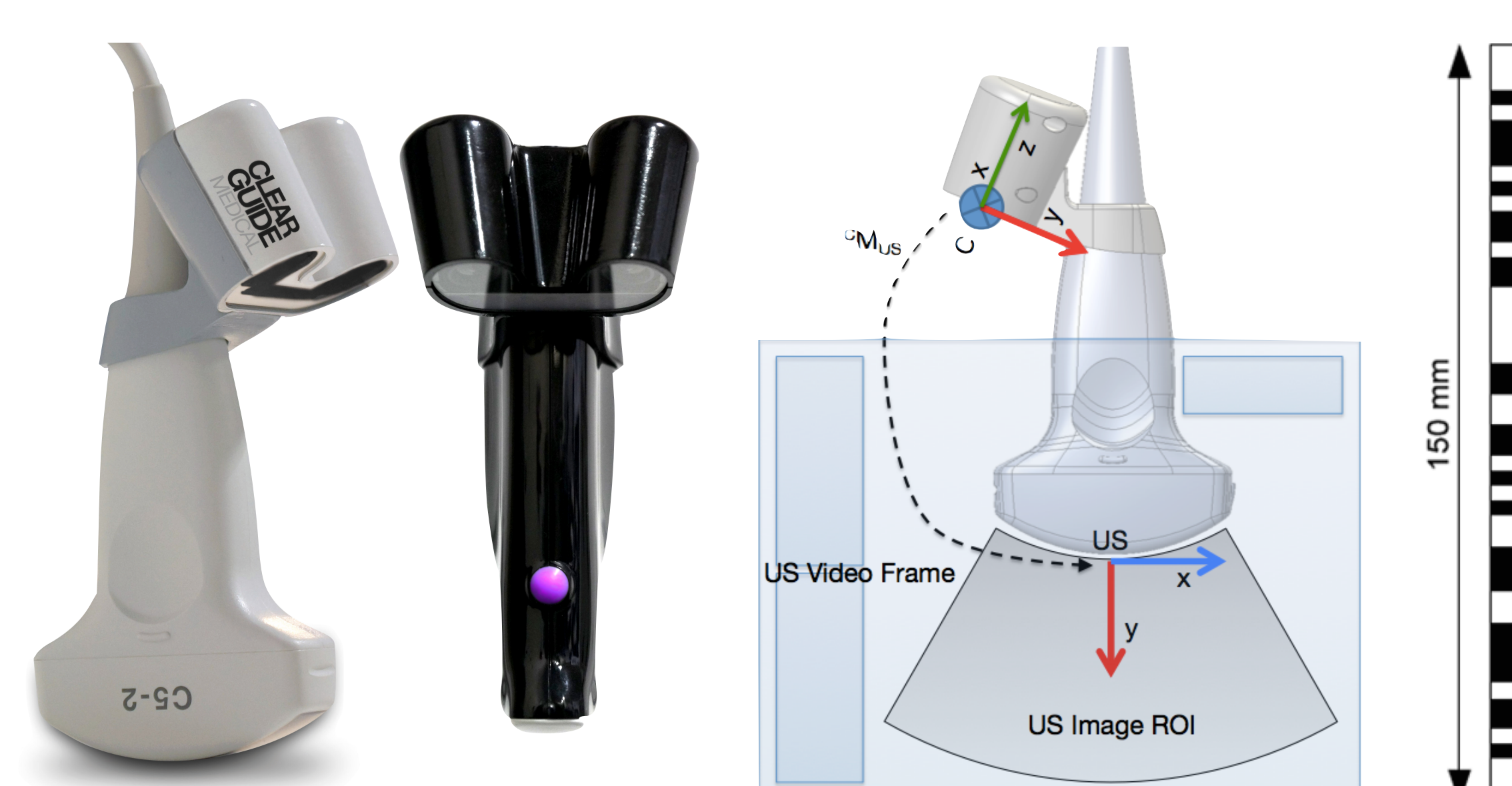


Fig. 1: Different US probes with optical heads (left); US region of interest and characteristic features in live US video (center); non-repeating needle pattern (right)

## Solution



Fig. 2: Insertion depth tracking (magenta lines) on guidance display (left screen)

**Optical head:** stereo cameras (Ximea MU9PC\_MH; USB 2.0, 5 MP), on-board IR lighting, optional projection unit (Microvision PDE2); **probe-specific brackets** mount onto US probe (in- or out-of-plane) (Fig. 1)

**Guidance computer:** receives and duplicates live US (quad-core Intel i7, Windows 8 64-bit, Epiphan DVI2PCIe frame grabber), computes and overlays instrument pose on US view; user can **define targets** on touchscreen for visual/auditory approach feedback (Fig. 2)

**Remote viewing:** optional browser-based interaction

Guidance Modes	On-screen display	In-situ projection
Active tracking	needle overlay on live US (on PC or remote)	target deviation; needle overlay on live US
Passive guidance	stereo-view alignment lines	shadow alignment lines

## Specifics

**Ultrasound-agnostic:** detects imaging modes from live US stream in real time and extracts US ROI for guidance display

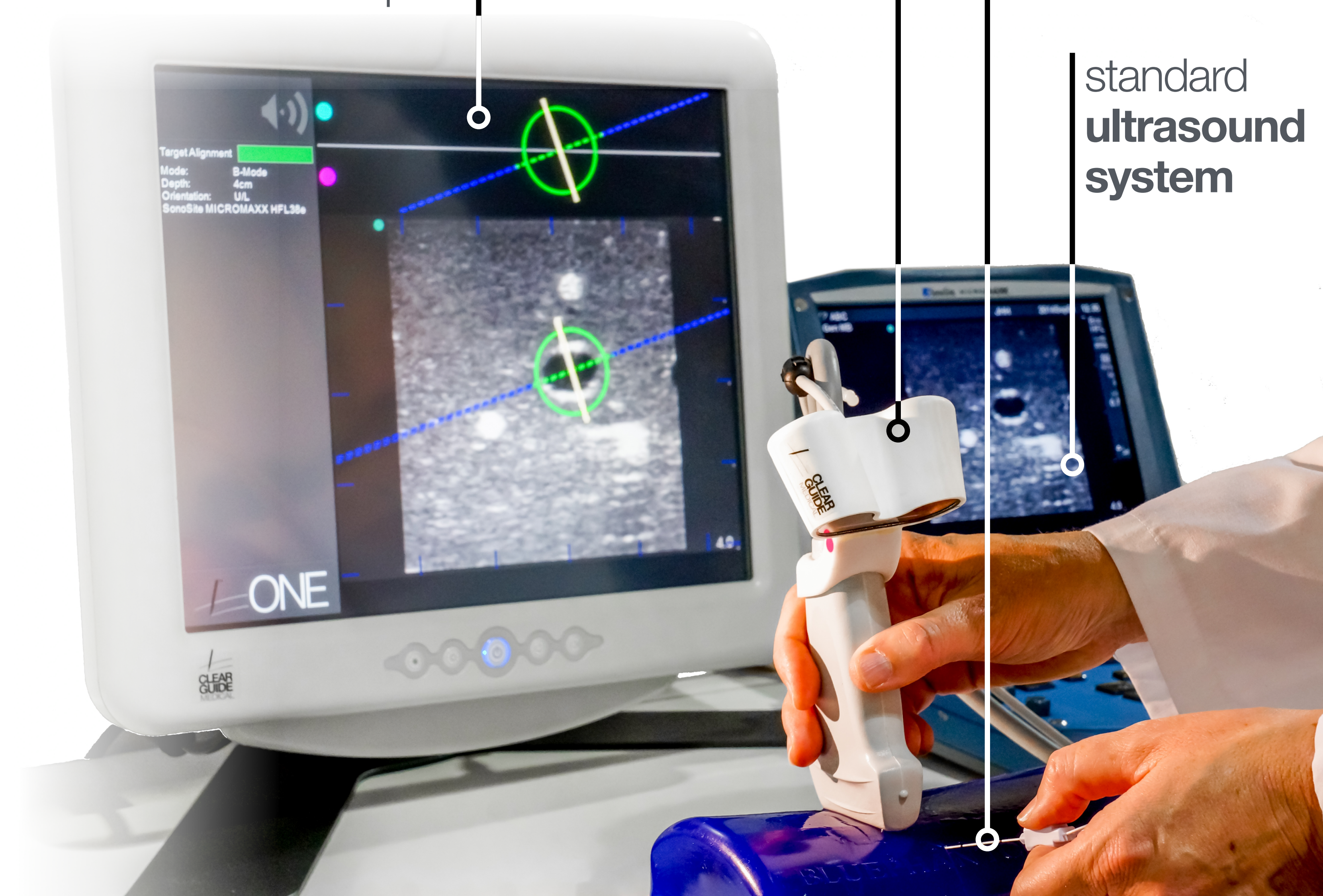
**Insertion depth guidance:** tracks instrument tip through non-repeating pattern on shaft (Fig. 1)

**touchscreen computer,** connected to ultrasound machine's video port

**optical head** with stereo cameras and illumination

standard or special-pattern instrument

standard ultrasound system



## Validation

**Phantoms:** transparent porcine gelatin (Sigma-Aldrich G2500); **targets:** 2.4mm steel ball suspended at 6cm depth; **ultrasound:** Ultrasonix SonixTablet, linear L14-5/38 and convex C5-2/60 probes

Targeting by two novice users with **on-screen needle overlay** and standard needles; no retractions; perpendicular distance measurement through orthographic photography (Fig. 3)

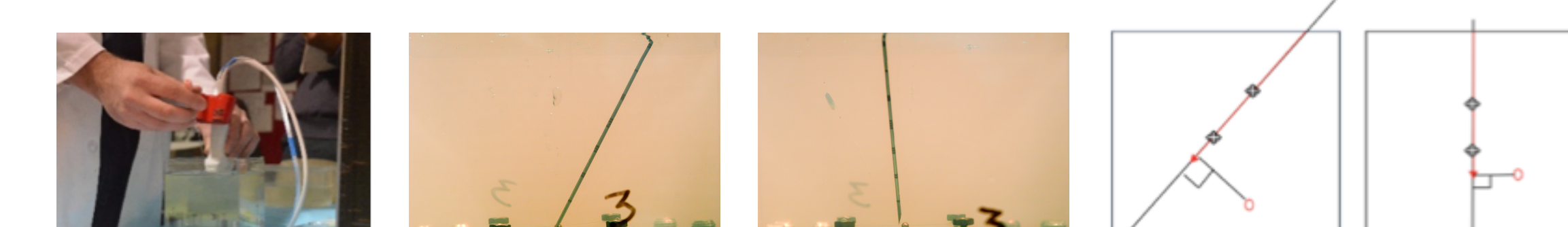


Fig. 3: Guided insertion (left); orthographic views (center); error computation (right)

Probe	avg. [mm]	med. [mm]	range [mm]	std. dev.	n
overall	3.27	2.85	0.3 - 10.5	2.28	41
convex	3.80	4.21	0.3 - 7.3	2.17	15
linear	2.96	2.11	0.7 - 10.5	2.33	26

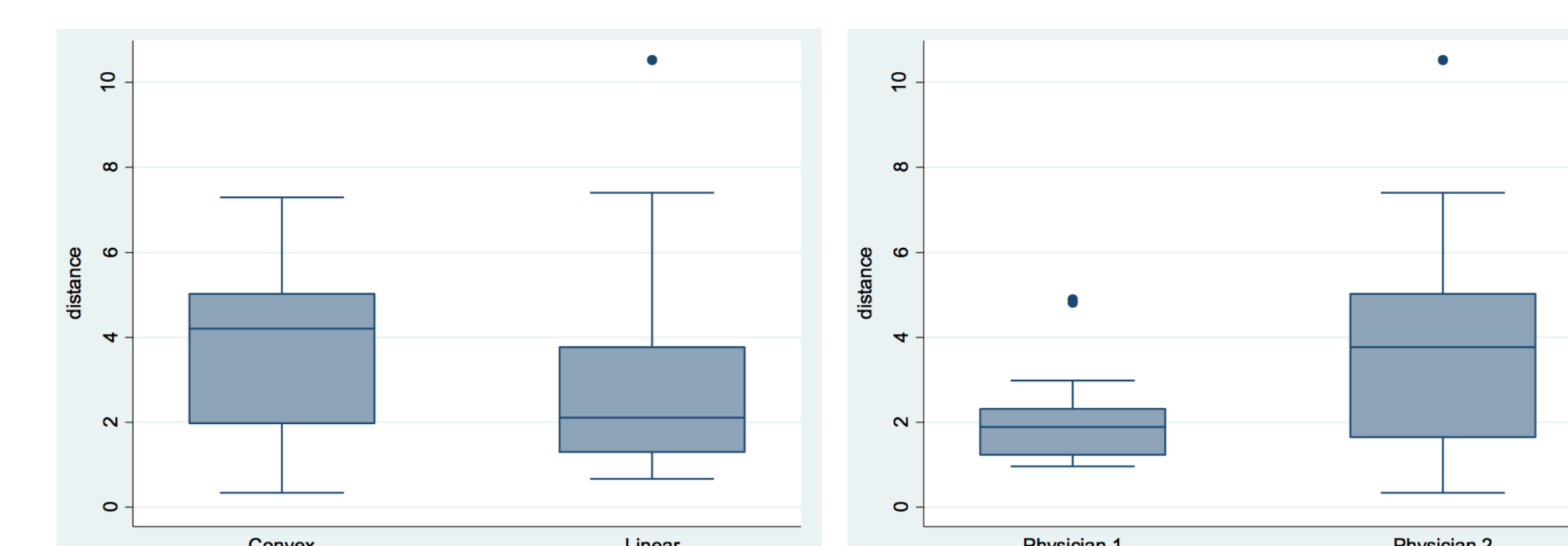


Fig. 4: Phantom accuracy results - by probe (left) and subject (right)

## Conclusion

We present the first handheld **clinical-grade, camera-based, interventional instrument guidance system** for ultrasound. It attaches to standard ultrasound systems, and provides multiple visualization modalities, incl. on-screen and remote display and in-situ projection.



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