



(12) **United States Patent**  
**Avanzi**

(10) **Patent No.:** **US 9,411,440 B2**  
(45) **Date of Patent:** **Aug. 9, 2016**

(54) **DIGITAL ULTRASONIC EMITTING BASE STATION**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventor: **Roberto Avanzi**, Munich (DE)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/533,535**

(22) Filed: **Nov. 5, 2014**

(65) **Prior Publication Data**

US 2016/0054819 A1 Feb. 25, 2016

**Related U.S. Application Data**

(60) Provisional application No. 62/040,977, filed on Aug. 22, 2014.

(51) **Int. Cl.**  
**G06F 3/033** (2013.01)  
**G06F 3/0354** (2013.01)  
**G06F 3/01** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **G06F 3/03545** (2013.01); **G06F 3/017** (2013.01)

(58) **Field of Classification Search**  
CPC ..... G06F 3/0433; G06F 3/0418; G06F 3/038; G06F 3/043; G06F 3/0436; G06F 3/03545; G06F 2203/0384; G01S 5/186; G01S 5/22  
USPC ..... 345/156-184, 419; 181/122; 324/671; 438/149

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,451,723 A \* 9/1995 Huang ..... G06F 3/0436 178/18.04  
5,889,511 A \* 3/1999 Ong ..... G06F 3/045 345/173

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1228480 A1 8/2002  
JP 2002041229 A 2/2002  
WO WO-0065530 A1 11/2000

OTHER PUBLICATIONS

Anonymous: "Least squares—Wikipedia, the free Encyclopedia", Wikipedia, Mar. 30, 2013, pp. 1-16, XP055111205, Retrieved from the Internet: URL: [http://en.wikipedia.org/w/index.php?title=Least\\_squares&oldid=547861529](http://en.wikipedia.org/w/index.php?title=Least_squares&oldid=547861529), p. 1-2.

(Continued)

*Primary Examiner* — Prabodh M Dharia

(74) *Attorney, Agent, or Firm* — Haynes and Boone, LLP

(57) **ABSTRACT**

An acoustic tracking system is provided that includes receivers that detect first acoustic signals from a first set of transmitters disposed on a digital pen and second acoustic signals from a second set of transmitters disposed on a base station. The acoustic tracking system also includes a processing component that defines a two-dimensional plane on which the base station lies and determines a three-dimensional position of the digital pen relative to the base station. The processing component projects the three-dimensional position of the digital pen onto the two-dimensional plane and records, based on the projected three-dimensional position, the three-dimensional position of the digital pen relative to the base station, where the recorded three-dimensional position of the digital pen represents an object representative of movement of the digital pen.

**29 Claims, 6 Drawing Sheets**

