Mechanism of Autonomous Mowing Robot for Long Grass

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Abstract
A land full of grass can be easily seen all over the world. For example, a golf course, a large playground, courtyard, garden, waste plowed farmland and wild wasteland, all of above are full of grass. Almost all mowing work are operated by manpower, especially the long grass section. There have been some autonomous mowing robots for short grass up to now. However, there is almost no commodity for long grass mowing in the market. The main possible consideration may be the issue of safety. It is highly possible that a sharp mower blade may cause harm under the condition that the mower is not operated directly by a skilled person. In this paper, we will focus on the mechanism design for an autonomous mowing robot that can cut long grass safely. We will also outline the safety requirements for an autonomous mowing robot for long grass.

Keywords: Long grass, mowing robot, autonomous, agricultural machinery.

1. Introduction
A land full of grass can be easily seen all over the world. For example, a golf course, a large playground, courtyard, garden, waste plowed farmland and wild wasteland, all of above are full of grass and a mowing machine is needed for trimming. Almost all mowing work are operated by manpower, either carrying or driving, especially the long grass section. There have been some autonomous mowing robots for short grass up to now. However, it is now common in countries that the rural population is declining, while the cost of labor is increasing year by year. Therefore, if the mower can be working automated and unmanned, and allowed to adapt to different sizes of the work area, we believe that it should be considerable development and market size in the future.

Mowing machine is a kind of agricultural machinery. The trend of agricultural machinery industry are: (1) needs of automation since the aging of agricultural manpower and rural manpower reduction; (2) miniaturization, functional diversification and low prices; (3) environmental awareness resulting the regulatory requirements or need on the reduction of the relevant emissions, noise and energy consumption [1]. Therefore, it is important to co-ordinate products that meet market needs in response to this trend. Since autonomous robots must be able to operate autonomously in unattended
situations, the primary consideration for autonomous mowing robots is the issue of safety. In this paper, we will focus on the mechanism design for an autonomous mowing robot that can cut long grass safely.

2. Overview of Mowing Machine

Generally, there are four kinds of mowing machine.

1) Portable lawn mower, as shown in Fig. 1(a) [1]: This is the most popular kind of mowing machine. It is carried by a person and operated manually and cuts the grass by rotating the blade at the front end. It is suitable for a non-smooth terrain or a hillside. However, it is dangerous since the blade is exposed and the mowing efficiency is poor. And it usually has drawbacks of noise and air pollution because of fuel-engine driven. Hence some manufacturer replace the blade by a tendon rope or the fuel-engine by a motor, as shown in Fig. 1(b) [2].

2) Self-propelled lawn mower, or push-type lawn mower, as shown in Fig. 1(c) [3]: This lawn mower is usually pushed by hand and cuts the grass with the blades above the fuselage. The blade is mounted below the lawn mower, thus providing better safety. But for longer grass, there will be problems due to the mechanism. Most of its power source is by fuel engines, hence the noise and exhaust are still inevitable.

3) Driving lawnmower, as shown in Fig. 1(d) [4]: This lawnmower is of a large body with a rotating blade below the fuselage. The operator can sit on it and control it like driving a car. This type of mower is more suitable for large and flat land, usually park, stadium, or large squares.

4) Automated lawnmower, as shown in Fig. 1(e) [5]: The aforementioned lawn mowers need to be operated by people. This lawnmower basically uses the concept of sweeping robots, with the cleaning component replaced by a blade for mowing weed. It can be regarded as an autonomously moving robot. However, due to safety considerations, the blade must be completely hidden in the body, so it can only be used to cut the short grass. In addition, due to the characteristics of its institutions, it can only be applied to flat grass.

Fig. 1. Different types of mowing machine.

For the 4 types of mowing machine, only the portable lawn mower is suitable for long grass. However, it must be carried by a staff to operate, and it is very dangerous due to the exposed blade.

In a wasteland covered with long grass, it is likely to lurk some danger. Operating a lawn mower to finish a large grassy field of long grass requires a lot of manpower and time. In these cases, if one can have the help of autonomous mower, he will be able to avoid the dangerous and save much time.

3. Safety Requirement for Autonomous Robot

Machines or robots are working for people to save time and manpower, and to avoid dangerous. However, the safety should be the first and most important consideration on designing the manpower workings by robot workings. Almost all automatic or autonomous facilities (including systems) have to meet some safety requirements. For example, ISO 13482 is an international standard on the safety of personal care robots (life
support robots) [6]. Hence all personal care robots have to meet the requirements of ISO 13482. Ni and Leung suggested some safety and liability of autonomous vehicle technologies [7]. ISO 26262 [8] is an international standard of safety-related features of electrical and electronic systems for the cars with total weight less than 3.5 tons and less than 8 passenger-seats. In our opinion, a safe autonomous long-grass mowing robot should meet the following regulations:

1. It will not make people hurt, especially by the blade.
2. The blade will not be broken by hard objects.
3. It can cut the long grass successfully.
4. It does not need to be driven by people.
5. It can move autonomously.
6. It can be commanded.
7. It can be stopped in emergency.
8. It has the ability of obstacle avoidance.
9. It can avoid falling into a hole or falling down due to terrain.
10. It can be programmed on moving.

The first regulation, which is the most important regulation, is to prevent people working or moving around the mowing robot to get injury in accident. The third regulation is the main function of the robot.

4. Possible Mechanism of Autonomous Mowing Robot

The simplest design of a mowing robot is to cut the grass with a high-speed rotating blade or tendon, just as people cutting the grass with a sickle in hand. But this will have a high chance of accidental injury to people nearby. In addition, because of the softness and flexibility of the stems and leaves of grass, if the blade rotation speed is not fast enough, the long grass cannot be cut smoothly. Our design of the autonomous mowing robot contains four parts: (1) grasping part, (2) cutting part, (3) motion part, and (4) sensing part, as shown in Fig. 2. All parts are controlled by a central control unit. The motion part can be wheels or tracks. The sensing part may contain infrared, ultra-sonic, or laser distance sensors, force-feedback sensors, limit sensors, thermal sensors, cameras, or other sensors.

The grasping part and the cutting part work in close cooperation. The grasping part is responsible for the long grass caught up, and then the cutting part cuts the grasped grass, as shown in Fig. 3. This mowing method is similar to the way people cut long grass. The cutting part can be a sickle, a gear saw, a chain saw, or clipping blades.

Fig. 4 is our design of autonomous mowing robot. It has four wheels for moving. The cutting part is a gear saw below the fuselage with a fence-type security mechanism. Anything touch the fence while the robot moving forward will cause the robot stop the gear saw immediately for safety. The grasping part is composed of two 3-arm rotating plate like shuriken in opposite direction and with...
phase angle difference 60°, as shown in Fig. 5. This phase angle difference is to ensure that the arms of these two grasping blades never collide with each other during rotation. Hence this mechanism can grasp the grass 6 times in one period. The grasped grass will be cut by the gear saw below the fuselage.

5. Discussion and Conclusion

A general self-propelled mower can only mowing short grass. For long grass cutting, only the portable lawn mower can deal with. Mowing with this type of mowing machine is not only hard but also of some potential dangers. In this paper, we have designed a new way for cutting long grass like the way of human cutting. Also the designed mowing robot can cut long grass in a safe way. This mowing robot without sensing part has been verified that it can successfully cut long grass. We will integrate software design and sensing systems to enable the design of the robot for autonomous moving with programmed route. We believe that an autonomous mowing robot for long grass will be commercially available in the market in the near future.

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