Advanced pasture management through innovative robotic pasture maintenance*

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***Abstract*— The results of the i-LEED project should demonstrate an advanced pasture management combining a pasture care and management robot with the i-LEED software in order to provide significantly improved pasture regrowth, biomass quality and consequently better feeding of the grazing cattle. The information from the barn and the pasture complementing one another will lead to a more balanced and demand driven feed supply to the cattle, particularly affecting the improved amount of valuable milk components of the dairy cattle. Besides the positive effects for the pasture and cattle, the required working time for pasture care and management should decrease. Furthermore, less greenhouse gas emissions are expected due to avoiding of open and compacted soil, as well as better nutrient distribution and a higher productivity.**

I. Introduction

Contemporary agricultural production faces new challenges. The world population increases steadily with a trend to surpass the 9 billion mark by 2050. This will affect the demand for meat and dairy products globally and cause higher retail prices in Europe. The higher living standard, rising incomes and urbanisation are often associated with the addition of protein to the diet and increased consumption of higher value meats, such as bovine and dairy products. Not only the quantity but ever more the quality is demanded. In the past 50 years the meat production has increased by 300% whereas the number of bovine, porcine, poultry and ovine animals has grown, at 57%, 137%, 400% and 49%, respectively. By 2050 compared with production levels in 2005/07 the required increase of the meat production is estimated to 200Mt a year [1], which is a reason why the meat is anticipated to be one of the fastest growing commodities in the coming years. The consumption of dairy products in the coming years until 2020 is expected to increase modestly in developed countries. Milk and dairy products are anticipated to be one of the fastest growing sectors in the coming years, increasing demands on agricultural resources. In the context of the reformed Common Agricultural Policy (CAP) the animal products from EU should become more competitive on the world market and ensure a fair standard of living for farmers [2].

The required additional production needs to be provided by increased productivity and the real and essential challenge lies in meeting the rising demands in a more sustainable manner. The productivity gains will depend on protecting the available resources, R&D, and on the ability of the industrial sector to adopt the latest technologies.

A possible solution to stay sustainably competitive is based on continuous grazing farms, which can be considered as low-input farming systems (LIFS). Mostly in disadvantaged areas of some EU countries, a stronger tendency of LIFS was noticeable in the previous period aiming at aspects of sustainability [3]. In such systems high pasture graze portions (35-60%) of the total annual feeding ration are preferred. Hence the management of the pasture has a high relevance, because under optimal conditions with constant grazing the grass growth remains very young and shows high energy values (9,8-11,3MJ ME). In some cases a complete dispense on concentrate during the grazing period can cause a decrease in fat- and protein percentage as well as an increase of urea content in milk. For this reason a continuous monitoring of the pasture and milk parameters needs to be striven for, in order to provide better quality of the products as well as animal health and welfare. One of LIFS disadvantages is a significant amount of work required in order to stay manageable.

On the contrary to conventional high-input farming system HIFS, LIFS provokes less negative impacts on the environment and the quality of life of rural and neighbouring communities. Fewer changes on the landscape can be observed, decreasing its homogenisation and destruction of traditional landscape elements and, consequently, loss of habitats. Furthermore, the general public likes to see the dairy cows on the pasture, and therefore the dairy industry tries to keep grazing to remain the standard [4].

In the civil society ever more people are worrying about animal welfare conditions and the negative effects of livestock production units on the appreciation of the landscape [4]. Accurate data about feeding, animal health and welfare can be achieved only by using ICT and thus, it is possible to optimise the production and make it more sustainable. In spite of the growing population the demographic trends indicate that the number of the well versed agricultural workers will either remind static or even decrease especially in the developed countries and cause additional expenditures in agricultural production. Considering these facts the implementation of ICT and

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robotics also for livestock husbandry on pasture should be striven for in order to make this method more competitive.

Introduction of field robots in the agricultural or off-road sector with relatively high working speed (range up to 3m/s), which have been considered as optimal for carrying out selected operation with the pasture robot, are rarely addressed in the literature. Associated accurate path following and integrity considerations of a robot moving at high speed under harsh conditions (slope, sliding, varying soil conditions, obstacles, rollover risk) poses in fact many challenging problems. The main existing approaches [5, 6] assume currently a known and non-varying environment, such as road conditions or very low speeds, and the robot stability is generally only addressed from a passive point of view, using rollover protective structure, or thanks to mechanical design properties [7]. In off-road conditions (varying soil properties, slope, sliding), large lateral errors are usually observed if a classical control approach is used [8], usually based on the pure rolling without sliding assumption, and the robot stability need to be addressed with respect to the rollover risk. Moreover, the robot must be able to detect and avoid potential obstacles during its motions in the pasture (e.g. machines, animals, humans). Many methods have been proposed in the literature for this function [9] but their performances are often limited to robots moving at very low speeds, neglecting the sliding and skipping effects in the obstacle avoidance reaction in off-road conditions. Making mobile robots safe and reliable is an absolute necessity for them to find their market.

II. Objectives

The aim of the project is to optimise the feeding of cattle on pasture as well as the management of the pasture through introduction and fusion of innovative tools. The new i-LEED software, which will be developed within the frame of the project, will interact with a global Herd Management Software (HMS) and provide control of the pasture robot as well as providing calculations of the optimal feeding strategy for cattle and maintenance of the pasture providing support for the farm manager by decision making.

Within the project a concept of pasture robot including several variants will be developed based on existing wheeled robotic platforms. The pasture robots will be redesigned in order to allow stable movement under difficult terrain conditions. During the optimisation phase aspects of energy consumption, energy availability and mobility management will be particularly considered. The pasture robot should be able to move under specific circumstances at relatively high speed (up to 3m/s) in the pasture with a high-precision, in order to obtain an economically viable solution. In the same time the accuracy of defined path following should stay stable with a lateral error not higher than 20cm.

Furthermore, different actuators (mulcher and seeder) and adequate sensors for pasture care will be implemented on the robot platform. The sensors should provide information about the biomass to ensure optimised feeding of cattle and allow detection of cowpats and leftovers, heading gramineous plants, undesired plants (nettles, crowfoot etc.) or areas without vegetation, in order to carry out selective improvement of the pasture condition after grazing. This task have to be done by mulching only the areas with cowpats, leftovers and heading gramineous plants as well as by seeding on areas without vegetation.

III. Materials and Methods

The literature survey and analysis considering the basic concept for pasture robot, which will be adapted within the frame of the i-LEED project, indicated that a solution with a caterpillar track can cause considerable damages on the pasture, in particular during the sharp turns and manoeuvres [10]. The wheeled robots in general have lower amortisation and maintenance cost, steering with high-precision is more reliable especially during turns at high speed in presence of sliding, their energy consumption is considerably lower (to speed up the outside track during turns requires considerably more power), and finally, to repair a wheeled system is under certain conditions much easier. The better distribution of total weight, one of the main advantages of a vehicle with tracks, plays a subordinate role because a light weight low-energy consuming solution is pursued in the i-LEED project. Based on these facts, similar decisions made by other authors [11, 12, 13] and ideas to consider further agricultural field tasks (not only on pasture) using the same robot platform, a wheeled platform was chosen.

The stability problem will be approached based on adaptive and predictive control techniques, designed to compensate for the perturbations encountered in a natural environment and perform accurate path following. Certain approaches [14, 15] can lead to an oscillating behaviour of the robot, even at limited speed, but the improved algorithms presented in [16] can handle this problem.

A. *Pasture robot*

To avoid problems considering conflicts between the pasture robot and cows, all the missions will be carried out on the paddocks not occupied by animals. The robot will access the paddocks from the opposite site than the cows, because cows need to return to the automatic milking systems (AMS) two to three times per day along the passageway and in case the robot would use the same passageway unnecessary robot-cow encounters, with unknown implications, could not be avoided. In the advanced phase of the project the cohabitation of cows and robot in the same paddock could be also an interesting constellation which needs to be considered to experience feedback for future work, before the product introduction on the market.

One version of the pasture robot will be developed using the platform RobuFast [16](IRSTEA) another version will be developed based on a commercial available mobile, remotely controlled mulcher [17] (LfL) and a third version of the pasture robot will be developed based on the RoboTurk platform [18] (EGE) see Figure 1. The conditions on pasture which can affect the kinematical and dynamical behaviour of the pasture robot were analysed and the requirements defined in order to choose or rather develop the pasture robot.

Figure 1. : *Robotic platforms: RobuFast - IRSTEA (top), i-LEED LfL (middle), RoboTurk (bottom left) and rendering of the novel konzept of EGE (bottom right)*

Considering the functionality which the pasture robot has to fulfill, two main tasks are defined: scouting – data collection about the condition of the pasture, and pasture maintenance – sowing and mulching. Figure 2 illustrates the process of the functionality of the robot for one paddock.

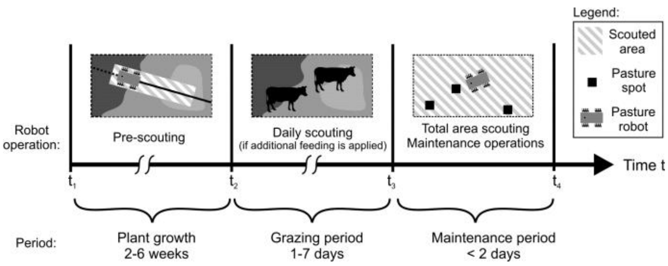

Figure 2. *Process of the robot for one paddock*

1) Scouting

Scouting operations take place during the period of growth before grazing, optionally during the grazing period (if additional feeding after a grazing day is applied) and immediately after grazing. The aim of scouting is to collect information about forage quality and biomass quantity, as well as to locate suboptimal zones on a pasture in order to provide the necessary information for controlling the agricultural implements mounted to the pasture robot and thus gain optimal maintenance of the pasture.

Commercially available sensors for these tasks will be evaluated, tested and integrated in the pasture robot, if applicable. E.g. an approach for determining the biomass quantity using a 2D laser scanner (wavelength 660 nm) was carried out. For this purpose the sensor was attached to a framework for scanning a defined area of grass, whereas the scanning plane was perpendicular to the direction of motion and the sensor traversed over the area with constant speed. After scanning the grass was cut, collected, the samples were weighted and later dried (method of the Association of German Agricultural Analytic and Research Institutes - VDLUFA) to determine the dry mass as reference. Moreover a NIR sensor (wavelength range of 950-1650 nm) is tested in regard to the identification of dry matter content and feed substances (e.g. nitrogen) of the grass on pasture.

In order to localise the spots on the pasture on which maintenance operations are desired test with the 2D-laser scanner were carried out, too. With the regard to the detection of faults in the sward, so-called seeding spots, output dimensionless echo amplitude values depending on the surface properties of the target object are used. In principle amplitude data can deliver an estimate of the relative reflectivity of an object [19]. With the first test series under model conditions the difference between the reflectance of the areas covered with grass and soil was proven. The laser scanner was installed stationary above a cut dry lawn area (z = 740 mm), so that the scanning plane was perpendicular to the ground level. The scanning zone was split into two areas: the first was covered with 30 mm high cut lawn (see Figure 3 on the right) and in the second trays filled with local dry topsoil were placed onto the grass (see Figure 3 on the right). The trays simulated faults in the sward, e.g. caused by trampling of the cattle or other animals. In this test series the both zones have approximately the same height. The trays were total covered to assure a laser beam reflection on the soil. A width of 1200 mm was scanned, which corresponds to the working and scanning width of the pasture robot.

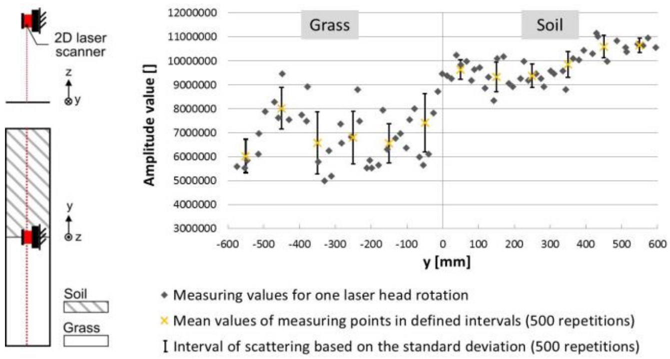

Figure 3. *Experimental arrangement (left); amplitude values collected with Pepperl&Fuchs R2000 laser scanner for one laser head rotation in relation to the y-coordinate and mean values in defined intervals for 500 repetitions*

2) *Mulching and seeding*

The maintenance operations: mulching and seeding take place after grazing. Because of the plant growth and the impending weed infestation, the maintenance operations, especially mulching, have to be finished within two days after animals have left the pasture. The maintenance operations include mulching of leftovers and heading gramineous plants, seeding of faults areas without vegetation and spreading cowpats.

B. *i-LEED Software*

The i-LEED pasture management software (PMS) should allow planning and managing the entire grazing activities in combination with one or more pasture robots. For this purpose it combines data from the mission planning software, the attached sensors, the herd management system and the feed ration software. The aim of the software is to support the farmer by decision making in order to increase the efficiency of the pasture utilisation while reducing the risk for the animals' health and negative environmental impacts due to grazing activities. The PMS is supposed to be a comprehensive repository of all relevant information about grazing activities. Moreover it allows scheduling of the grazing rotation and supports the operation of the pasture robots.

1) *Mission planning*

In addition to scheduling the operations to be performed by the pasture robot in the different paddocks, one of the main issues of the mission planner is to generate the trajectories to be followed by the robot with respect to the needs of the mission (e.g. full or partial coverage of a paddock, reach successive areas, speed reference), while taking into account and adapting to both the constraints of the environment (e.g. shape of the paddocks, static obstacles, fences) and kinematic and dynamic constraints of the considered robot (e.g. wheelbase, maximum wheels steering angle and rate).

Based on a prior knowledge of the environment, fences location and identification of several kinematic and dynamic parameters of the robot, the proposed planning approach is based on the junction of elementary primitives (arc of circles, line segments) with arc of clothoids to generate continuous curvature trajectories feasible for the pasture robot [20].

2) *Robot control*

The control algorithm of the robot must perform three main functions, namely the accurate path following of previously planned trajectories, the management of obstacles, and the conservation of the robot stability.

To accurately guide the pasture robot along the previously planned trajectories at the speed requested by the mission, the control algorithm needs to continuously adapt the parameters considering the encountered off-road environment, in particular the soil conditions that may lead to important sliding phenomena.

Compared to indoor rigid and asphalted ground, the displacement with wheels on agricultural grounds, by nature (structure, compaction, humidity etc.) and varied topology (slope), can lead to uncertain kinematic and dynamic behaviours of a mobile robot, in particular when the speed of displacement is relatively high. In such conditions, the pure rolling without sliding assumption (widely used in mobile robotics because it significantly simplifies the modelling of vehicle based on conventional wheels), cannot be directly exploited without obtaining low guidance performances. In order to adapt the control algorithm accordingly, the understanding of the interaction of the robot with the ground is essential. However, describing the physical phenomena during the interaction of the wheels of the vehicle with the ground is particularly complex, all the more on natural grounds. The models of such interactions are generally dedicated to the automobile industry (e.g. analytic approach based on the detailed description of the physical phenomena inside the tire, or empirical approaches from experimentations performing on test bench), and thus difficult to simply adapt for a vehicle rolling on a natural ground. Nonetheless, without aiming to come back to the forces occurring at the wheel level, the sliding phenomena at the interface of the wheel with the ground can be represented through the sideslip angle representing the difference between the theoretical direction of the linear velocity vector at the wheel centre (described by the wheel plane) and its actual direction. Assuming that this angle robustly represent the sliding influence on vehicle dynamics, the approach can be used to indirectly estimate the sideslip angles of the wheels of the robot within of a suited observation algorithm.

Although the trajectory planner generates obstacle-free trajectories, the robot must have capabilities to detect obstacles and avoid them (or immediately stop if not possible). Considering an example of an isolated obstacle inside one paddock, a simple approach can be defined to change the reference of the lateral deviation with respect to the current trajectory, taking the advantage of the capabilities of the previously developed controllers [16]. Another approach could be to redefine the trajectory to new feasible one which avoids the obstacle. This approach will be necessary to choose in case when the robot counteracts to several obstacles simultaneously and finding a feasible obstacle-free path between several obstacles in real-time is required.

IV. RESULTS

A. *Development of the pasture robot*

1) *Specification*

After an analysis of the surface and terrain conditions on pasture by detection of the soil profile vehicle parameter like ground clearance, track gauge, wheel base and axle articulation were defined (see Table 1).

TABLE I. REQUIREMENTS FOR THE ROBOT PLATFORM

Parameter	Value (up to)
Climbing ability [°]	35
Possible cross slope [°]	35
Min. axle articulation [mm]	150
Min. ground clearance [mm]	150
Wading depth [mm]	150

2) Scouting

Tests on cultivated grassland have shown that the estimation of the biomass quantity based on the grass height using a 2D-laser scanning technology (wavelength of 660nm) is possible. Figure 4 shows the result of measurements on cultivated grassland within one season (3 repetitions per sample area of 1 m²):

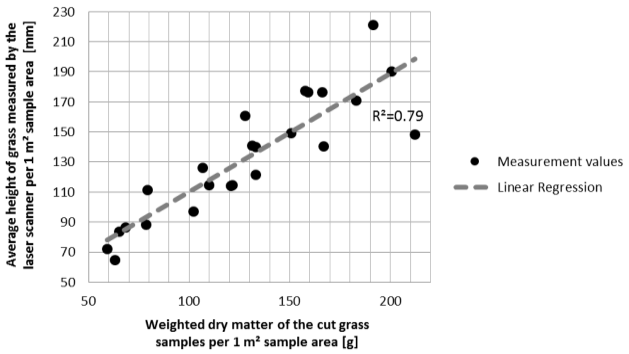

Figure 4. *Relationship between measured grass height using the laserscanner and the actually measured dry matter*

A linear regression resulted in a correlation coefficient R^2 of 0.79. Similar measurements are running on pasture areas to develop an algorithm for determining biomass on the basis of grass height data.

In regard to the detection of seeding spots for example , measurements under model conditions have shown that the 2D laser scanner R2000 (Pepperl&Fuchs) is able to distinguish between grass and soil spots under the described conditions via the in section III mentioned dimensionless echo amplitude value. The results are illustrated in diagram on Figure 3, showing inter alia amplitude values for one laser head rotation (resolution 1°) in relation to the y-position of the measured surface, calculated using the distance values of the laser for each measuring point.

The different scattering around a particular mean value (see Figure 3) of the measuring points for the two zones is clearly visible. The scattering of the amplitude values in the grass zone is much higher in comparison to the values of the soil zone. It is apparent that only one amplitude value cannot be used to state something about the surface zone. To determine the type of zone several neighbouring measuring values must be considered, especially their mean value and scattering. In the diagram calculated mean values in defined intervals ($y_{n1} < y < y_{n2}$) with an interval length of $\Delta y = 100$ mm were calculated for 500 repetitions. For the robot operation on pasture a resolution of $\Delta y = 100$ mm is necessary to detect sward faults in the size of a cattle footstep. Because of the circular movement of the laser beam the distances between neighboured points in y direction on the flat reference level (z = 0) increase with |y|. Consequently with increasing |y| the intervals contain a lower number of measuring values. The depicted coefficients of variation of the amplitude values for the grass zone ($-600 < y < 0$ mm) are in the range from ±10.8% to ±19.8%. The values for the soil zone ($0 < y < 600$ mm) vary in a smaller range between ±2.8% and ±6.6%. The relative high mean value for area y = [-500 to -400] mm () confirms the necessity to observe the scatteringof measured values to identify the surface type.

The method for detection of seeding spots can be used under certain circumstances, (the definition of the amplitude as parameter needs to be considered [19]) for detection of suboptimal zones on pasture, like faults in the sward. Especially the scattering and the average values of echo amplitude data can be characteristic parameters of soil or rather grass zones. Further tests, considering different environmental and physical conditions (illumination, moisture of soil, sensor position etc.) and combination with additional sensors as well as measurements in motion are necessary to develop an algorithm, which can deliver enough information to identify zones on pasture.

3) Mulching and seeding

One of the most important criteria by using a mulcher implemented on an autonomous robot is safety. Objects appearing on the pasture such as stones etc. should not be thrown uncontrolled by the moving tools of the mulcher. If there is an animal or even a person near of the operating area, the mulcher has to stop immediately. Another very important point for the operation of the pasture robot is reliability. Objects appearing on the pasture such as stones etc., should not restrict the functionality or damage the machine. Under difficult conditions, e.g. lying vegetation, the machine should not be blocked with organic material, which under certain circumstances can lead to loss of functionality. Furthermore, due to the power autonomy and operational costs the energy consumption of the mulcher should be as low as possible. On pasture the surface can be quite rough and hilly. For this reason the mulcher must have appropriate height guidance and has to be designed quite short to avoid damaging the grass sward. The shorter the better is the ground adjustment of the tools of the mulcher. Large quantities of grass should be chopped as fine as possible spread evenly. Accumulation and clumping of chopped plants biomass have to be avoided, especially under wet conditions. Considering the energy consumption and the problems related to soil compaction, low weight of the mulcher is preferable. An evaluation of the mulcher types based on the above mentioned requirement criteria, resulted with a conclusion that the flail mulcher would be the most suitable one for mulching operations on cattle pasture.

The seeder should similarly have low energy consumption. Consequently, the drill seeding is not suitable, because of its traction power requirement for soil tillage. Broadcast seeding, methodology in which the seeds are casted onto the soil surface, corresponds more closely to the conditions of pasture maintenance. Considering the problems appearing by soil compaction low weight of the seeder is preferred. Furthermore, the seeding rate needs be adjustable and the farmer has to have a possibility to change it before the robot starts its operation on the paddock. Considering different growth intensities within one paddock the final product of the pasture robot should provide variable seeding rates on different paddock zones. As there is a mixture of different seed types, a segregation of the seeds by vibrations during the transport on the rough pasture must be avoided by e.g. a stirrer if applicable. Under windy weather conditions an even distribution must be provided. That means the flight path of the seed must be minimised by placing it very close to the ground. Finally the seed container must protect the seeds against rain or damp air. Based on these requirements a fertilizer spreader, which was developed at the Bavarian State Research Center for Agriculture [21], will be modified in order to provide controlled seeding on the pasture.

B. *i-LEED Software*

1) *Mission planning*

The mission planning interface allows either: selecting of waypoints on a georeferenced map directly, in order to define the trajectories for the robot, or generating of parallel trajectories to cover a whole paddock automatically, with respect to a chosen spacing. As an example, Figure 6 illustrates automatically generated trajectories to cover an entire paddock with 1.5m and 10m spacing respectively. At the end of each track, the half-turn (180 degrees turn) trajectories however needs to be calculated carefully, taking into account different parameters such as the dimensions of the vehicle wheel-base, the maximum front-wheel steering angle, the maximum angular velocity of the front-wheels with respect to the vertical axis and the velocity of the vehicle during the manoeuvre. Figure 5 presents several half-turn trajectories, calculated for differently defined working widths (spacing between adjacent trajectories). The tightest half-turn is illustrated with the thick black line, and the turn which reaches the null curvature at 90 degrees, allowing to insert a line segment at that point if higher spacing is required, with thick light grey line. If the distance between the adjacent trajectories needs to be arranged between these two previously described cases, a half turn with a slight overlapping of the headland is needed, as presented with the doted black line. If the defined working width is too tight, a loop-turn (bulb-turn) is calculated, as presented with the doted grey line.

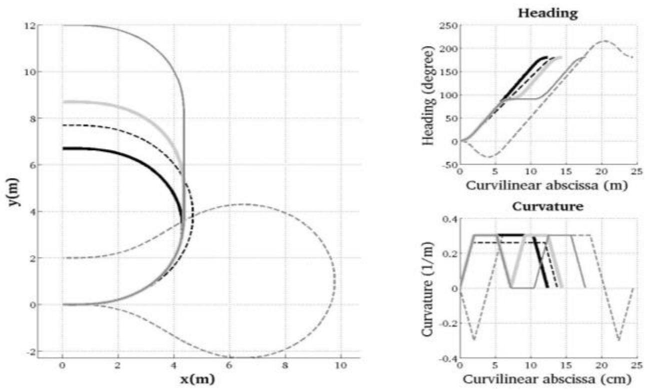

Figure 5. *Half turn with respect to different inter-distances*

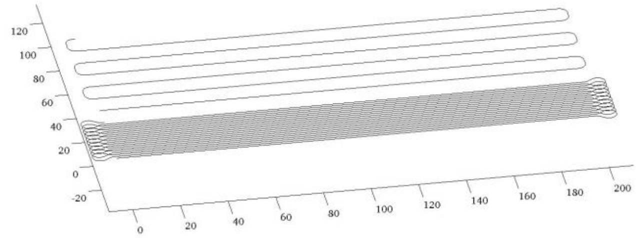

Figure 6. *Full and partial coverage*

1) *Robot control*

The classical kinematic modelling of a car-like vehicle can be complemented by sliding parameters. The approach is described through equations of motion of the robot with respect to the path to be followed (i.e. in terms of curvilinear abscissa, and lateral and angular deviations). This model can be converted into an almost linear one using the theory of chained forms [22]. The derivations with respect to the time are replaced by derivations with respect to the curvilinear abscissa, aiming to obtain control performances independent from the vehicle velocity. This step is essential while it enables in particular independent development of steering and speed controllers. The control theory of linear systems complemented with model predictive control techniques can then be used to compensate the delay of the steering actuator. The delay needs to be avoided because it could lead to significant overshoot, especially at each beginning and end of curves.

To ensure the stability of the robot and prevent the risk of rollover, for example during sharp turns at high speed, the proposed approach use the on-line estimation and prediction of a stability criterion - the lateral load transfer (LLT) [23], in order to limit and slow down the robot velocity in case of risk situations. The LLT represents the repartition of the normal components of the tire-ground contact forces. It can be calculated from the roll-model of the vehicle, requiring the knowledge of different parameters as the mass and track of the vehicle, the location of the center of gravity, but also the lateral acceleration. To predict the evolution of the LLT, it is therefore necessary to predict the lateral acceleration. For that, a yaw model of the vehicle is considered, which includes some variables which cannot be directly measured e.g. the global sideslip angle and the front and rear cornering stiffnesses. These variables can nevertheless be estimated through the design of observers.

V. CONCLUSIONS AND FURTHER WORK

The i-LEED project contributes to the following goals of the CAP and the Standing Committee on Agricultural Research (SCAR) of the European Commission:

1. Maintenance of permanent pasture [control of certain unfavourable plants (nettles, shrubs, trees etc.) without using herbicides; maintenance of a dense sward in order to avoid soil erosion and sward degeneration and enhancement of the pasture productivity for high quality products of ruminants

2. Sustainable agricultural production and resource conservation [optimised feed supply for the cattle due to known amount of available pasture, avoiding oversupply or feed shortages and therefore metabolism and health problems for animals; enhancement of the ecosystem permanent grassland by using site specific, indigenous seeds and site and phytocenosis specific management; better distribution of cowpats (and nutrients) and therefore reduced loss of nutrients due to higher growth rates and earlier grazing of areas around cowpats after regrowth and affecting and killing fewer insects with the mulcher, because with the robot only parts of the paddock, where it is necessary, will be mulched]

3. Facilitating the establishment of young farmers, fostering the employment in rural areas and improving the quality of life in rural areas [work activities shift to more control tasks involving modern technology, therefore the farm as the workplace will become more attractive for young farmers; acquired skills involving modern technologies will open opportunities for the young farmer for extra income from non-agricultural activities and better competitiveness of permanent grassland due to higher productivity, lower working time requirements and the proposed higher direct payment].

Highly automated machine function is an emerging technology within the agricultural sector. No standards exist today relating to this domain. Currently for outdoor agricultural robotic applications, the main referential to link up is the 2006/42/CE machine directive dedicated on health and safety protection of operators. This directive demands from the manufacturer to take all relevant solutions and necessary measures to reduce as much as possible the risks after a failure mode and effects analysis (FMEA), but without any considerations of robotic issues at the time of this directive elaboration in the last century. One important issue will be the further development of guidelines, directives and standardisation e.g. within the ISO working group "Agricultural autonomous machines", in order to allow straight forward development of robotics in field of agriculture.

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