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SIMPLE GEOMETRIC ALGORITHMS TO AID IN CLEARANCE MANAGEMENT FOR ROBOTIC MECHANISMS

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ABSTRACT

For Robotic Mechanisms which are required to operate in quarters limited by external structures, the problem of clearance is often of considerable interest. In such cases it is possible to distinguish between "contact prediction" and "minimum safe clearance management."

The advantage of the distinction is principally in the fact that the latter may be quite simple and well suited to real-time calculation, whereas the former may require more precision, sophistication, and computational overhead.

This paper deals with the selection of global geometric shapes such as lines, planes, circles, spheres, cylinders, etc., and the associated computational algorithms which provide relatively inexpensive estimates of minimum spatial clearance for safe operations. The Space Shuttle, Remote Manipulator System, and the Power Extension Package are used as an example.

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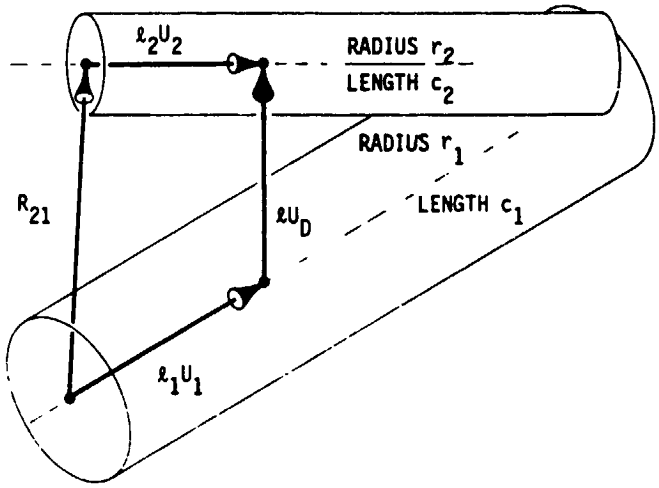
CONTACT PREDICTION (HIGH RESOLUTION)	MINIMUM SAFE CLEARANCE MANAGEMENT
o REQUIRES ACCURATE, DETAILED GEOMETRIC MODELING	o ALLOWS THE USE OF GLOBAL GEOMETRIC SHAPES FOR THE ENCLOSURE OF LARGE PIECES OF STRUCTURE
o REQUIRES ACCURATE MOTION MODELING	o ALLOWS MORE TOLERANCE IN MOTION MODELING
o COMPARATIVELY HIGH COMPUTATIONAL TIME AND LARGE PROGRAM SIZE	o COMPARATIVELY LOW COMPUTATIONAL TIME AND SMALL PROGRAM SIZE
o USUALLY INVOLVES BASIC GEOMETRIES (POINTS, SPHERES, CUBES)	o USUALLY INVOLVES MORE COMPLEX GEOMETRIES (CIRCLES, CYLINDERS, CONES, SPATIAL TRAJECTORIES, SURFACES OF REVOLUTION)



$U_D = UNIT(U_1 \times U_2)$

$R_{21} + \ell_2 U_2 = \ell_1 U_1 + \ell U_D$

$U_1 \cdot U_D = 0$

$U_2 \cdot U_D = 0$

TO DETERMINE
MINIMUM CLEARANCE

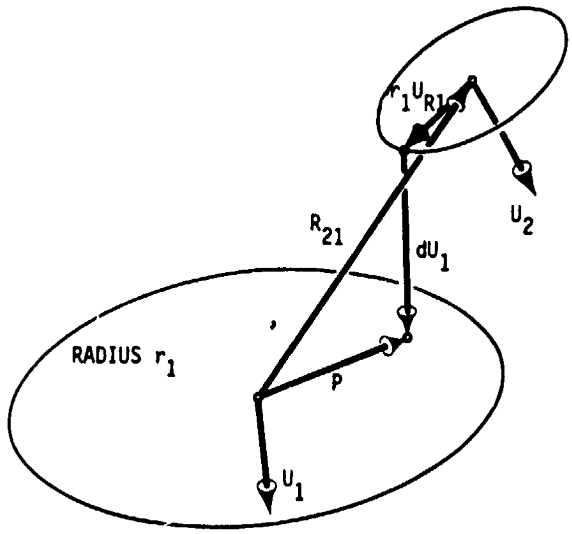
$d = \ell - r_1 - r_2$

$d > 0$

$0 < \ell_1 < c_1$

$0 < \ell_2 < c_2$

FIGURE 1.- CYLINDRICAL-SHELL-TO-CYLINDRICAL-SHELL CLEARANCE.



$U_{R1} = U_2 \times (UNIT(U_1 \times U_2))$

$R_{21} + r_1 U_{R1} + dU_1 = P$

$U_1 \cdot P = 0$

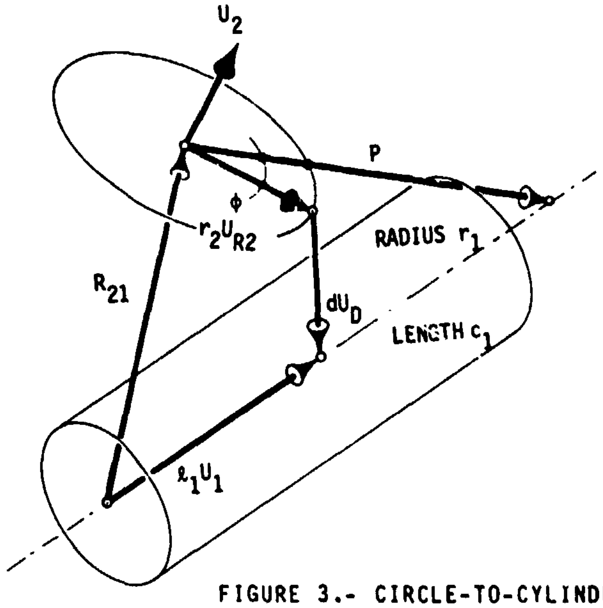
$p = LENGTH\ (P)$

TO DETERMINE
MINIMUM CLEARANCE

$d > 0$

$p < r_1$

FIGURE 2.- CIRCLE-TO-PLANE CIRCULAR AREA CLEARANCE.



$$R_{21} + r_2 U_{R2} + dU_D = \ell_1 U_1$$

$$U_D \cdot \frac{d}{d\phi} U_{R2} = 0$$

$$U_D \cdot U_1 = 0$$

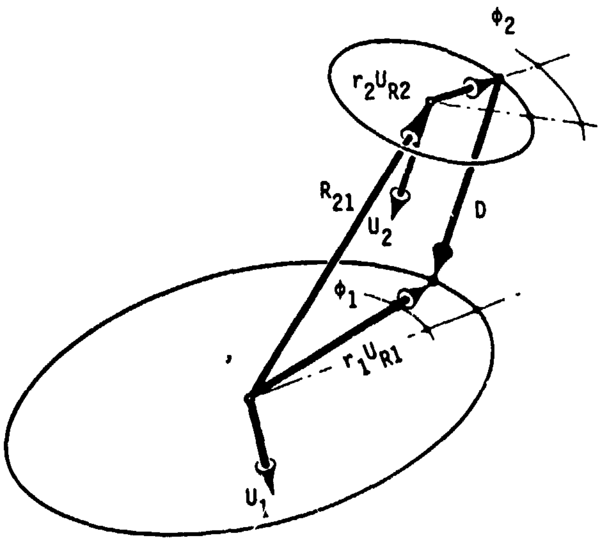
ADJUST ϕ TO MINIMIZE d

TO DETERMINE MINIMUM CLEARANCE

$$d > r_1$$

$$0 < \ell_1 < c_1$$

FIGURE 3.- CIRCLE-TO-CYLINDRICAL-SHELL CLEARANCE.



$$R_{21} + r_2U_{R2} + D = r_1U_{R1}$$

$$D \cdot \frac{d}{d\phi_1} U_{R1} = 0$$

$$D \cdot \frac{d}{d\phi_2} U_{R2} = 0$$

D = LENGTH (D)

ADJUST ϕ_1, ϕ_2 TO MINIMIZE d

TO DETERMINE MINIMUM CLEARANCE

$$D \cdot U_1 > 0$$

FIGURE 4.- CIRCLE-TO-CIRCLE CLEARANCE.

CLEARANCE MANAGEMENT MODEL APPLICATION TO SHUTTLE/ REMOTE MANIPULATOR/POWER EXTENSION PACKAGE (PEP)

- PEP CONTROL SYSTEM EXECUTES TWO-AXIS MOTION SWEEPING OUT DISK-LIKE CYLINDER
- RMS SECTIONS CYLINDRICAL
- SHUTTLE SECTIONED AND MODELED AS CYLINDERS AND LINES
- THE ALGORITHMS AND AN EXECUTIVE LOGIC WERE USED TO AID IN DESIGNING OPERATIONAL TRAJECTORIES AND CONFIGURATIONS FOR THE POWER EXTENSION PACKAGE AS WELL AS OTHER SHUTTLE PAYLOADS

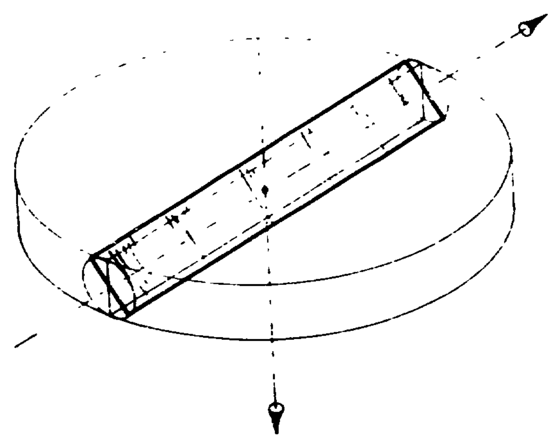


FIGURE 5.- CYLINDRICAL VOLUME SWEPT BY POWER EXTENSION PACKAGE DEPLOYED.

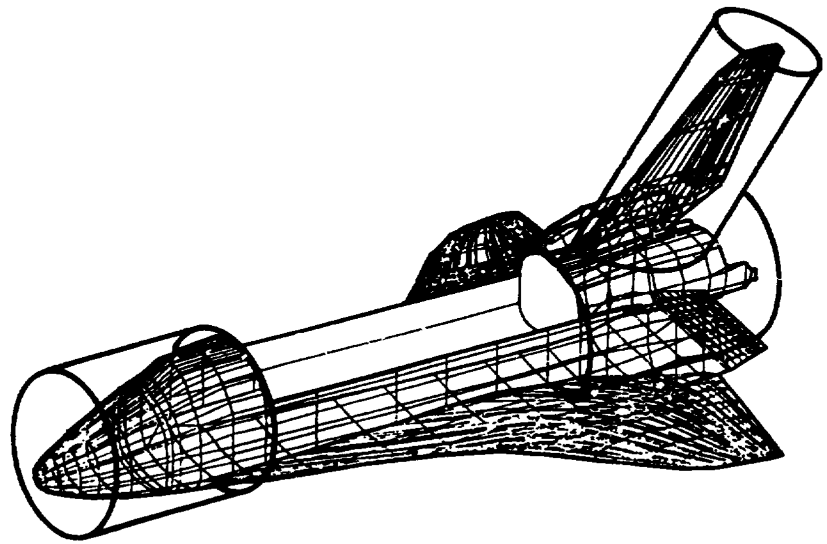


FIGURE 6.- CLEARANCE MANAGEMENT MODEL CYLINDRICAL ENCLOSURE OF SHUTTLE ORBITER.

CONCLUSIONS AND EXTENSIONS

- THE DISTINCTION BETWEEN "CONTACT PREDICTION" AND "MINIMUM SAFE CLEARANCE MANAGEMENT" LED TO A SIGNIFICANT SAVING IN COMPUTATIONAL TIME AND COMPLEXITY FOR THIS APPLICATION

- THE FOUR SIMPLE GEOMETRIC COMBINATIONS DISCUSSED HEREIN HAVE BEEN INTEGRATED INTO AN ALGORITHM TO MANAGE THE OVERALL CLEARANCE BETWEEN CYLINDERS

- THE CIRCLE AND CYLINDER DEMONSTRATION HEREIN MAY BE GENERALIZED TO SURFACES OF REVOLUTION AND CONES, ETC., FOR MORE COMPLICATED APPLICATIONS

- EVALUATION AND SELECTION OF SUITABLE DISPLAYS AND CUES FOR MANUAL CONTROL SHOULD BE INVESTIGATED