Robotour

ROBOTIKA.CZ OUTDOOR DELIVERY CHALLENGE

Zborník z workshopu

ROBOTOUR 2010

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Robotour 2010

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Robotour 2010 – obsah

Robotour - robotika.cz outdoor delivery challenge

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***Abstract*—In this paper, we present an international contest for autonomous robots: Robotour – robotika.cz outdoor delivery challenge. The main task is a navigation in real-world situations. First three years were held in park Stromovka, Prague, Czech Republic and raised an interest of many teams, media and general public. Last year, the contest started to migrate. To our knowledge, there is no similar European outdoor contest for fully autonomous machines. Note, that there are some common features with American Mini Grand Challenge and a younger Japanese Real World Robot Challenge. The rules of Robotour are described in more detail together with experience gained over the past four years – both from the organizers' and the participants' point of view.**

Keywords: autonomous robots, outdoor, international competition

I. Introduction

Competitions such as Eurobot [1] and DARPA Grand Challenge [2] have repeatedly shown that both young students and senior researchers are attracted by competitive research environments. Autonomous robotics is a multidisciplinary domain which offers educational opportunities and interesting real-world research topics.

In 2004, the American Defense Advanced Research Projects Agency (DARPA) organized the first Grand Challenge. The goal of DARPA was to foster a research in fully autonomous vehicles. In the first year, only 11.78 km of the 240 km long route were completed by the best team. Already in the second year of the competition (2005), five vehicles finished the 212 km long route. This shows a tremendous impact the challenge has had on the field of fully autonomous ground vehicles.

Since 1994, the Eurobot competition attracts many young people (more than 2000 in year 2010) [3]. Eurobot has successfully shown how an international competition can be used to teach young people how to cooperate and how to develop complex systems.

In 2006, the Robotour – robotika.cz outdoor delivery challenge has been founded. In our opinion, the large gap in complexity between Eurobot-like competitions (e.g. RobotChallenge [4], Istrobot [5] and other) and competitions like DARPA Grand Challenge needed to be bridged. In about the same time, other organizers felt similar insufficiency and more competitions were born. Since 2003, Field Robot Event focuses on the agricultural automation [6]. Since 2006, European Land Robotic Trial allows research teams and industrial companies to demonstrate their unmanned outdoor systems in realistic scenarios and terrains [7]. One year after Robotour – in 2007 – Tsukuba Real World Robot Challenge (RWRC) took place in Japan for the first time [8]. Since 2009, a similar straight line outdoor challenge takes place in Písek, Czech Republic [9].

Robotour – robotika.cz outdoor challenge is focused on autonomous ground vehicles and their orientation in the real-world outdoor environment. The robots perform a delivery task in complex environments of city parks. They are not allowed to leave paved roads. Participants of various background are welcome. In the previous years, students from high schools, university researches and hobbyists took part.

In this paper, we describe the Robotour – robotika.cz outdoor delivery challenge. General rules are covered in Section II. In Section III, we share experience obtained from the organizers' point of view. Reflections of the participants are captured in Section IV.

II. Rules

A. Historical Overview

The rules for each year change slightly and the contest becomes more and more challenging every year. The unified theme of all years is robot's ability to autonomously navigate in outdoor environments and to move payload from one place to another. The robots have to be fully autonomous, which means that after a task entry they have to control themselves.

Since the first year, the basic requirement is to navigate on paved roads in the park without leaving them – similar to cars not leaving the streets. In the second year, a possibility of robot cooperation was introduced. In the third year, obstacles were added and robots had to deal with them successfully. In the fourth year, robots did not know exactly their start position and had to deal with obstacles more carefully.

The fifth year of this contest should be a next step towards smarter and more autonomous robots. In contrast to the previous years, the robots get only a map and coordinates of the destination. The robots should be able to navigate around the park even if they have never been there before. The map and the destination should be the only information the robots get before the start. Robot successfully solving this task should be able to demonstrate its ability with a corresponding map in any park.

Fig. 1. A simple map of the Lužánky park in Brno given to the participants in 2009.

B. Detailed Rules

1) Task: The task for the robots is to deliver payload in a given limit of 30 minutes to a destination as far as 1 km. Robots must be fully autonomous, not leave a road and choose correct path on junctions. The starting place, starting time and the destination will be the same for all the robots.

2) Map: Vector map of footpaths in a park will be based on a vectorization of an ortophotomap and teams could improve it further. The basic idea is taken from Open Street Map [10]. A robot is allowed to use only this shared map – all other maps are prohibited!

3) Robots: A team can deploy multiple robots this year, but only a single designated one is used to compute a score. Every robot must have an emergency stop button, which stops its motion. The button must be easily accessible, red and must form a fixed part of the robot (aka Big Red Switch), so it could be used in a case of a danger. The team must show that it is easy to manipulate with the robot – two people must be able to carry it several tens of meters. There is also a minimal size – robot has to carry 5l beer barrel (at least an empty one).

4) Leaving the Road: The robots are expected to stay "on the road" which means to stay on the paved passage ways. If any robot leaves the road, its trial ends. The team has to take care of their robot and remove it immediately.

5) Obstacles: There could be obstacles on the road. Besides natural obstacles like benches there could also be artificial obstacles. A typical (artificial) obstacle is for example a figurant, a banana paper box or another robot. Robots must not touch an obstacle. Contact with an obstacle means an end of a trial. The robot may stop in front of an obstacle and visually or acoustically give a notice. Note, that the robot has to detect, that the obstacle is no longer present.

6) Robots Interaction: Situations, in which a faster robot catches up with a slower one, will not be explicitly handled. The faster robot can handle the slower robot as an obstacle, i.e. avoid it or wait until the "obstacle" disappears. In general, the road rules will be respected: right of way, avoidance to the right, passing on the left.

7) Start: All robots will start from the same park road simultaneously. A minimum width of this road is 3 meters. The starting area for each team will measure approx. 1.5×1.5 meters. Starting areas will follow one after another on one side of the road. Within the starting area, each team can place its robot as they see fit. The order of the robots on the start is given by their results in the previous round (a better robot will be closer to the destination). The order in the first round will be given by the order of successful homologation. Robots start automatically via their internal timers. During the last minute before the start, no interaction with the robot is allowed.

8) Score: The team, whose robot manages to proceed along the route best, wins. The aerial distance of the last position of the robot (leaving the road, a collision or a time-out) to the destination is critical. For every meter towards the destination, a team gets one point. If the team carries a payload, its score is doubled ("points for the payload"). Each robot can carry only one "payload". A 5l beer barrel (full) serves as a payload. In every round, a robot can obtain points at most equal to twice the aerial distance of the start and the destination.

9) Organization: The contest will consist of four trials for each team. The start and destination will be different for every trial. The selected destination will be announced to all teams 10 minutes before the start. The speed of the robots is not important (actually, it is limited to 2.5 m/s). All points gained during all trials will be summed together. The trial starts at a specified time and ends after 30 minutes. The robot must leave the starting area within 10 minutes of the start. If the robot does not move for 60 seconds its trial ends. Each team has to arrange for one person familiar with the rules that will be part of the referee team during the competition.

10) Homologation: A team can participate in the contest only if it is able to score at least one point. Another necessary condition is an ability to travel along a 10 meters long route fragment without a collision with any obstacle. The starting procedure will be tested (the automatic start) as well as the functionality of the emergency stop button. Usage of liquids, corrosive or pyrotechnic material as well as live beings is strictly prohibited. Every robot has to be accompanied by a team member, older than 18 years, who is fully responsible for the behavior of the robot.

11) Technical Documentation: Every team has to provide basic technical documentation about their robot (for presentations, general public and journalists). Three winning teams will be asked for a more detailed description for a website presentation and to make the entry of novices in the following years easier.

III. ORGANIZATION

Robotour is organized as a three-day event (Friday to Sunday). Friday is dedicated to the testing, clarification of rule details and homologation. During the homologation, we want to make sure that robots are not dangerous, have a functional emergency stop button and are able to gain at least one point in the contest. Saturday is the contest day. Finally, there is a workshop on Sunday. It is after the contest, so the competitors have a fresh experience with their robots and algorithms. They are also not stressed any more and thus this is a good moment for sharing knowledge.

We started to enforce this three-day template after the first competition in 2006. That competition ended on Saturday and most teams left without letting us and other teams know what has worked and what has not. What was even more important was that teams left exhausted from the programming marathon and one team had a car accident on the way home. Since the following year, the workshop is mandatory.

The Robotour contest is relatively self-supporting and the expenses are minimal. There is no special playground – a public park is used instead. There is no need for renting a hall because the event takes place outside. To be precise, some room is necessary as a base for the teams especially in bad weather conditions. It is recommended to have a partner who provides this place, like Planetarium Praha in the first park Stromovka did. A good idea is also a combination with an exhibition of robots and a related technology parallel to the contest.

There is no registration fee, but the teams have to take care of catering and pay an accommodation.[1] Small items remain on the bill: leaflets printing, diplomas, cup for the winners, and a Saturday night dinner. The dinner is usually sponsored and the goal is to unite the teams and give them a chance to relax a little bit after the contest. Note, that prices are rather symbolic, which lowers expenses on one side and also reduces a potential rivalry between the teams.

A. Duties over the Year

The first task of the organizers is a precise specification of rules for the next contest. They are presented on the robotika.cz website in Czech and English languages. The core remains the same (autonomously navigate in a park) and the changes are usually a consequence of a discussion at the workshop and experience gained.

The second task is to ensure an affordable accommodation for a relatively large group of people (50 people needed accommodation in 2009). An agreement with a university dormitory serves well. The reservation must be performed usually a month in advance and that defines a clear deadline for the registration of the teams.

Finally, it is necessary to find an interesting park, manage permission for the contest day and find building with large enough room(s) for team base with many electric outlets.

B. Experience of the Organizers

There were couple lectures we have learnt over the last four years organizing Robotour (and previously several years of organizing Czech Cup of Eurobot). The basic scenario was already mentioned and serves good and is worth a recommendation. What has changed over the years are two major trends: the number of teams is increasing and the task is getting more difficult. In the first case, we tried to find some optimal timetable of the rounds and we are still not satisfied. What suits the teams does not suit a general audience and vice versa. This year, we will start all the robots from one place simultaneously, which could be attractive for spectators, but may cause problems to many teams.

[1] Accommodation is usually partially or fully sponsored.

Fig. 2. Robot of the R-team (left) leading the allied robot of RobSys (right).

The task complexity is another issue. Beginners have a harder position to enter the contest every year. For 2010, we discussed a new category (WagonOpen), but we will probably cancel it. The reason is a new, for the beginners with outdoor robots highly recommended contest “Robotem rovně” (Robot, go straight!) in Písek. In Písek, the task is to navigate as far as possible on a 3 meters wide and 300 meters long park road. This is exactly the first stage which is necessary to enter the Robotour contest.

IV. Reflections

A. Questions

To reflect an influence the competition has had on its participants, we have asked some of the past successful teams few questions:

1) What did you expect from the competition?
2) What did the competition give you?
3) What were you disappointed with?

B. Asked Teams

The following teams were asked:

- **Propeler-team**, Opava: A group of high school students, who placed 2nd in 2006.
- **LEE**, Prague: Researchers and students from Czech Technical University in Prague. Winners of the year 2008 and the year 2009.
- **R-team**, Rychnov nad Kněžnou: A team of a high school teacher. Since 2010, he organizes *RobotOrienteering* in Rychnov nad Kněžnou. R-team finished 2nd in 2008 (in a coalition with the RobSys team, see Figure 2).
- **Roboauto**, Brno: A self-funded group of researchers, which ranked 2nd in 2009.

- **Radioklub Písek**, Písek: Hobbyists and professionals, who also teach electronics in a club. Radioklub Písek got a 3rd place in 2009. Since 2009, the club organizes *Robotem rovně* (mentioned in Section III).

C. Answers

1) What did you expect from the competition?:

- Propeler-team:
  - The competition motivated us to build our first robot.
  - Having almost no restriction on the dimensions of the robot allowed for a simple construction – We could use a notebook, get an image from a camera and use a bought chip to control the motor and the servo (we did not understand microchips and servos at that time).
- LEE:
  - We wanted to see a comparison of several approaches to the mobile robotics.
  - The competition gives us an opportunity to have our solution judged in an unbiased fashion.
- R-team:
  - After Istrobot and Eurobot, I wanted to try something new.
- Roboauto:
  - The competition served as a motivation to finish a functional version of algorithms and of the robot.
  - We wanted to present our results to a general public.
  - We expected to meet with a like-minded community.
- Radioklub Písek:
  - After seeing the robots in 2007, we believed we could do better.

2) What did the competition give you?:

- Propeler-team:
  - We met people in the same domain of interest, saw their approach and other technology.
  - Every year, we have a motivation to catch up with our first result.
- LEE:
  - We have seen, how a relatively simple solution (by R-team) can solve a given task.
  - We realized that the increasing accuracy of hardware and sensors can have a huge impact on the accuracy of simultaneous localization and mapping.
  - We have been shown, how important it is to deal with the technical details and with the reliability of the robots.
- R-team:
  - I have learned that even the hardware is not fully reliable. Indoor robots do not suffer from such problems.
  - I realized how difficult the task is, even though I have expected some difficulties even beforehand.
- Roboauto:
  - It has fulfilled our expectation.
  - The competition gave us a practical experience with deploying a robot.
  - We have got an inspiration for further improvements of the hardware and algorithms.
  - We feel in touch with people with similar interests.
- Radioklub Písek:
  - We realized the competition is not as simple as it seemed for the first look and few others.

3) What were you disappointed with?:

- Propeler-team:
  - We are not really disappointed: When the robot works, everything is fine.
  - Answering the question "What does the robot do?" is difficult, when the task difficulty is not obvious.
- LEE:
  - Although there is a lot written by the competitors at robotika.cz, every year someone new comes and repeats previous mistakes.
- R-team:
  - In my opinion, the competition has become too difficult. Only one or two best teams can fully cope with the rules.
- Roboauto:
  - Problems with a reliability and with a robustness are bigger than we have expected.
  - We are disappointed with only a small media attention.
  - We hoped to get an attention of potential sponsors or future team members, which has not happened so far.
- Radioklub Písek:
  - We are sad that the cooperation of multiple robots is not encouraged any more. We have learned several interesting things doing that. On the other hand, as the competition evolves, it does not suffice to copy a solution from the previous year.

V. Summary

We have introduced Robotour – robotika.cz outdoor delivery challenge, its rules and their evolution over the time. We share experience gained while organizing several years of the competition and show several patterns worth following. The competition has been successful in attracting people to robotics and giving them an opportunity to learn. The contestants enjoy a chance to meet others, exchange ideas and compare their approaches in an independent manner. As the competitors note, while seemingly simple, the competition became difficult to participate in. This in turn led to a creation of two new robotic competitions in Czech Republic, which differ in the level of difficulty. Currently, there exists an evolutionary path for a person interested in robotics through these outdoor competitions up to Robotour and possibly even further.

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Robotour 2010 - pravidla

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***Abstrakt* – Pátý ročník soutěže autonomních outdoor robotů se bude konat 18. září 2010 na Slovensku v jednom ze tří předvybraných parků v Bratislavě. Na rozdíl od předešlých ročníků roboti dostanou pouze mapu a souřadnice cíle. Roboti nebudou přesně znát svoji startovní polohu a interakce s operátorem se omezí na zadání cíle. Robot úspěšně řešící tuto úlohu by měl být schopen demonstrovat své schopnosti v jakémkoli parku s odpovídající mapou.**

I. Cíl

Cílem soutěže Robotour je podpořit vývoj robotů schopných dopravit vás třeba ráno do práce nebo vám přivézt stavební materiál, co jste si právě objednali v online obchodě.

Cesta k takovému cíli nebude ani jednoduchá ani krátká, ale věříme, že výsledek bude stát za to.

II. Mapy

V předchozích ročnících bylo hojně využíváno mapování soutěžního prostřední před vlastní soutěží. Tyto mapy sahaly od jednoduchých záznamů ujeté vzdálenosti (odometrie) a směru (kompas) až po netriviální analýzu obrazu z kamery a zapamatování si význačných bodů.

Takový způsob navigace ale předurčoval robotům pohyb pouze tam, kde jeho tvůrce strávil často i několik dnů relativně namáhavým a vyčerpávajícím vytvářením velmi specifických map. Je poměrně zřejmé, že vytvořit tímto způsobem mapu pro robota na cestu například z Písku do Opavy, nebude práce zrovna na jedno odpoledne.

Na druhou stranu ale existují dostupné mapy, na jejichž tvorbě se podílí mnoho lidí a díky tomu mají stále lepší pokrytí. To je možné jen proto, že se všichni shodli na tom, jak má taková mapa vypadat. Pokud má být malá skupina lidí někdy schopná postavit robota schopného pohybu v „našem světě”, je třeba aby tento robot využíval „naše mapy” — to jest mapy, které je schopen vytvořit i někdo jiný než autor robota. A to jsme se rozhodli v tomto ročníku podpořit…

III. Motivace pro rok 2010

Pátý ročník by měl být dalším krokem na cestě k chytřejším a autonomnějším robotům. Na rozdíl od předešlých ročníků roboti dostanou pouze mapu a souřadnice cíle. Roboti nebudou přesně znát svoji startovní polohu a interakce s operátorem se omezí na zadání cíle. Robot úspěšně řešící tuto úlohu by měl být schopen demonstrovat své schopnosti v jakémkoli parku s odpovídající mapou.

Stejně jako v minulých ročnících jsou podporováni robustnější roboti schopní převážet náklad. Pro zvýšení divácké atraktivity bude start robotů hromadný. Dále bude zavedena samostatná kategorie WagonOpen pro podpoření začínajících týmů.

IV. Pravidla

Úkol Úkolem robotů je v zadaném časovém limitu 30min dopravit náklad do cíle vzdáleného až 1km. Roboti musí být plně samostatní, nesjíždět z cesty a správně se rozhodovat na křižovatkách podle zadané mapy. Místo startu i místo cíle bude pro všechny roboty stejné.

Mapa Vektorová mapa chodníků v parku bude vycházet z vektorizace ortofotomapy a týmy si ji mohou dále zpřesňovat. Základní idea je převzata z Open Street Map. Ve výsledku budou moci roboti použít pouze tuto sdílenou mapu — jakékoli jiné mapy jsou zakázány!

Roboti Tým může letos nasadit pouze jednoho robota. Každý robot musí mít EMERGENCY STOP tlačítko, které robota zastaví. Tlačítko musí být snadno přístupné, červené a musí být pevnou součástí robota (aka Big Red Switch), aby se v případě hrozícího nebezpečí dalo snadno stisknout. S robotem musí být možnost snadno manipulovat: libovolné dvě dospělé osoby ho mohou odnést několik desítek metrů. Je zároveň definovaná minimální velikost — na robotovi musí být během celé soutěže umístěn 5l pivní soudek (alespoň prázdný).

Vyjetí z cesty Je dovoleno se pohybovat pouze po parkových cestičkách. Pokud robot sjede z cesty, aktuální pokus pro něj končí. O jeho včasné odklizení se musí postarat soutěžící tým.

Překážky Na trase se mohou nacházet překážky. Kromě překážek přirozených (lavičky atp.) mohou být na trať umísťovány i překážky umělé. Za typickou (umělou) překážku se považuje například figurant, papírová krabice od banánů či jiný robot. Roboti nesmí vejít v kontakt s překážkou. Kontakt s překážkou znamená ukončení pokusu. Robot může před překážkou zastavit a vizuálně či zvukově upozornit, že překážka byla detekována. Fakt, že překážka už není přítomná musí roboti detekovat sami.

Interakce robotů Situace, kdy rychlejší robot dojede robota pomalejšího, nebude nijak zvláštně řešena. Rychlejší robot se může k pomalejšímu zachovat například jako k překážce — tj. objet ho nebo počkat, až odjede sám. Obecně budou respektována pravidla silničního provozu: přednost zprava, vyhýbání se vpravo, předjíždění vlevo.

Start Všichni roboti budou startovat současně na jedné z parkových cest (všichni stejné). Minimální šířka cesty, na které se bude startovat, je 3 metry. Startovní oblast pro jeden tým bude mít velikost cca 1.5x1.5 metru. Startovní oblasti budou umístěny těsně za sebou při jedné straně cesty. V rámci startovní oblasti může tým umístit robota podle vlastního uvážení. Pořadí robotů na startu bude dané výsledky v předešlém kole (lepší robot bude blíže k cíli). V prvním kole bude pozice určena pořadím úspěšné homologace. Roboti startují automaticky pomocí vnitřních časovačů. Minutu před startem už nesmí docházet k žádné interakci s robotem.

Bodování Vyhrává tým, jehož robot bude trasu nejlépe zdolávat. Rozhodující je vzdušná vzdálenost poslední pozice (vyjetí z cesty, kolize či vypršení časového limitu) k cíli. Tým získává 1 bod (tzv. „bod za cestu") za každý metr směrem k cíli = vzdálenost(start,cíl)-vzdálenost(konečná pozice,cíl). Za vezení nákladu získává tým dvojnásobek („body za náklad"). Každý robot může vézt jeden „náklad". Nákladem se rozumí 5l pivní soudek (plný). V daném kole tedy robot může získat nejvýše počet bodů roven dvojnásobku vzdušné vzdálenosti start-cíl. Pokud robot neopustí startovní oblast, získá 0 bodů.

Organizace Soutěž bude mít 4 kola. Pro každé kolo bude vybrán jiný start a cíl. Vybraný cíl bude oznámen 10 minut před startem kola. Rychlost v této soutěži nehraje roli (je omezena na 2.5m/s). Do celkového výsledku se sčítají body za všechna kola. Kolo začíná vždy v určený čas a končí po 30 minutách. Robot musí opustit startovní oblast nejpozději do 10 minut od startu. Pokud se robot mimo startovní oblast nebude 60 sekund pohybovat, bude aktuální pokus ukončen. Každý tým musí zajistit jednu osobu znalou pravidel, která bude během soutěžního dne patřit do týmu rozhodčích.

Homologace Tým se může zúčastnit soutěže, pokud ukáže, že je schopen získat alespoň jeden bod. Nutnou podmínkou je projet desetimetrový úsek bez kontaktu s překážkou. Testována bude startovací procedura (automatický start) a funkčnost EMERGENCY STOP tlačítka. Použití tekutin, žíravin, pyrotechnických materiálů a živých bytostí je zakázáno. Každý robot bude během jízd doprovázen jednou osobou z týmu, starší 18 let, která je za jeho chování zcela zodpovědná.

Technická dokumentace Každý tým dodá ke svému robotu (robotům) základní technickou dokumentaci (pro prezentace, veřejnost a novináře). Vítězné týmy (1. až 3. místo) pak budou požádány o podrobnější dokumentaci pro webovou prezentaci a tedy zjednodušení zapojení nováčků do soutěže v následujícím roce.

Kategorie VagónkyOpen roboti BODY a TAIL z minulých ročníků se mohou zůčastnit nové kategorie „WagonOpen". Její hodnocení bude nezávislé na hlavní soutěži a hlavní motivací je umožnit zapojení nováčků. Tato soutěž bude mít 3 kola a cílem bude se udržet za vedoucím robotem. Každý robot (vagónek) bude mít rampu na umístění majáčků pro napojení více robotů v kolonu. Detaily budou upřesněny v FAQ1. Omezení rozměrů a bodování za inteligenci a za náklad bude převzaté z hlavní soutěže tak, aby hardware robota mohl být využit v dalším ročníku v hlavní kategorii.

V. Odlišnosti oproti minulému ročníku

- Hromadný start všech robotů z jednoho, předem neznámého, místa.
- Je zakázáno mapovat si soutěžní prostor před vlastní soutěží. Místo toho mohou týmy využívat mapu, na jejíž tvorbě se mohou aktivně podílet.
- Kolona robotů HEAD, BODY a TAIL již není nijak podporována.
- Každý robot musí být schopen uvést 5l sud piva (alespoň prázdný).
- Přesná poloha cíle bude známá 10min před startem.
- Automatický start pomocí časovače.
- Místo PAUSE tlačítka bude pouze vyžadováno EMERGENCY STOP tlačítko, které může kdokoliv použít v případě nebezpečné situace — například poruše robota. Jeho stisk znamená ukončení pokusu.
- Za Big Red Switch není možné považovat klávesnici (ano, je pozoruhodné, že i po těch letech to pořád některým týmům není jasné). Prostě dejte na svého robota snadno dostupný červený vypínač. Bez odpovídajícího BRS nebude robot do soutěže připuštěn.
- Není omezení na velikost překážky. Mohou tedy nastat situace, kdy bude celá cesta blokovaná a překážku není možné objet.
- Nebude k dispozici referenční maják.
- Nebude kategorie „volná jízda".
- Troubit na překážku je i nadále možné, ale efekt to bude mít pouze v případě, kdy je překážkou například zvědavá babička. Naopak lavička (přes zvukovou podobnost obou zareagovat cizí robot nebo krabice od banánů.

Robotour 2010 – zoznam tímov

BestBase (Bratislava)
Daniel Žilinec
Róbert Najvirt

Brmlab (Prague)
Michal Tuláček
Václav Hula

CGS Robotics (Italy)
Matteo Unetti
Nicola Giordani
Torquato Cecchini

Eduro (Prague)
Tomáš Roubíček
Jiří Iša
Jan Roubíček

Istrobotics (Bratislava)
Pavol Boško
Peter Boško

Odysseus (Prague)
Jaroslav Halgašík
Lenka Mudrová
Matouš Pokorný
Petra Kaplanová

Propeler (Opava)
Tomáš Kotula
Martin Kotula
Eva Kotulová

Roboauto (Brno)
Jan Najvarek
Tomáš Ondráček
Pavel Brzobohatý
Vojtěch Robotka

Roboauto Quido (Brno)
David Herman
Jirka Zbirovský

Sirael (Praha)
Kamil Řezáč
Jaroslav Sládek

Robozor (České Budějovice)
Martin Kákona
Jakub Kákona
Martin Povišer
Lukáš Čížek
Josef Szylar
Roman Dvořák
Kryštof Celba

Radioklub Písek
Martin Černý
Pavel Hubka
Karel Kozlík
Milan Říha
Antonín Seiner
Blanka Seinerová
Martin Stejskal

Short Circuits (Praha)
Pavel Jiroutek
Dan Polák
Lukáš Polák

Smelý Zajko (Bratislava)
Pavel Petrovič
Miroslav Nadhajský

Tatran Team (Trenčín)
Michal Kukučka
Juraj Ečery
Marek Šutliak

URPI Team (Bratislava)
Marian Kľúčik
Michal Bachraty

Organizačný tím
Martin Dlouhý
Zbyněk Winkler
David Obdržálek
Ondřej Luks
František Duchoň
Richard Balogh

Robotour 2010 – výsledky

Pořadí	Tým	1.kolo	2.kolo	3.kolo	4.kolo	Plný sud	Celkem
1.	**Eduro Team**	100	0	73	49	ano	444
2.	**Roboauto Quido**	84	0	53	16	ne	153
3.-4. (*)	**Tatran Team Trenčín**	28	0	17	23	ano	136
3.-4. (*)	**Radioklub Písek**	0	0	1	65	ano	132
5.	**Roboauto**	11	11	1	34	ano	114
6.	**Short Circuits Praha**	17	2	43	9	ne	71
7.	**Robozor**	1	0	0	34	ano	70
8.	**CGS Robotics**	0	2	27	0	ano	58
9.	**Propeler**	20	2	5	19	ne	46
10.	**BestBase**	5	2	3	2	ano	24
11.	**Brmlab**	9	0	0	9	ne	18
12.	**Odysseus**	0	2	4	11	ne	17
13.	**Sirael**	0	0	2	0	ne	2
14.-15.	**Istrobotics**	0	0	0	0	ne	0
14.-15.	**Smelý Zajko**	0	0	0	0	ano	0

(*) Tatran Team Trenčín i Radioklub Písek vezl plný sud, takže celkový rozdíl byl 2 metry a tedy pod přesností měření. Z tohoto důvodu jsme se rozhodli tato dvě místa spojit.

Brmlab Praha

Michal Tuláček, Václav Hula
http://brmlab.cz

brmlab
hackerspace prague

Brmbot Outdoor

Tescoma spherical mirror

Chassis

Video

brmlab
hackerspace prague

- http://brmlab.cz/
- The place for your ideas and projects
- Lots of hackerspaces in Europe
  - Germany, Iceland, Hungary, ...
    http://hackerspaces.org
  - Bratislava – Progressbar
    http://www.progressbar.sk/
  - Brno – Underground hackerspace
  - OK1KPI Písek ☺
- Join us!

Robozor České Budějovice

Martin Kákona, Jakub Kákona, Martin Povišer, Lukáš Čížek, Josef Szylar, Roman Dvořák, Kryštof Celba
http://www.robozor.cz

ROBOZOR.cz ROBOTICS CLUB

robot Vector

JADERNÁ ELEKTRÁRNA TEMELÍN
HLAVNÍ PARTNER

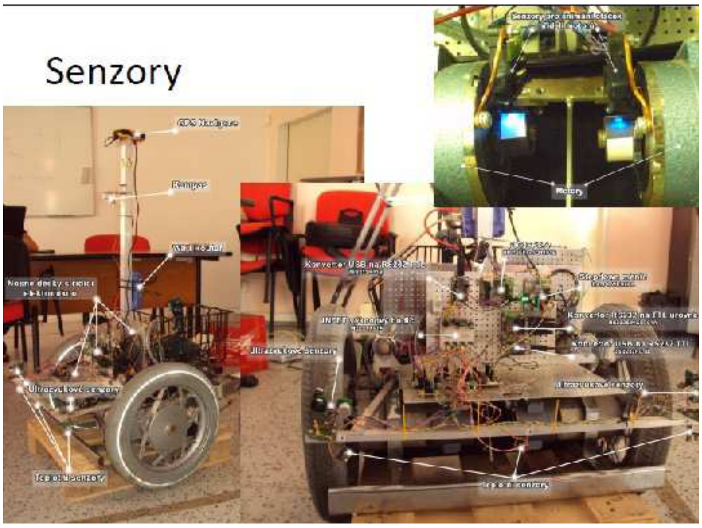
MLAB

EKOLO Jaromír Vejr

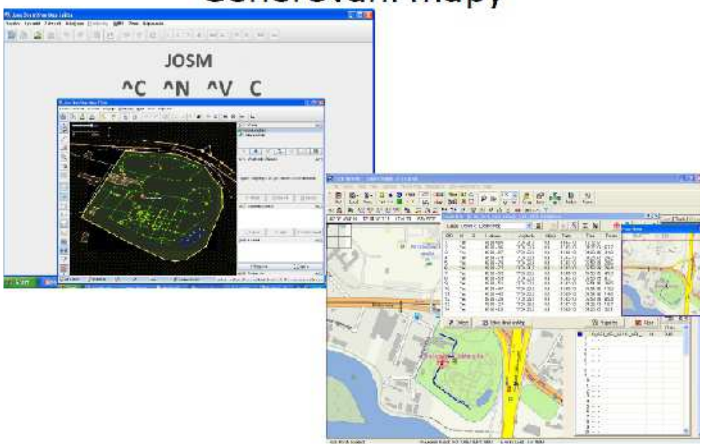
UST

Anténa

Senzory

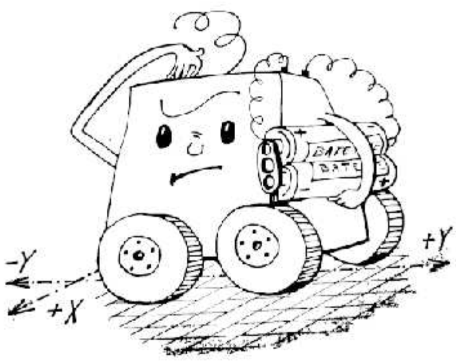


Generování mapy



Antény - pokusy

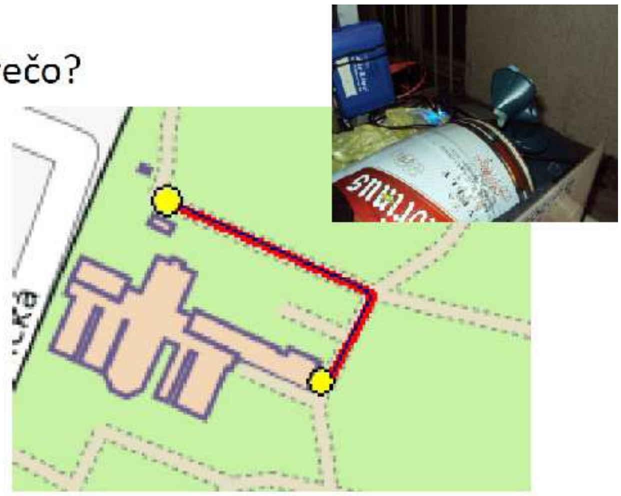
Řízení



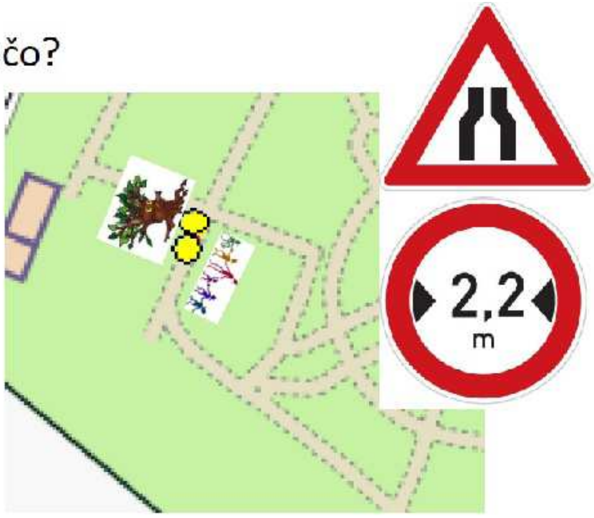
Telemetrie

Prečo?

Prečo?

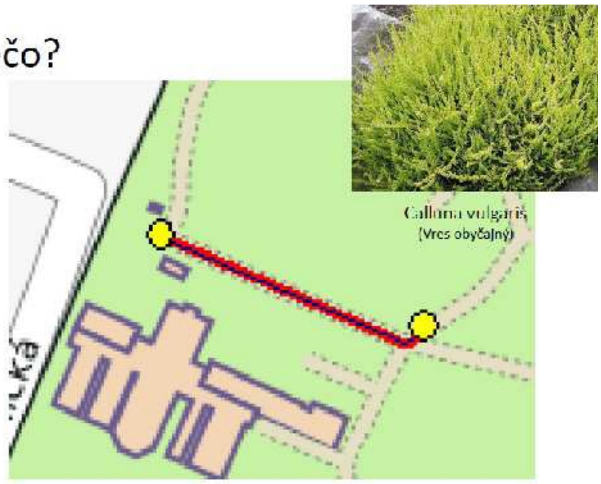


Prečo?



Prečo?

Prečo?



Tatran Team Trenčín

Michal Kukučka, Juraj Ečery, Marek Šutliak
http://www.tatran-team.szm.com/

ŠPECIFIKÁCIA ROBOTA – VŠEOBECNÉ INFO

- Platforma postavená na pásovom podvozku.
- Implementované ručné diaľkové ovládanie.
- Vlastná koncepcia (mechanika, riadiaca elektronika, softvér).

  + spoľahlivosť

  + odolnosť

  + jazdné vlastnosti v teréne

  - použité cenovo dostupnejšie umelohmotné pásy (rýchle opotrebovanie).

LOKALIZÁCIA

- GPS prijímač pripojený cez bluetooth (na strane PC cez virtuálny COM port)
- Spracovanie obrazu – detekcia prevažne zeleno zafarbených objektov (tráva, rastliny, listy) – vyhýbanie sa oblasti mimo cesty.
- Použitie Dijkstrovho algoritmu pre určenie najkratšej cesty vo vektorovom grafe yaloženom na importe OSM exportu mapy, východzej polohy a cieľového bodu.

ROBOT - POHONY

- 2 x jednosmerný 24V motor s prevodovkou
- Riadiaca elektronika – regulácia pomocou PWM, elektronika spracovania stavov snímačov.
- Komunikácia riadacej elektroniky pomocou RS232 (použitý vlastný protokol, AT89s8252, program napisaný v assembleri)

  * vstup: rýchlosti a smery otáčania motorov

  * výstup: aktuálny stav snímačov

SOFTVÉR

- Platforma .NET, jazyk C#
- Použitá knižnica pre video processing obrazu snímaného web kamerou– AForge .NET
- Použitie Dijkstrovho algoritmu pre určenie cesty z grafu zostaveného z dát OSM exportu, štart. polohy a cieľa.
- Vyhodnocovanie stavov snimačov z prednej časti robota (detekcia prekážok)
- Komunikácia:

  * COM rozhranie (cez USB konvertor): riadiaca elektronika,

  * Bluetooth (virtuálny COM): GPS

  * USB: web kamera

ROBOT – DETEKCIA

- 5 x optický difúzny snímač Balluff (detekcia prekážok pred robotom)
- 2 x IR snímač (snímanie bočných prekážok pri otáčaní) – neimplementované
- USB WEB kamera (800 x 600 pixels) – detekcia cesty.
- GPS Navilock BT-413 – detekcia aktuálnej polohy

THE END ☺

Robotour Solution as a Learned Behavior Based on Artificial Neural Networks

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Abstract—**Our contribution describes a mobile robot platform that has been built for the purpose of the contest Robotour – robotika.cz outdoor delivery challenge. The robot is a standard differential-drive robot with a good quality consumer market digital video camera with a lightweight, but high-performance laptop computer used as the main control board. Supplementary board is used to control motors and sensors of the robot. The robot utilizes a behavior-based architecture and its vision module that is responsible for track-following is utilizing an artificial neural network that was trained on a set of images. This is a novel solution that has not been used in Robotour contest previously, and our early experiments demonstrate promising results.**

Keywords – robotour, navigation, artificial neural networks, learning robots

I. Introduction

Applications of robotics technology in both production and personal use are becoming possible with the development of new materials, motors, sensors and vision, ever decreasing cost of computing and memory capacity, and development of new algorithms and control strategies. Robots must be able to operate in dynamic and unpredictable environments. Therefore, one of the most important challenges to be solved reliably is robot navigation – in both indoor and outdoor environments. The robots must be able to localize themselves on a supplied map, create their own map representations of the explored environment, and they must be able to navigate their environments safely, without colliding with obstacles, or failing to follow the paths, roads, trails, and tracks. The real improvements in the technology typically occur when there is a large motivational pressure to produce a working solution. This might either be a goal to produce a final product, or alternately, with somewhat more relaxed requirements and settings, which are suitable for experimentation, and research, when the goal is to develop a robot to participate in a robotics contest.

Robotour – robotika.cz outdoor delivery challenge, organized by the Czech association robotika.cz, is an annual meeting of teams building and/or programming outdoor robots that navigate in a city park filled with trails, trees, grass, benches, statues, water ponds, bridges, and people. The task changes every year, but the main challenges are 1) be able to localize and navigate on a map supplied by the organizers, and 2) be able to follow the trails and paths without colliding with the obstacles or leaving the path without reaching the goal. See [1] for the exact rules of this year's contest.

Various solutions for the challenge were developed, however, in most cases, they did not take advantage of advanced artificial intelligence algorithms. In particular, only few different vision algorithms were developed until today, several teams shared the successful solution of [2], and many solutions rely on the use of odometry, compass, and GPS. We would like to address this area, and prepare a solution for the contest in 2010 or 2011 that will utilize AI algorithms. The second author has participated in the competition team several times in the past, and collected some experience and motivation for a new attempt. In this article, we describe the principles our solution is based on and is currently being built. In the following sections, we describe the mechanics and the hardware, robot overall architecture, the software components, and the AI methods that we aim to use. Finally we summarize the experience with building and programming the robot up to date.

II. Mechanics

The robot is a simple robot with differential-drive kinematics with one supporting free-rolling caster wheel. The length of the sides of its square base is 45 cm; the air-inflated wheels of a diameter 15.3 cm are mounted on the outside of the base, in the front of the robot. The total weight is about 6 kg without any load. The robot provides a storage space of ca. 20 x 20 x 45 cm to carry a heavy load (approx. 5 kg), which can be placed close to the center of rotation, above the propelled wheels, so that it does not have a negative impact on maneuverability of the robot. The main control unit is a portable computer, mounted in a flat plastic frame with a foam to compensate the shocks. The lead acid 12V 9Ah rechargeable battery, being the heaviest component, is stored under the base, between the wheels, keeping the centre of gravity low. Color camera with a true optical image stabilizer and CCD image sensor is mounted using anti-shock foam on a U-shape construction frame built of aluminum profiles, together with GPS and IMU sensor, see Fig.1. The camera is inclined 10° downwards. The IMU sensor must be mounted far from any sources of electric and magnetic fields, such as motors and wires. Placing GPS high compensates also for obstacles in the surrounding terrain, which may hinder the GPS satellites signal. The robot is built from raw materials, except of the motors, wheels and consoles that hold them, which are all part of a set from Parallax. The aluminium framework allows mounting a rain shield for the computer and the camera when necessary.

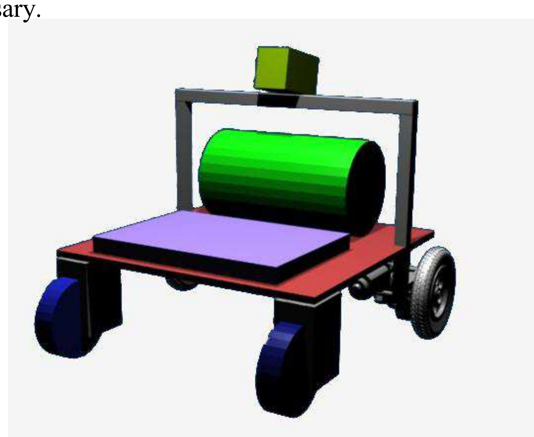

Figure 1. 3D Model of the robot showing main parts. In real implementation, we have mounted only one caster wheel as it proved to be sufficient, and allowed more accurate control.

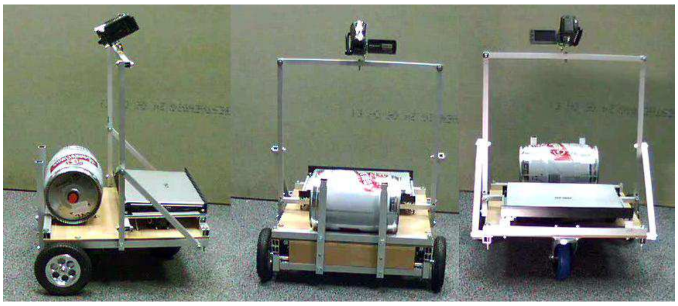

Figure 2. The resulting constructed robot from the side, front, and back. The control electronics is installed under the PC. The robot has already been tested in outdoor settings and has traveled a distance of several km.

III. Hardware Architecture

The robot is propelled by two 12V DC motors with built-in transmission, rotating at up to 150 rpm and consuming 1.5A at no load. The encoders with 36 ticks per rotation are used for speed and position feedback and are equipped with on-board microcontrollers that are directly connected to the motor drivers HB25, supplying them with the proper PWM signal to keep the requested speed. In this way, the main microcontroller board, which is the SBot control board, designed in our group originally for SBot mobile robot, is freed from the low-level motor control, and dedicates this task to both of the encoders that have an implementation of a standard P (proportional) controller and are connected using the same 1-wire serial bus. Unfortunately, we found that the original firmware for the encoders supplied by Parallax did not satisfy our needs for several reasons. Most importantly, the encoders were not designed for dynamic change of speed, but only for simple positional commands that accelerate from zero speed to a fixed predefined speed, and then decelerate after traveling the required distance. They do not allow to change the speed in the middle of such positional command. However, movements, where the speed and rotation is changed arbitrarily at any time, are required in the Robotour task, where the robot has to dynamically respond to the visual feedback when it has to align its movement with the shape of the path. Fortunately, Parallax makes the source-code for the encoders firmware available, and thus we could modify it to suit our application and support immediate smooth changes of the instant speed.

The obstacles are detected using the standard SRF-08 and Maxbotix LV EZ1 ultrasonic distance sensors that are connected to the main control board.

Outdoor robots are typically equipped with a global positioning device, i.e. GPS, and it is the case for our robot too. Information from the GPS module that is connected directly to the main computer using USB port, however, is not so reliable due to atmospheric and other occlusions, and serves only as a guidance for map localization. It is confronted with visual input and complemented by the current heading obtained from compass sensor. The compass sensor is part of the complex 9 DOF IMU sensor that includes several axes of gyroscopes, accelerometers, and magnetometers, thus compensating for various robot inclinations when traveling uphill or downhill. This is important since the simple compass sensors provide incorrect information once the robot and thus also the sensor is tilted.

Finally, for the visual input, we chose to use a standard video camera Panasonic SDR-T50, due to a very good ratio of parameters/price. The video camera is built around a CCD sensor, which has the advantage over the CMOS image sensors of taking the image instantly. Cheap CMOS cameras therefore suffer from a serious vertical distortion when the camera is moving, since the different rows of the image are scanned at different times. In addition, the camera has a built-in true optical image stabilizer, which further compensates for distortions due to the movement. Unfortunately, we found this stabilizer to be insufficient, and thus we have supported it with an anti-shock foam placed between the camera and the platform where it is tightened using flexible textile tape. The camera renders its image either as 16:9 or 4:3 image, however, it sends a wider signal down to its video output jack connector, which is further connected to a USB frame grabber card and the main computer. The main computer is a 2-core powerful PC with a GPU that can be used for the intensive image processing computation. The computer and the Sbot control board are connected using a serial port or a virtual serial port over radio BlueTooth connection. In debugging and testing applications, the robot can be controlled using a wireless gamepad connected using a proprietary 2.4GHz radio link.

In general, the robot is designed in such a way that it can be used in many different applications. For instance, a stereo vision system or an arm with a gripper can be installed in the cargo hold area. Additional sensors can be easily mounted on the aluminum profiles or wooden base. Fig. 3 shows overall system architecture.

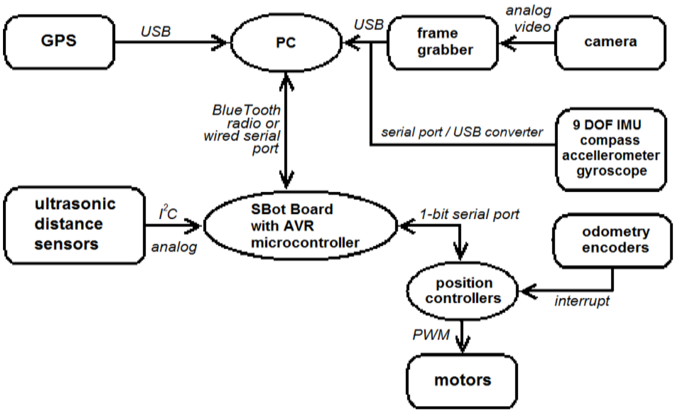

Figure 3. System hardware architecture.

IV. SOFTWARE CONTROLLER ARCHITECTURE

The software architecture is tailored for the Robotour contest. In this year's contest, the goal for the robot is to navigate to the target without knowing its starting location. It is only given the target coordinates and an official map of the park. It may not use other map information. The software controller is logically divided into five main components, see Fig.4.

The first component, planning, uses the map with the destination location and generates a path plan for the robot to follow. It tries to minimize the number and complexity of the crossings as these are the most critical places and candidates for navigational errors. The component outputs a sequence of locations that are to be visited by the robot. Whenever requested, the module can generate a new plan after a problematic place in the map has been reached.

The second component, localization using map, is responsible for the most accurate localization of the robot on the map. It is using the information from the compensated compass (IMU) for heading, from GPS for position estimation, and from the position encoders to estimate the distance traveled and turns made. All the information is integrated and with the help of the map and the path plan, the target distribution is determined using a probabilistic Monte-Carlo estimation. The output of the localization module is a probabilistic distribution over the expected heading in the very next correct movement, and the expected distance to the next crossing or target.

The third module, path recognition, is the most important one for the actual control of the motors, and has a priority over the localization module. It receives the image from the front camera and recognizes which parts of the image correspond to the path, and which of them correspond to other surfaces. The next section explains this procedure in more details. The output of this module is again a probabilistic distribution over the space of possible headings that can be projected to the input frame, where the headings leading to more “path” areas are more likely than those leading to less “path” area. Input from the odometry and gyroscopes helps this module to improve its estimation of the path using its previous estimations and the relative displacement of the robot.

The obstacle recognition module is responsible for detecting obstacles in the planned path of the robot and for stopping the robot in case of a possible collision early enough so that avoidance could be attempted by the coordination module. The robot is currently equipped with three ultrasonic distance sensors (front ahead, front left, front right), and thus the module reports on its output whether the path is blocked completely, or only partially, and also what is the size of the expected free buffer in front of the robot.

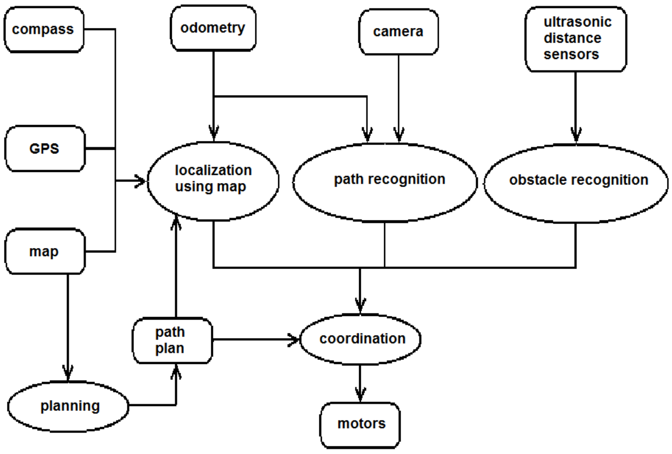

Figure 4. Overall controller architecture.

The most complex module is the coordination module. Its purpose is to take the prioritized outputs from the other three modules, and to determine the best possible angular and linear velocity for the next instant movement. When the confidence of the module is getting low, the robot slows down. If the confidence falls even lower, the robot stops, and starts rotating left or right, depending, which direction is expected to be more promising, until it finds a heading, where the module confidence is sufficiently high again. If such heading is not found, the robot attempts to return back in the reverse direction as it arrived to the problematic location, possibly moving in the reverse of the planned direction on the map. After returning back a short distance, it retries. The retries are repeated several times while gradually extending the back-up distance. If all attempts to pass the problematic location fail, the planning module is asked to generate a different path.

The controller is arranged in a behavior-based manner, individual behaviors are developed and tested independently before they are integrated in a common controller.

V. PATH RECOGNITION

Our goal was to use artificial neural networks in order to help the robot navigate and stay on the path. We obtained many images from a park with trails, and we have manually marked the regions in these images that correspond to the traversable path. This input was used to train the neural network (a standard multi-layer perceptron) to recognize the path. See figure 5 for an example of such manually classified image.

Figure 5. Manual preparation of training images.

Sending the whole image to the network as the input would obviously be infeasible. Instead, we first tried to scale the image to a lower resolution of 400x300 pixels, and divide it into 100 rectangular regions of equal sizes that covered the whole image. Each region formed an input to a neural network, and the whole region was about to be classified as "path" or "not path". However, the resulting resolution of the classified image was not satisfactory, even after a further reduction of the region size so that the image was divided into 2500 segments. Therefore, we decided to use a sliding region. For almost every pixel in the image, we define a corresponding region – it's larger neighborhood, which forms the input vector. The classification output produced by the network for each pixel in the image is then a real number from 0 to 1, estimating how much the network believes the pixel lies on the path. Two examples of images that were not used in the training phase are shown in the Fig.6.

Figure 6. Examples of path recognition.

We used the RPROP training algorithm for multilayer perceptron, in particular the implementation that is present in the OpenCV package. The training used tens to hundreds of manually classified images from various places in a park with various path surfaces, light and shadow conditions. Since this is still an ongoing work and only preliminary results are available, we restrain from a statistical analysis of the results at this moment, and refer the reader to the page dedicated to the project with detailed results and data [5].

Once the network is trained and produces the classifications for the image frame pixels, the path recognition module enters a second phase, when it tries to evaluate all possible travel directions (headings) with respect to the chances that the robot will stay on the path. For this purpose, the module analyzes a family of triangles of the same area with the base at the bottom of the frame and the third vertex placed in the middle of the image. For each such triangle, we compute an average path likelihood. The triangle for which the path is most likely, i.e. where most pixels lay on the path, is likely to be the correct new heading. However, the module outputs a full distribution over all possible headings so that the coordination module can take advantage of this information, for instance to determine different directions at a heading, or when trying to resolve ambiguous cases. Fig.7 depicts the analyzed family of triangles. Two example pictures are further analyzed in Fig. 8, where the bars show how "likely" it is that following in the various directions is a "good" idea in order for the robot not to leave the path.

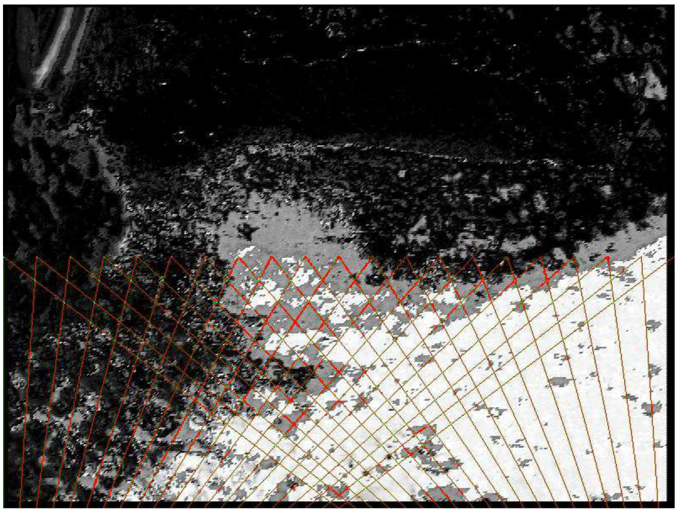

Figure 7. Triangles representing different turning projected to the image of recognized path.

VI. Conclusions and Future Work

We have designed and implemented a robotic hardware and software platform to be used in the Robotour contest for outdoor robots navigating in park environment. The hardware platform is implemented in a general way and most components of the software platform can be reused in other applications, the robot can be extended with stereo vision or manipulator. We have designed, implemented and tested in this context a new method for path recognition, which is based on artificial neural network that is trained on a set of static images that are similar to the environment where the robot is to be operating. We are currently working on integrating all the components of our prototype so that it could perform in its first

Robotour contest this year. In the remaining 10 months of the project, we will analyze the results from our participation, and propose, implement, and verify improvements so that the robot can serve both as a competitive platform in the contest and as an educational tool in the course Algorithms for AI Robotics, which is provided at our department to students of Applied Informatics.

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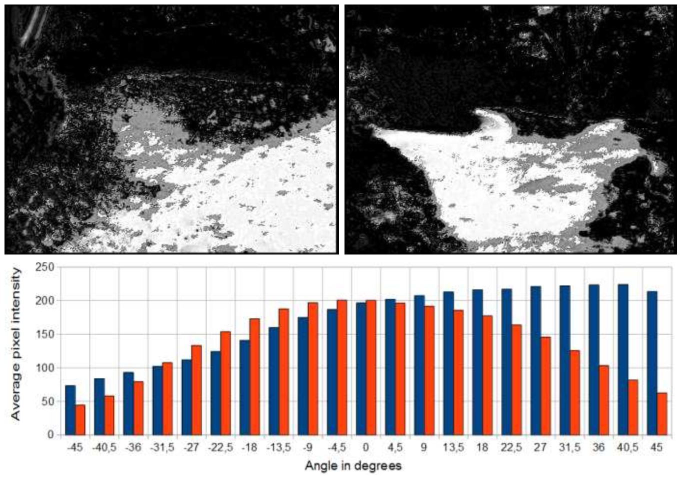

Figure 8. Two scenes after path recognition. The bars show the average pixel intensity of pixels inside of triangles for a range of different rotations for both of the resulting images (blue/dark for the left image, red/bright for the right image).