A Grasping-Climbing Mechanism for Pruning Tree-Branches Using a Multirotor Helicopter

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In this paper, we propose a grasping and climbing mechanism for pruning tree-branches close to electrical power lines. By means of a multirotor helicopter, the mechanism is placed on it and deployed to the target, namely, a tree-branch and, by using a couple of claw-like grippers, it is firmly grabbed. In order to prune a specific point of the tree-branch, the grasping-climbing mechanism has the ability to move along it thanks to an extra couple of grippers which perform the walking task along the target. The proposed climbing-grasping CAD mechanism is presented along with some kinematic analysis of the performance of this mechanism.

***Key Words*:** Multirotor helicopter, Grasping, Climbing

1. Introduction

Multirotor aerial vehicles have been the focus of attention in the last fifteen years, this is mainly due to the simplicity in the construction and easy maintenance. This platform is being used for both research and civilian application such as aerial video and photography; some examples related with automatic control of such systems can be found in [1], [2], [3], [4] and [5]. Although there is important research on the field of search and rescue operations [6] and in crop management [7], aerial video and photography is probably one of the best successes in the practical application of multirotor helicopters [8].

Usually, a multirotor helicopter is equipped with a video camera and some navigations instruments like GPS and compass as well as a flight controller and a power unit. The multirotor then is able to explore the environment commanded by a user from the home position. The navigation system helps the user to control the multirotor with the minimum effort allowing him to focus only in the scenario he wants to capture with the video camera. As was described previously, the main capability of a multirotor helicopter is exploration, however, a new field in aerial robotics called Aerial Manipulation has emerged increasing the range of potential applications. Performing a direct interaction with the environment provides to users the capability not only for inspection but also for interact with the environment in different types of scenarios. Assisting a human been in case of a heart attack is one example of this kind of new applications. By using that the authors call “ambulance drone” [9], the multirotor equipped with an AED (Automated External Defibrillator) flies to the emergency place to provide assistance to the affected person. Regarding with aerial robots for agricultural crops, DJI has introduced the “AGRAS MG-1”, which is an octocopter designed for precision variable rate application of liquid pesticides, fertilizers and herbicides, bringing new levels of efficiency and manageability to the agricultural sector [10].

The examples mentioned above are clearly new applications related with multirotor helicopters. Particularly, we are interested in pruning tree branches, since a tree growing near powerlines represents a potential hazard for the security of the residents as well as for the electricity supply. If a tree branch hits one of the cables of the power line, it may cause an electrical arc and sparks affecting the energy supply or even fire around the contact area [11]. In order to keep the security, tree branches must be kept away from electric power lines. For removing these branches, usually we need a working person and a crane, the latter is to access the target and the former one to prune branches with a specialized tool. Pruning trees close to electric powerlines represents a risk; this means, there is always the possibility of an accident caused by a high voltage. Usually, the minimum required working distance for pruning trees close to a primary distribution lines (between 750 Volts and 150,000 Volts) and a transmission lines must be 3 and 6 meters respectively. For a human worker, pruning these branches may become a difficult and hazardous task, that is, it is necessary to find a solution to keep safe the people working in such activity.

2. Aerial Pruning Robot Concept

The concept for pruning tree branches that we propose is based on the idea that a traditional climbing robot takes a long time to achieve the target, which means the tree branch. Climbing from the base of the trunk for a climbing robot represents a task full of challenges, this because the robot can fall on the way to the tree branch due to the irregular of the surface. By using a multirotor helicopter, the climbing process can be avoided helping the user not only to achieve the target faster but also to navigate safely.

Fig 1 shows the concept of the proposed aerial pruning robot, basically, the multirotor helicopter should fly to the tree branch instead of climbing like the traditional way, after that and flying close to the target, the helicopter will be able to grasp using a couple of claw-like grippers. Once the grasping process has been done and before pruning, the helicopter will be detached from the pruning system for moving and pruning freely. Later, the pruning machine will start pruning the tree branch and finally, the multirotor will be attached again to move the pruning system to the home position.

2.1 Grasping and pruning mechanism

The robotic gripper we are using in this research is composed by a couple of claws with teeth to help the mechanism to grasp the tree branch, we call this configuration “skew-gripper”, since each of the claws are placed in different planes. The pruning system is composed by a DC motor, a gear box and a circular saw, Fig 2 shows the complete CAD model of the mechanism which is placed on the top of an hexarotor helicopter.

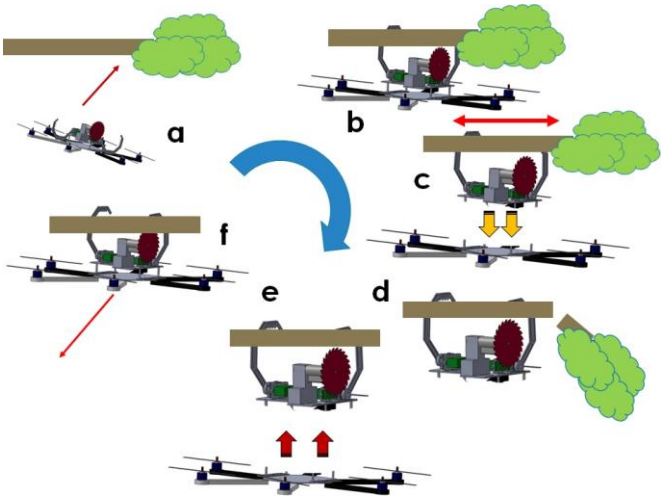

Fig. 1: Aerial grasping and pruning task, main concept. In (a) the multirotor is flying to the target. In (b) the tree branch has been grasped. In (c) the helicopter is detached from the pruning mechanism and it is moving along the branch. In (d) the mechanism is pruning the tree branch. In (e) the helicopter is recovering the pruning mechanism. Finally, in (f) the helicopter is returning to the home position.

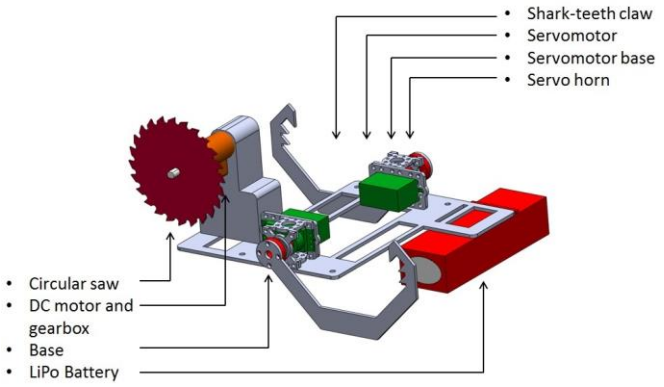

Fig. 2: Grasping and pruning mechanism, main components

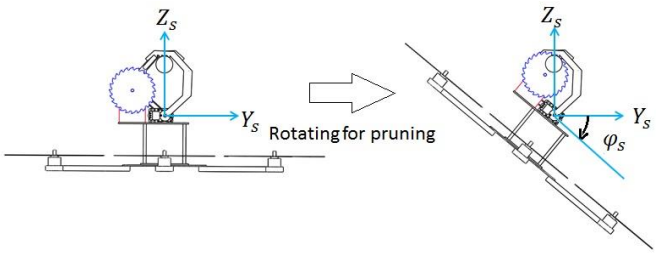

Fig. 3: Pruning technique

Currently, there is only one single system, this means, the attached and detaches mechanism has not been designed yet, so the pruning process is performed with the helicopter attached to the pruning mechanism. Fig 3 shows how the pruning process is performed, notice that the couple of servomotors are placed on the same axes, which allows the base-plate to rotate and therefore, prune the tree branch.

3. Moving along tree branch

In order to move along the tree branch to be pruned, a climbing mechanism was added to the grasping and pruning mechanism. This new couple of claws will help the helicopter to reposition the circular saw more precisely in case the grasping has not been in an adequate position. Fig 4 shows the proposed mechanism and the climbing sequence, it has two DOF, one is for open-close the gripper and the other one is for producing a rotational movement for climbing purposes.

4. Climbing CAD Simulation

The gait process is as follows: For the sake of clarity, the climbing grippers are in color blue, and the grasping mechanism in color purple. First, the aerial pruning drone should grasp the tree branch with the purple grippers. Once the helicopter is well fixed to the target, the climbing grippers in color blues start closing until create a close area between the grippers and the branch. When the purple grippers have enclosed the tree branch, they will start moving for gating along the branch and at the same time, the grasping grippers have to start opening. Finally, when the circular saw is placed in an adequate position, the grasping gripper have to close again and the climbing grippers have to open to start pruning the branch. Fig 5 shows the complete process.

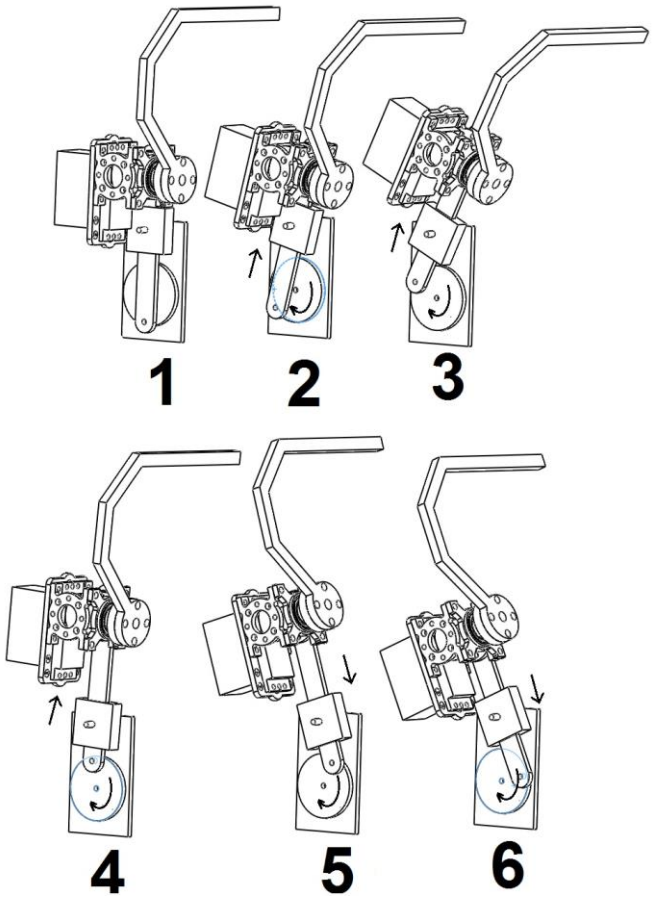

Fig. 4: Climbing sequence. Notice that the system has two DOF, one for walking and one for grasping

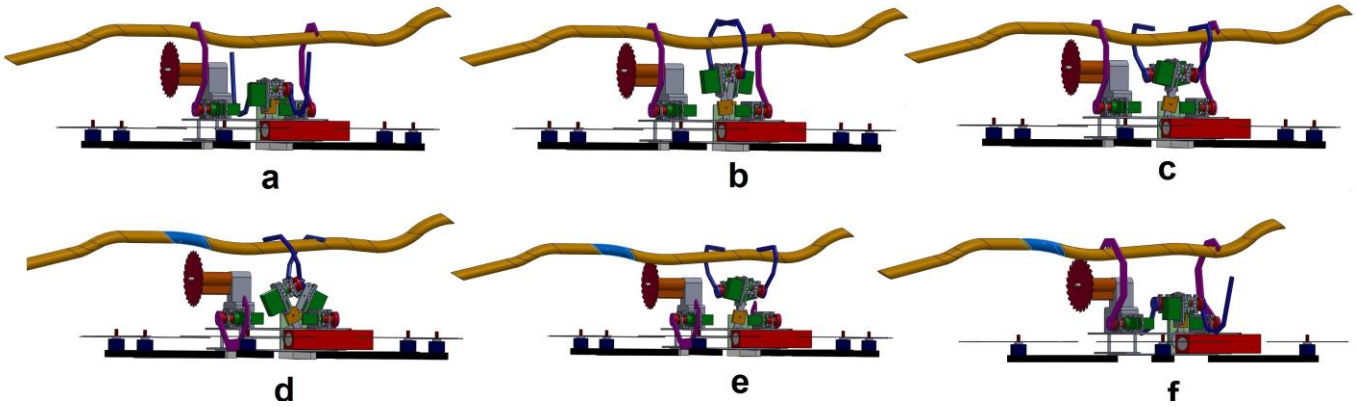

Fig 5: Climbing process. In (a) the grippers used for climbing start closing. In (b) the tree branch is in the enclose area ready for the transition between the grasping gripper and the climbing grippers. (c), (d), (e) show the walkng process and finally, in (f) the pruning mechanism is ready to prune.

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