US006181983B1

(12) **United States Patent**
Schlemmer et al.

(10) **Patent No.: US 6,181,983 B1**
(45) **Date of Patent: Jan. 30, 2001**

(54) **METHOD OF COMMAND CONTROL FOR A ROBOT MANIPULATOR**

(75) Inventors: **Maximilian Schlemmer**, Seeshaupt; **Manfred Schedl**, Pfaffenhofen; **Michael Steinmetz**, Wessling; **Georg Grübel**, Weilheim; **Reinhard Finsterwalder**, Pucheim, all of (DE)

(73) Assignee: **Deutsches Zentrum für Luft-und Raumfahrt e.v.**, Bonn (DE)

(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) Appl. No.: **09/100,014**

(22) Filed: **Jun. 19, 1998**

(30) **Foreign Application Priority Data**

Jun. 20, 1997 (DE) 197 26 166
Jan. 11, 1998 (DE) 198 00 552

(51) **Int. Cl.**[7] **G06F 19/00**

(52) **U.S. Cl.** **700/245**; 700/250; 700/251; 700/262; 700/263; 700/244; 318/568.11; 318/568.12; 318/646; 318/628; 318/648; 900/9; 900/15; 395/80; 395/81; 395/82; 395/83; 395/96; 395/98; 708/442; 708/625

(58) **Field of Search** 700/245, 262, 700/263, 250, 251, 244; 318/568.111, 568.24, 646, 628, 648; 900/9, 15; 395/80–98; 708/442, 625

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,589,810 5/1986 Heindl et al. .
4,593,366 * 6/1986 Sugimoto et al. 395/97
4,999,553 * 3/1991 Seraji 395/80
5,179,514 * 1/1993 Rastegar et al. 364/167.01
5,214,749 * 5/1993 Brown 395/95
5,276,390 * 1/1994 Fisher et al. 318/568.1
5,293,461 * 3/1994 Grudic et al. 395/97
5,430,643 * 7/1995 Seraji 364/167.01
5,737,500 * 4/1998 Seraji et al. .

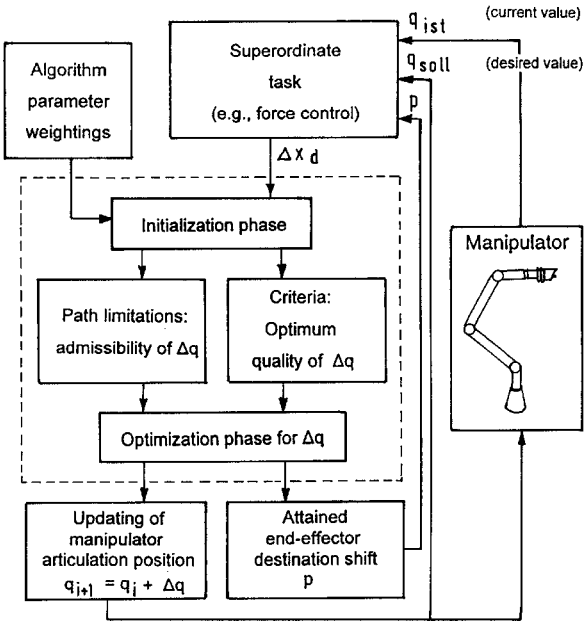
FOREIGN PATENT DOCUMENTS

33 44 633 6/1984 (DE) .

* cited by examiner

Primary Examiner—Ayaz R. Sheikh
Assistant Examiner—Firmin Backer
(74) *Attorney, Agent, or Firm*—Browdy And Neimark

(57) **ABSTRACT**

Beginning with a successive commanded end-effector destination shift, the method of the invention, which includes a calculation corresponding to a special algorithm of inverse kinematics using the Jacobi Matrix in the control of a manipulator, effects an optimization of weighted criteria (energy criteria, acceleration criteria and reference-position criteria) in a real-time cycle while reliably maintaining all path limitations and resulting in an optimized acceleration behavior. The method of the invention can be used in interactive path guidance of a manipulator and/or as a modular component of a superordinate task, such as for force-control objectives.

16 Claims, 2 Drawing Sheets