THREE OUTPUT EPICYCLIC GEAR SYSTEMS FOR ROBOTIC HAND

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Abstract: At present in robotic field most prototypes have number of fingers comprised between two and five, except in case of tentacle inspired system. The concept of under actuation in robotic grasping with fewer actuators than degrees of freedom (DOF) allows the hand to adjust itself to an irregularly shaped object without complex control strategies and sensors. The power transmission used in such a system confirms the requirements of adaptivity and compactness. In this study we are designing a one input three output differential mechanism incorporating an epicyclic gear train. A gear train having relative motion of axes is called planetary or epicyclic gear trains. In an epicyclic gear train system the axis of at least one of the gear moves relative to other. Coupling of two epicyclic gears axially produce a three output system with compact shape. The reverse of the system find its great application in the hybrid vehicles of next generation.

Keywords-Adaptivity, Compactness, Epicyclic gear system,Grasping,

I. INTRODUCTION

An increasing research interest in the robot end-effector is growing worldwide. There is an emerging industrial need to apply adaptive robotic hands to substitute humans in dangerous, laborious, or monotonous work. Common robotic hands do not usually consist of one single finger, except may be in the case of tentacle inspired systems. Most prototypes have a number of fingers comprised between two and five. The principle of under-actuation (i.e. having fewer actuators than degrees of freedom) in robotic hands can result in the reliably and easily grasping of the large variety of products. The purpose of the under-actuation between the fingers is to use the power of one actuator to drive the open/close motion of all the fingers of a robotic hand collectively. The transmission mechanism used to achieve such a property must be adaptive, i.e., when one or more fingers are blocked, the remaining finger(s) should continue to move.

When all the fingers are blocked, the force should be well distributed among the fingers and it should be possible to apply large grasping forces while maintaining a stable grasp.

Introducing under-actuation between the fingers of a robotic hand allows reducing the complexity of the systems, from the actuation point of view.

The ability of an under-actuated hand to pick up and move different objects is mainly determined by the mechanical design of the fingers. In contrast to fully actuated hands, neither the closing motion of under-actuated fingers nor the relative contact forces of the phalanges with the object−which strongly influence grasp performance−can be actively controlled.

The basic element commonly used to this end is the differential mechanism.In under-actuated grasping systems in the sense used in this paper, a spring element is generally used to constrain kinematic ally the outputs of the differential mechanism in its pre-grasping phase.

Usually, the spring is of negligible stiffness with respect to the actuation torque and used to keep both outputs in the same kinematical state. However, this is not obligatory, especially if multiple outputs are provided through stacked elements. It should also be noted that differential mechanisms, if the most common element used in under-actuation, are the not only technological solution to achieve this property in grasping.

II. REQUIREMENT OF ROBOTIC GRASPING HANDS

Main obstacles to the tele-operation or automation of complex tasks involving the grasping of various objects in an unstructured environment has been the lack of versatile grasping tools, i.e., of robotic hands. In many applications, the manipulation of objects with very complex mechanical hands or human hands is often not essential and grasping devices are sufficient.

However, simple grippers are not appropriate in most cases because they are not capable of adapting to the shape of different objects. Hence, the development of versatile robotic hands which are capable of grasping a wide verity of objects with a very simple control structure is of great interest for many applications. Such hands can be obtained with the help of under-actuation.

III. UNDER-ACTUATION

An under actuated mechanism is one which has fewer actuators than DOFs. When applied to mechanical fingers, the concept of under-actuation leads to self-adaptability. Self-adaptive fingers will envelop the objects to be grasped and automatically adapt to their shape with only one actuator and without complex control strategies. In order to obtain a determined system, elastic elements and mechanical limits must be introduced in statically under actuated mechanisms. While a finger is closing on an object, the configuration of the finger at any time is determined by the external constraints associated with the objects. When the object is fully grasped, the force applied at the actuator is distributed among the phalanges. A closing consequence of an under actuated two-DOF finger is in order to clearly illustrated the concept of under actuation. The finger is actuated through the lower limb. Since there are two DOFs and one actuator, one (two minus one) elastic element must be used. In the present example, an extension spring is used which tends to maintain the finger fully extended. A mechanical limit is used to keep the phalanges aligned under the action of this spring when no external forces are applied on the phalanges. It should be noted that the sequence occurs with a continuous motion of the actuator. The finger is in its initial configuration and no external forces are present. The finger behaves as a single rigid body in rotation about a fixed pivot. The proximal phalanx makes contact with the object. The second phalanx is moving with respect to the first one- the second phalanx is moving away from the mechanical limit- and the finger is closing on the object since the proximal phalanx constrained by the object. During this phase, the actuator has to produce force required to extend the spring. Finally both phalanges are in contact with the object and the finger has completed the shape adaptation phase. The actuator force is distributed among the two phalanges in contact with the object.

IV. PROBLEM DEFINITION

Currently robotics finds a great field of application in industries.. In large production and manufacturing industries, space station etc. robots are used according to different purposes in different conditions. Commonly a robot has to hold various objects of different size and shape in variable conditions .Thus a robot used in such large scale industries must be adaptive to any dimension in nature. Current system uses pneumatic/hydraulic system for the robotic actuation. But the main problem dealt with this system is that the problem of adaptivity and compactness. Robots are used as specified a working device which leads to cost problems. Installing and maintaining specific robots for every specified work is much difficult and expensive. Thus we should look out for such a compact robot which can work and maintain at any conditions.

V. POWER TRANSFER MECHANISMS

The movable pulley is perhaps the most well-known and commonly used mechanical element to distribute one actuation force to two outputs. Since a tendon is used, such a system can easily be employed to drive robotic fingers which commonly use tendons for actuation transmission.

The movable pulley can also drive fully actuated fingers (using coupled rotations) . More generally, this principle can be used to drive any mechanical system driven by two tendons and thereby provide adaptability. An important property of the movable pulley is that it is force- isotropic i.e. the two output forces are equal. It find quite difficult to use pulley mechanism for a three actuated finger system as due to lack of compactness.

Another power transmission method which is commonly used now in robotics as well as in other application fieldsis pneumatic and hydraulic systems. They have the capacity to transfer large amount of power. Although these mechanism are not implementing for space and other complicated applications due to leakage problems.

Commonly found differential mechanisms are based on either planetary or bevel gear transmissions.Planetary gear trains provide high power density in comparison to standard parallel axis gear trains. They provide a reduction volume, multiple kinematic combinations, purely torsional reactions, and coaxial shafting. The load in a planetary gear train is shared among multiple planets; therefore torque capability is greatly increased. More planets in the system, the greater load ability and the higher the torque.

The planetary gear train also provides stability due to an even distribution of mass and increased rotational stiffness. Thus here we use planetary gear system and its combination, which provide high adaptability and compactness with exact power transmission.

VI. IMPLEMENTATION

The implementation of the project into reality requires the task of splitting the single input asymmetrically into three outputs.

The simple epicyclic gear system splits a single input into two asymmetrical outputs. Two such epicyclic gear systems are coupled axially to make three outputs as shown in figure 1.

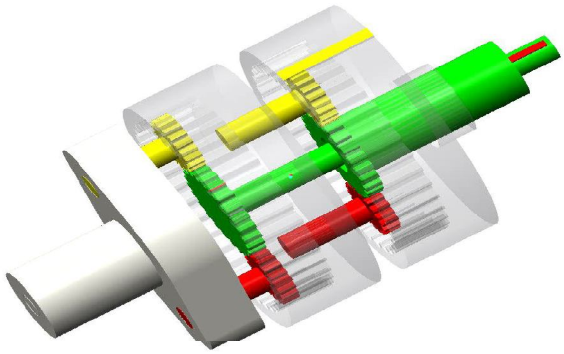

Figure 1:Three output differential gear system

In the first gear system, input is given to the planetary gear and the two outputs are obtained at ring and sun gears. Output from the sun is directly taken to the final stage as one of the three outputs. The second output of the first gear system obtained from the ring is given to the second gear system as the input. In the second gear system, similar to the first one, input is given to planet gear and outputs are obtained at ring and sun gears. These two outputs are the rest of the three required outputs.

A. Working

The input is given to the carrier of the mechanism. The planet gears of the first gear system rotate as it is connected to the carrier. In the first gear, the sun and ring gears are meshed with the planet gears and so the sun and ring gears also rotate. Thus a single input is reached at the first epicyclic gear system and two outputs are obtained as the rotary motions in sun and ring gears. The output from the sun gear is taken as the one of the three outputs. The ring gear is connected to the planet gears of the second gear system.

As the first gear system, a single input is fed to the planet gearsof the second gear system i.e. the output obtained in ring of first system is given as input to second system.
By this input we obtain two outputs as the rotary motions inthe sun and ring gears. These outputs are taken as the other two outputs in the required three outputs.

B. Mechanism to fingers

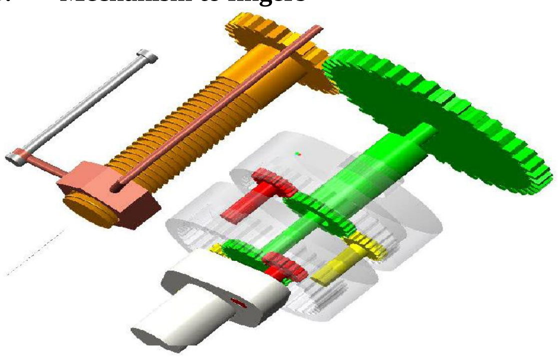

Figure 2:Implementation of differential mechanism in single finger

The fingers of the robotic arm work under linkage mechanism. So the three rotary outputs should be changed into three linear outputs. For the translation of the motion, a bolt screw mechanism can be used as shown in figure 2. Thus three linear motions are obtained at the final stage.

VII. DESIGN THEORY

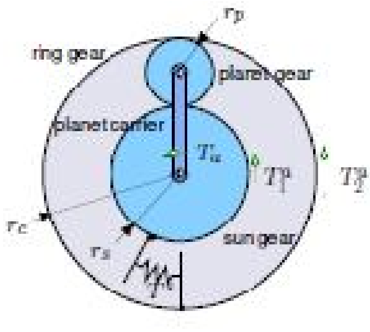

Figure 3: Simple epicyclic gear system

A. Analysis of planetary gear differential

Let N_S be the sped of the Sun wheel (S).
$N_{R:}$ speed of the ring gear (R).
$N_{C:}$ speed of the planet carrier (C).
$D_{S:}$ pitch circle diameter of sun gear.
D_R: pitch circle diameter of ring gear.
$D_{P:}$ pitch circle diameter of planet gear.

Table 1 simple epicyclic gear analysis

Action	C	S	P	R
C fixed, S given +1 revolution	0	1	$-D_S/D_P$	$(-D_S/D_P)*(D_P/D_A)$ = $-D_S/D_A$
C fixed, S given +X revolution	0	X	$(-D_S/D_P)*X$	$-(D_S/D_A)*X$
C given +Y revolution	Y	X+Y	$Y-(D_S/D_P)*X$	$Y-(D_S/D_A)*X$

Therefore, $X+Y = N_S$ -------------- (1)
And $Y-(D_S/D_A)*X = N_R$ --------------(2)
Subtracting (2) from (1)
$X*[1+\{D_S/D_R\}] = N_S-N_R$

Table 2 Speed calculation

Action	C	P_1	R_1	S_1	P_2	R_2	S_2
R_1 fixed c +1rev	+1	$1-D_{R1}/D_{P1}$ =-3	0	$3*D_{P1}/D_{S1}$ =1.5	0	0	0
S_1 fixed c +1rev R_2 fixed	+1	$1-D_{R1}/D_{P1}$ =-3	$-3*D_{P1}/D_{R1}$ = -0.75	0	$-0.75*D_{R2}/D_{P2}$ =-3	0	$3*D_{P2}/D_{S2}$ =1.5
S_1 fixed c +1rev S_2 fixed	+1	=-3	= -0.75	0	-3	$-3*D_{P2}/D_{R2}$ =-0.75	0

Table 3 Speed calculation with input speed 500rpm

Action	C	P_1	R_1	S_1	P_2	R_2	S_2
R_1 fixed c +500rev	+500	-3*500 =1500	0	750	0	0	0
S_1 fixed c +500rev R_2 fixed	+500	-1500	-375	0	-1500	0	750
S_1 fixed c +500rev S_2 fixed	+500	-1500	-375	0	-1500	-375	0

Table 3 Speed calculation with input speed 500rpm

Or $X = [\{N_S - N_R\}/\{D_R + D_S\}] * D_R$
And $Y = [N_S * D_S + N_R * D_R] / [D_S + D_A]$

B. Torque analysis

Assume that all the wheels of the gear train rotate at uniform speed, i.e. accelerations are not involved, and also each wheel is in equilibrium under the torque acting on it. Let T_S, T_C, T_P and T_R be the external torques transmitted by Sun, Carrier, Planet and Ring respectively, as shown in figure1.
According to D'Alemberts Principle,
$\Sigma T = 0$
ie. $T_S + T_C + T_P + T_R = 0$ ------------------- (3)
Sun and Carrier are connected to machinery outside the system and thus transmit external torques. Planet P can rotate on its own pin fixed to carrier, but is not connected to anything outside. Therefore it does not transmit external torque. The ring gear is either locked by an external torque or transmits power or torque either to or from the system through external teeth.
Therefore (3) becomes,
$T_S + T_C + 0 + T_R = 0$
Or $T_S + T_C + T_R = 0$
Assuming no losses in power transmission
$\sum T\Omega = 0$ or $\sum TN = 0$
Or $T_S * N_S + T_C * N_C + T_R * N_R = 0$
Proper directions of speeds and torques are to be taken into account.

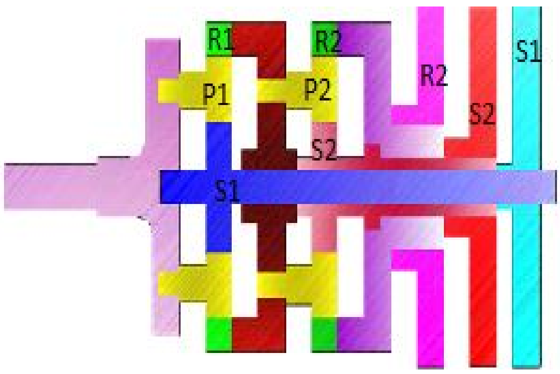

Figure 4: Cross sectional view

The output speed and torque for each finger are computed by fixing other two outputs. The table2&3 shows the speed calculation with input speed as 1 and 500rpm respectively. For computing the output speed and torque we assume that input torque =1Nm&input speed =500rpm and diameters of the sun, planet and ring gears as 20, 10 and 40mm respectively. The output torque is calculated by taking input power is equal to the sum of powers of the output. From this we obtain the output torque for the outputs sun1, sun2 and ring2 as 0.666, 0.666 and 1.333Nm respectively.

VIII. MERITS & FUTURE SCOPES

Three output differential gear systems can be used in production field as well as in space technology.The main advantages of this system are their adaptivity to hold any shape objects, suitable for any enviornmental condition and the output is taken as co-axially. The system is well adaptive for any objects and enviornmental conditions. By adjusting the gear properties speed and torque can be change with respect to the requirements.

The reverse mechanism of the system can be effectively employed in the hybrid vehicles. Toyota Prius which uses two propulsion systems. Epicyclic gears are used in the spilt drive mechanism. When three propulsion systems are used there is no way to couple to single one the reverse differential mechanism can be used for this. Presently there is only two propulsion system and single epicyclic gear for split drive mechanism. Considering these facts it has great application and future development in the automotive field as well as production field.

CONCLUSION

In this paper, a methodology was proposed for the robotic arm.This mechanism have large scale application in space applications, industrial purposes and other complicated situations. The main advantages of this system are their adaptivity to hold any shape objects,suitable for any enviornmental condition and the output is taken asco-axially. The reverse mechanism of the system can be effectively employed in the hybrid vehicles.

REFERENCES

[1] T. Laliberté, C. Gosselin, "Underactuation in Space Robotic Hands"-Paper Published at The 6th InternationalSymposium on Artificial Intelligence, Robotics and Automation in Space, Programme and Abstracts, 18-22 June2002, Canadian Space Agency, Québec, Canada.

[2] Rakic, M., "Multifingered Robot Hand With SelfAdaptability," RoboticsAnd Computer-integrated Manufacturing, Vol. 3, No. 2/3, pp. 269–276,1989

[3] Kennedy, B., "Three-Fingered Robot Hand With Self-Adjusting Grip,"Nasa Tech Briefs, Vol. 25, No. 12, pp. 59, December, 2001.

[4] Lionel Birglen and Cl´ement M. Gosselin., "Force Analysis of Connected Differential Mechanisms Application to Grasping",

Jinming Liu and Huei Peng, "Modeling and Control of a Power-Split Hybrid Vehicle,"IEEE transactions on control systems technology, Vol. 16, No. 6, November, 2008

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