פרויקט קמין 63376

Visual navigation for airborne ground robot's control

Scientific report:
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Ariel Tech Transfer

ARIEL UNIVERSITY

Abstract

In the presentation described algorithms for airborne ground robot's control and navigation developed in Ariel University during Kamin project.

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Abstract of the project:

The subject of the project is vision-based navigation: airborne control (tethered platform) of ground robots. The system may be used for the coordination of the ground robots.

The result of project will be airborne system of control and navigation simultaneously for a lot of ground robots that may be used for a wide class of robots: automated lawnmowers, robots for cleaning the rooms, tractors, snow-removal, garbage disposal and flushing vehicles, vehicles for people and goods transportation, agricultural and municipal vehicles, transport and so on. This system may be used for extra-terrestrial robots on other planets. The system can be used in “smart home” or “smart city”.

Keywords: autopilot, delay, drone, vision-based navigation, stable flight, visual airborne navigation, ground robot

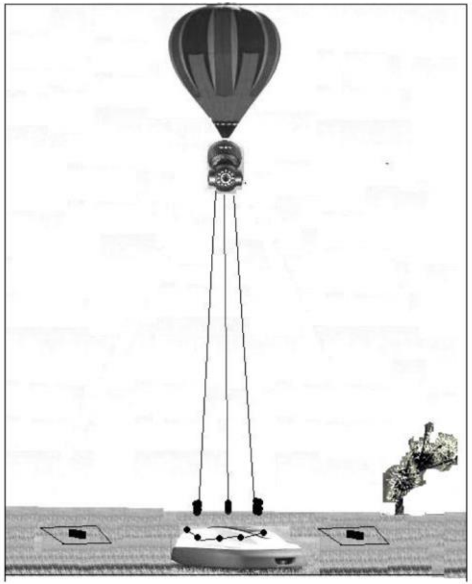


FIG. 1

Ground robots navigation and control- מטרת הפרויקט

שימוש

Future for machines is unmanned technology.

Our mission is providing computer BRAIN (navigation and control) for unmanned ground robots

Robot lawnmowers still a work in progress

Concept for Navigation-telecommunication systems

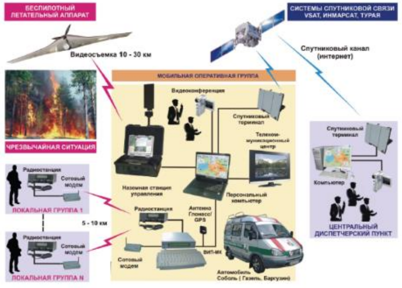


Рис. 2. Состав и схема взаимодействия НТК НП

Future For Rescue Service,Police, Army, Cosmos- unmanned technology

Unmanned aerial vehicles (UAVs)

terrestrial robots (landrovers,lawnmowers)

Satellite

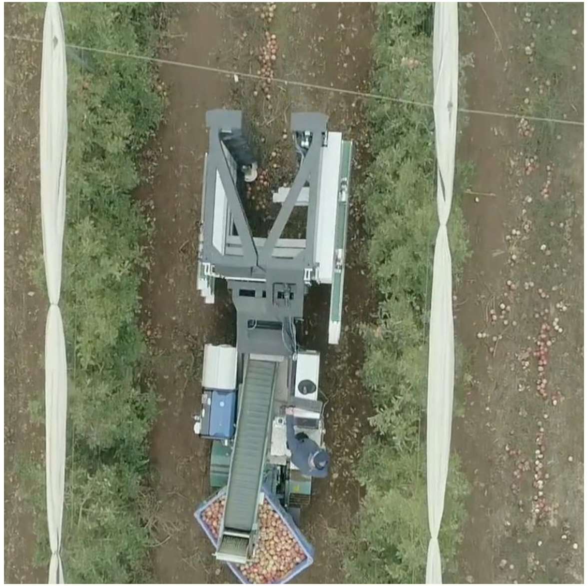
Planetokhods

Robot lawnmowers still a work in progress

The most popular outdoor agriculture robots currently:

A Remote Controlled Slope Mower

Robotic Fruit Harvester – the FFRobot

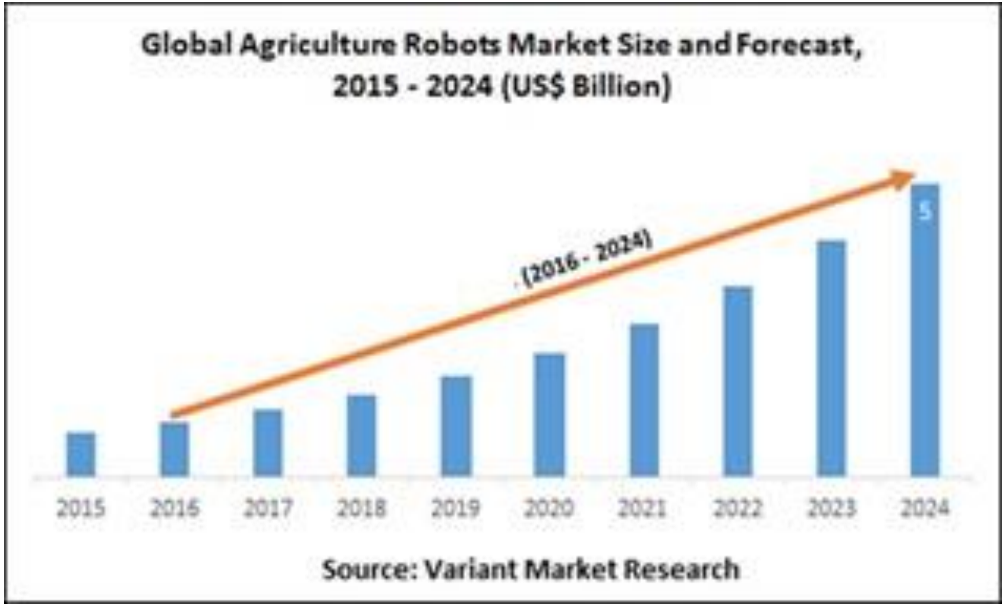


Target Markets for the project (exponential grow)

Market

The agricultural robot’s market is expected to grow from USD 2.75 Billion in 2016
to USD 12.80 Billion by 2024

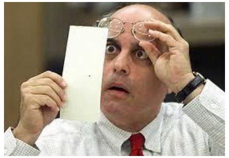
https://www.marketsandmarkets.com/Market-Reports/agricultural-robot-market-173601759.html


Global Agriculture Robots Market Size and Forecast, 2015 - 2024 (US$ Billion)

Source: Variant Market Research

Problems

Ground robot navigation problem



THE ROBOT REPORT

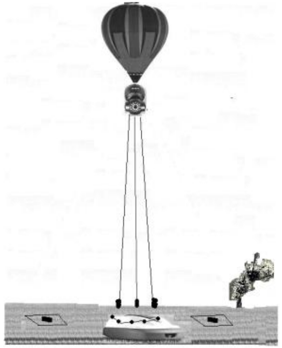
TRACKING THE BUSINESS OF ROBOTICS

Robot lawnmowers still a work in progress

- **Robots-lawnmowers need for border wires**
- **They have random navigation methodologies**
- **It is inconvenient, static, expensive technology.**

Solution:

Technology-
Airborne ground
robots control
(Patent)



Solution is Vision-based navigation of robots

Vision-based navigation of robots is similar to human navigation by the help of eyes vision

Airborne terrestrial robots control (Patents)

The solution of the problem is navigation by robot vision.
However, robot “eyes” are not on the robot, but eyes are autonomous:
they can observe the robot from above

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ
НА ПОЛЕЗНУЮ МОДЕЛЬ
№ 131276

УСТРОЙСТВО ДЛЯ КООРДИНАЦИИ
АВТОМАТИЗИРОВАННЫХ УСТРОЙСТВ

Патентообладатель(ли): *Общество с ограниченной ответственностью "ТРАНЗИСТ ВИДЕО" (RU)*

Автор(ы): *Купервассер Олег Юрьевич (RU), Купервассер Юрий Ильич (RU), Рубинштейн Александр Александрович (RU)*

Заявка № **2012147924**
Приоритет полезной модели **12 ноября 2012 г.**
Зарегистрировано в Государственном реестре полезных моделей Российской Федерации *20 августа 2013 г.*
Срок действия патента истекает **12 ноября 2022 г.**

Руководитель Федеральной службы
по интеллектуальной собственности

Б.П. Симонов

Bundesrepublik Deutschland

Urkunde

über die Eintragung des
Gebrauchsmusters Nr. 21 2013 000 225

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Vorrichtung für Koordinierung automatisierter Vorrichtungen

IPC:
G05D 1/02

Inhaber/Inhaberin:
Kupervasser, Oleg Jurjevich, Moskau, RU

Tag der Anmeldung:
07.11.2013

Tag der Eintragung:
10.07.2015

Priorität:
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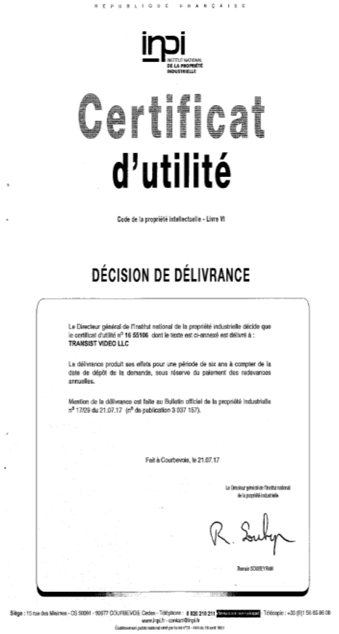
Die Präsidentin des Deutschen Patent- und Markenamts

Cornelia Rudloff-Schäffer

Cornelia Rudloff-Schäffer

München, 10.07.2015

Die Voraussetzungen der Schutzfähigkeit werden bei der Eintragung eines Gebrauchsmusters nicht geprüft. Den aktuellen Rechtsstand und Schutzumfang entnehmen Sie bitte dem DPMAregister unter www.dpma.de.



RÉPUBLIQUE FRANÇAISE

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DE LA PROPRIÉTÉ
INDUSTRIELLE

Certificat
d’utilité

Code de la propriété intellectuelle - Livre VI

DÉCISION DE DÉLIVRANCE

Le Directeur général de l'Institut national de la propriété industrielle décide que le certificat d'utilité n° **16 55106** dont le texte est ci-annexé est délivré à :
TRANSIST VIDEO LLC

La délivrance produit ses effets pour une période de six ans à compter de la date de dépôt de la demande, sous réserve du paiement des redevances annuelles.

Mention de la délivrance est faite au Bulletin officiel de la propriété industrielle n° 17/29 du 21.07.17 (n° de publication 3 037 157).

Fait à Courbevoie, le 21.07.17

Le Directeur général de l'Institut national
de la propriété industrielle

R. Soubeyran

Romain SOUBEYRAN

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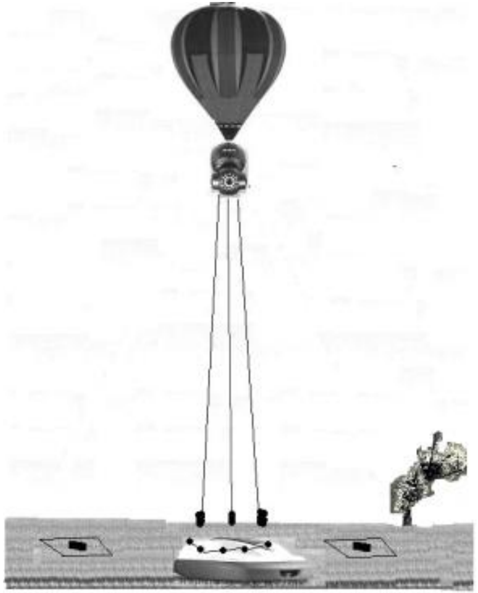
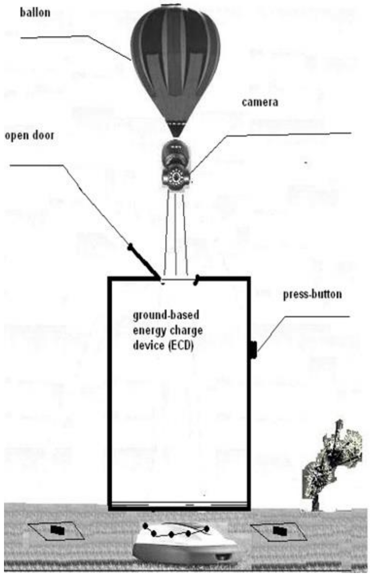
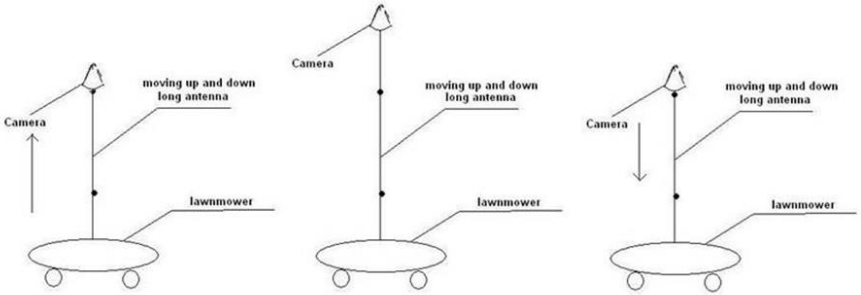
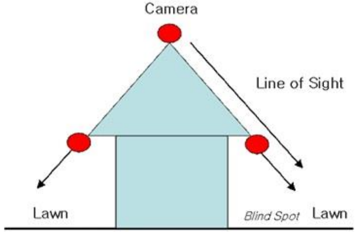
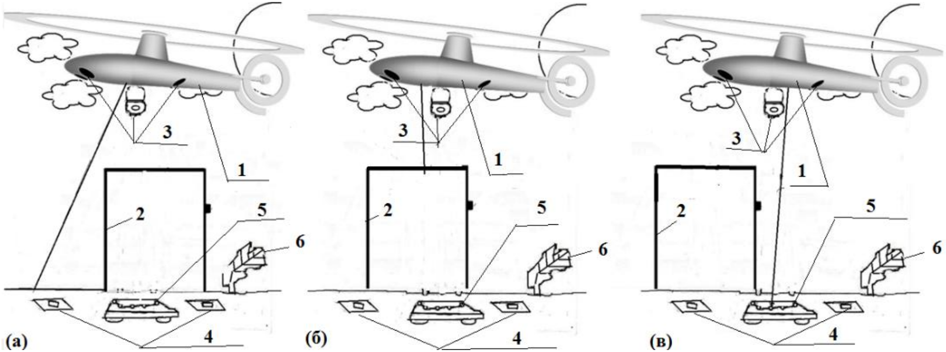


Technology: **Lawnmower videonavigation methods**









Technology: Gyroplane (autogyro)

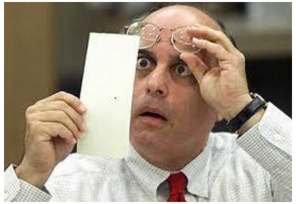
- Full low semi-space FOV by four camera, information translation by optic fiber or Wi-Fi.

Tethered gyroplane – quadracopter

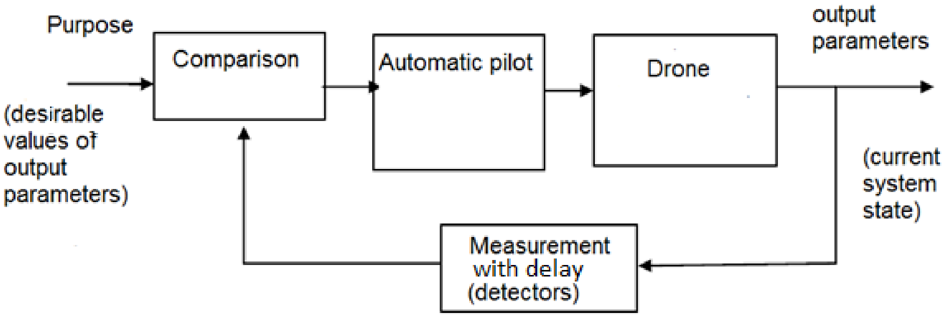
High-altitude wind power station.

Autonomous energy from rotation by high-altitude wind

High-altitude wind exists anywhere! Energy up to 10 KWatt/m^2.



Delay of vision-based navigation problem_2



Purpose

(desirable values of output parameters)

Comparison

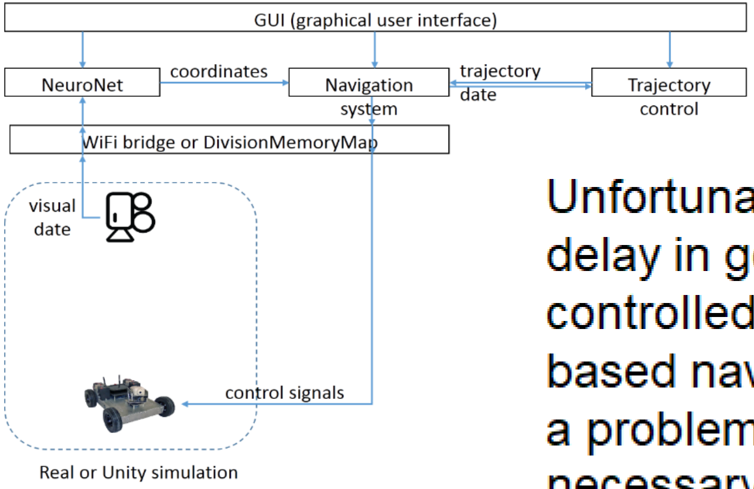
Automatic pilot

Drone

output parameters

(current system state)

Measurement with delay (detectors)



GUI (graphical user interface)

NeuroNet

coordinates

Navigation system

trajectory date

Trajectory control

WiFi bridge or DivisionMemoryMap

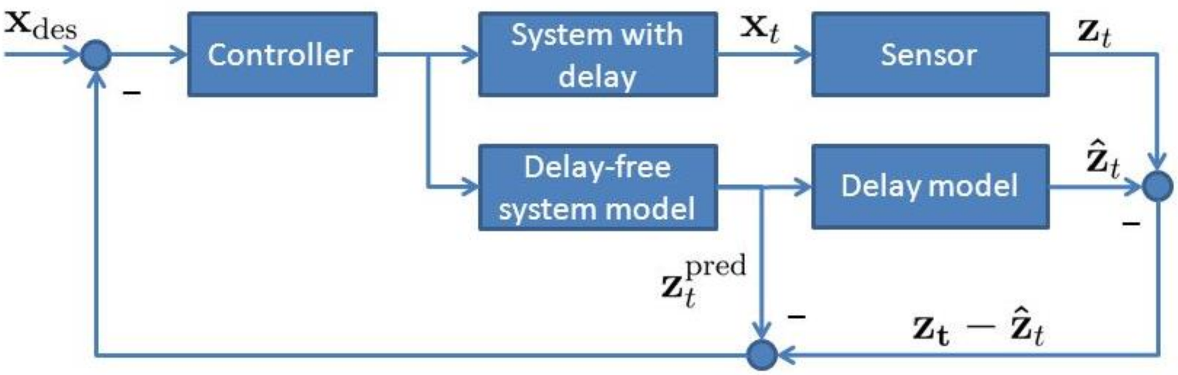
visual date

control signals

Real or Unity simulation

Unfortunately, there always exists noticeable delay in getting information about the output controlled parameters to autopilot for vision-based navigation measurements. So we have a problem, because of the lack of some necessary information for controlling.

Engineering solution:
Automatic control with delay by prediction



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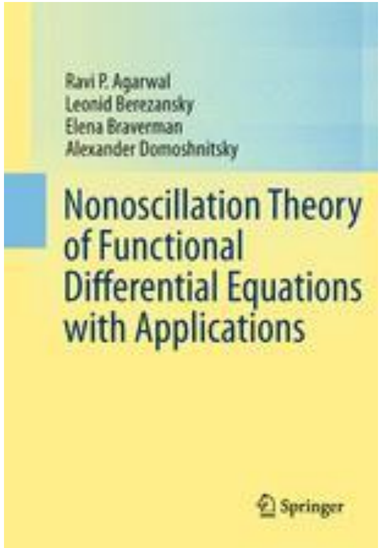
Scientific solution is based on

- A. Domoshnitsky, E. Fridman, “A positivity-based approach to delay-dependent stability of systems with large time-varying delays”
- R.P. Agarwal, L. Berezansky, E.Braverman, A. Domoshnitsky, “Nonoscillation Theory of Functional Differential Equations with Applications”
- V. A. Bodner, M.S. Kozlov “Aircraft Stabilization and Autopilots”


Ravi P. Agarwal
Leonid Berezansky
Elena Braverman
Alexander Domoshnitsky

Nonoscillation Theory of Functional Differential Equations with Applications

Springer

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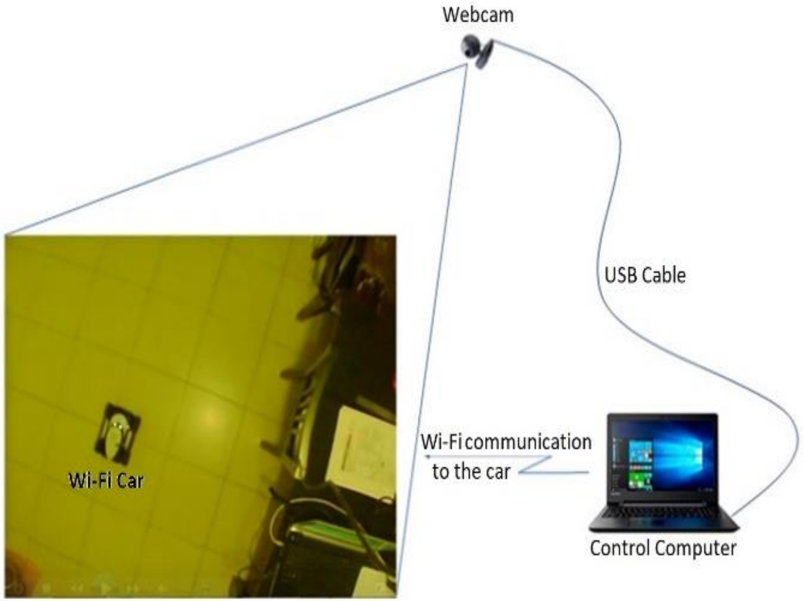
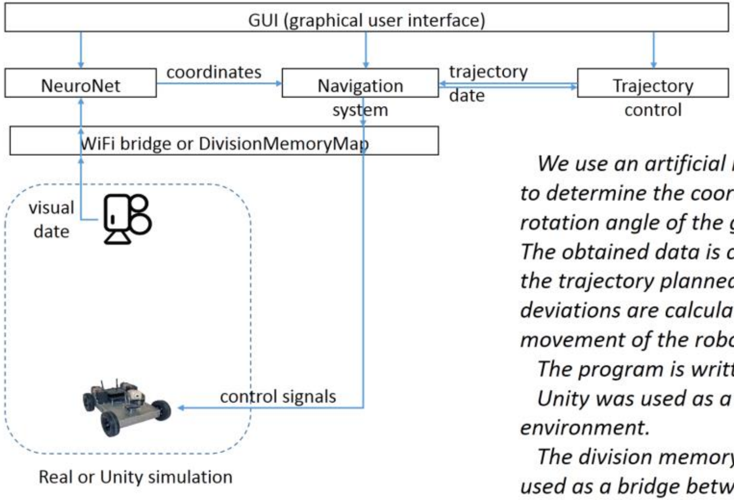
Proof of concept results (toy version and big real robot) are achieved (path and random walk)





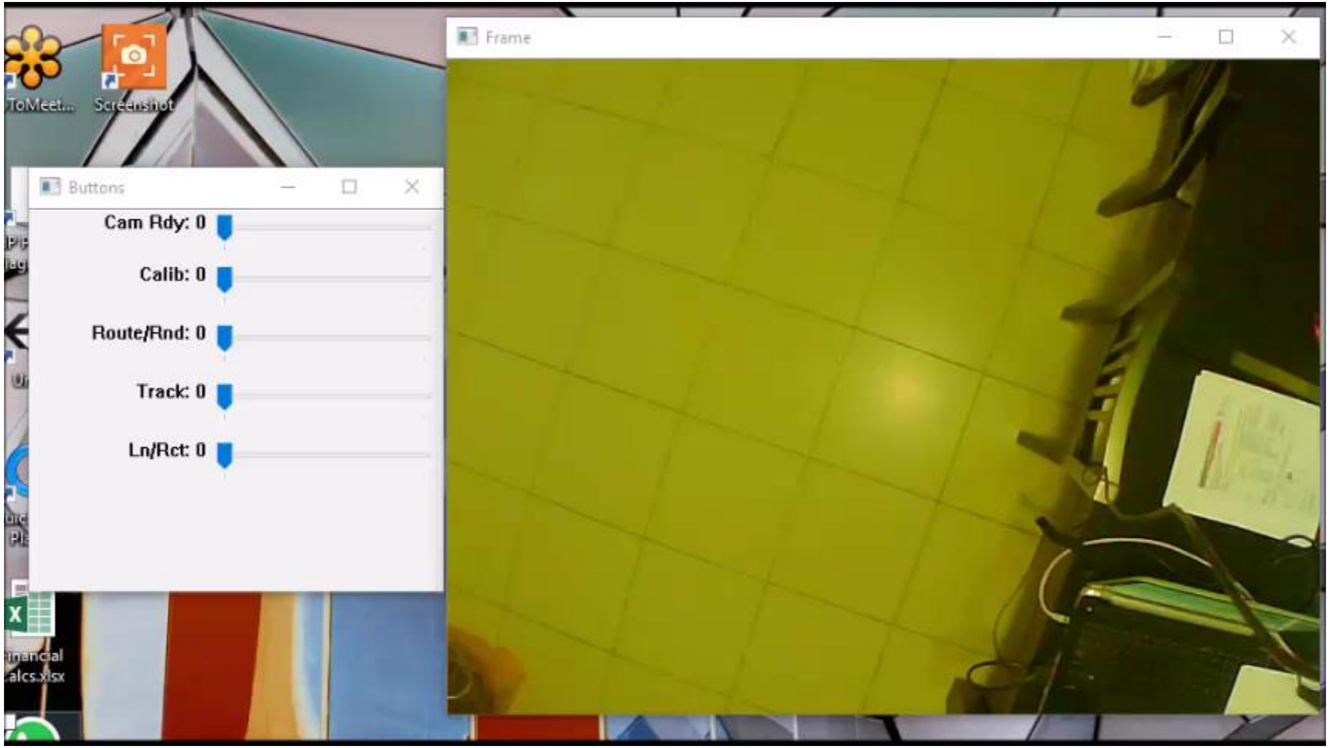
We use an artificial neural network to determine the coordinates and rotation angle of the ground robot. The obtained data is compared with the trajectory planned by the user, deviations are calculated and further movement of the robot is planned.

The program is written in MATLAB.

Unity was used as a simulation environment.

The division memory map in C ++ is used as a bridge between the two programs

Proof of concept results are achieved (path), toy model



Cam Rdy: 0

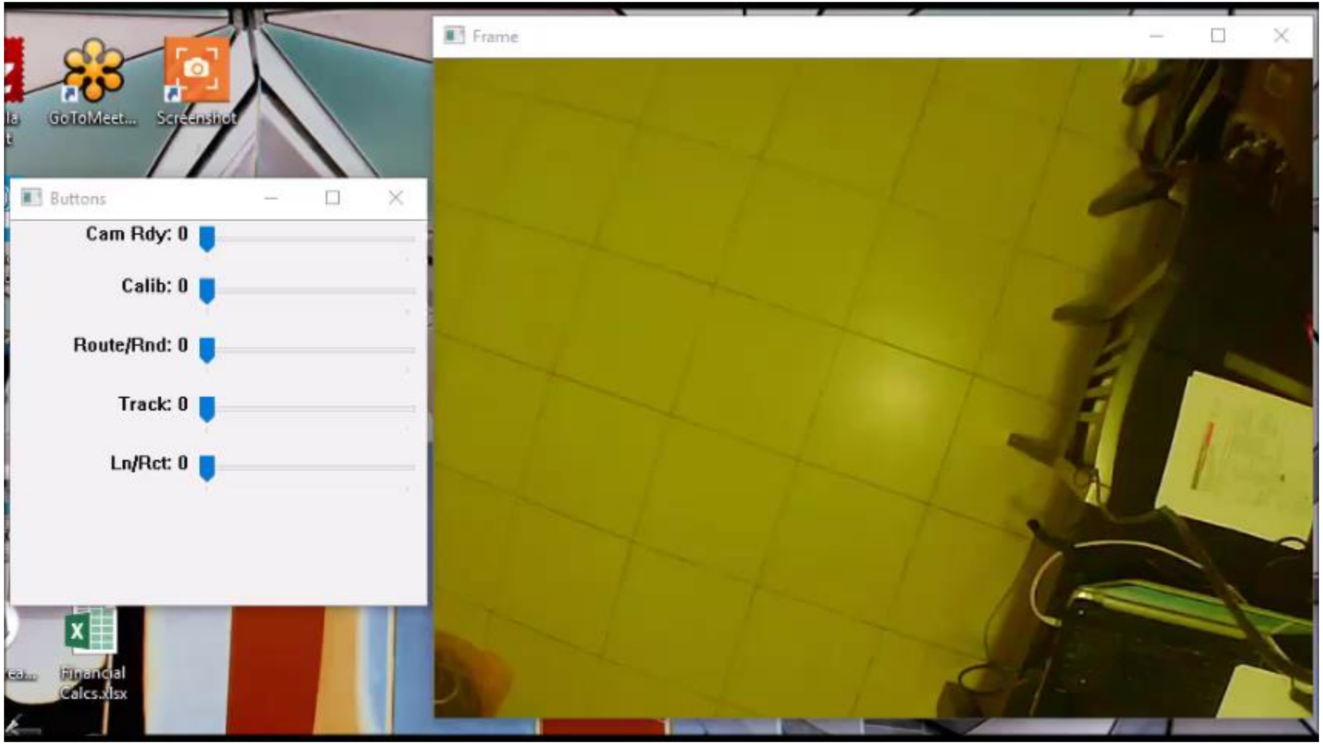
Calib: 0

Route/Rnd: 0

Track: 0

Ln/Rct: 0

Proof of concept results are achieved (random walk)б toy model



Cam Rdy: 0

Calib: 0

Route/Rnd: 0

Track: 0

Ln/Rct: 0

New big robot prototype-photo (Robot, Kamin)

Robot parameters

Где x и y – coordinates of ground robot

α - angle of rotation of the robot on the plane

v – translation velocity of the robot

ω - angle velocity of the robot

R – wheel radius

l – distance between wheelы

ω_R и ω_L – angle velocities of rotation of the right and left wheels

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Robot motion equations

$$\dot{x} = v \cos \alpha$$

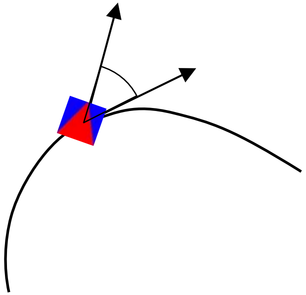
$$\dot{y} = v \sin \alpha$$

$$\dot{\alpha} = \omega$$

$$v = \frac{R(\omega_R + \omega_L)}{2}$$

$$\omega = \frac{2R(\omega_R - \omega_L)}{l}$$

Study state trajectory



1) For rotation, the stationary solution is
$\alpha(t)=\omega t+\varphi$; $v(t)=0$; $\varphi=0$

2) For linear motion, the stationary solution is
$\alpha(t)=\alpha$; $v(t)=v$

Linearization

$$\delta x(\dot{t}) = \delta v(\mathrm{t}-\tau)\ cos(\alpha(t)) - v(t) sin(\alpha(t))\delta\alpha(t)$$
$$\delta y(\dot{t}) = \delta v(\mathrm{t}-\tau) sin(\alpha(t)) + v(t) cos(\alpha(t))\delta\alpha(t)$$
$$\delta\alpha(\dot{t}) = \delta\omega(\mathrm{t}-\tau)$$

Control parameter

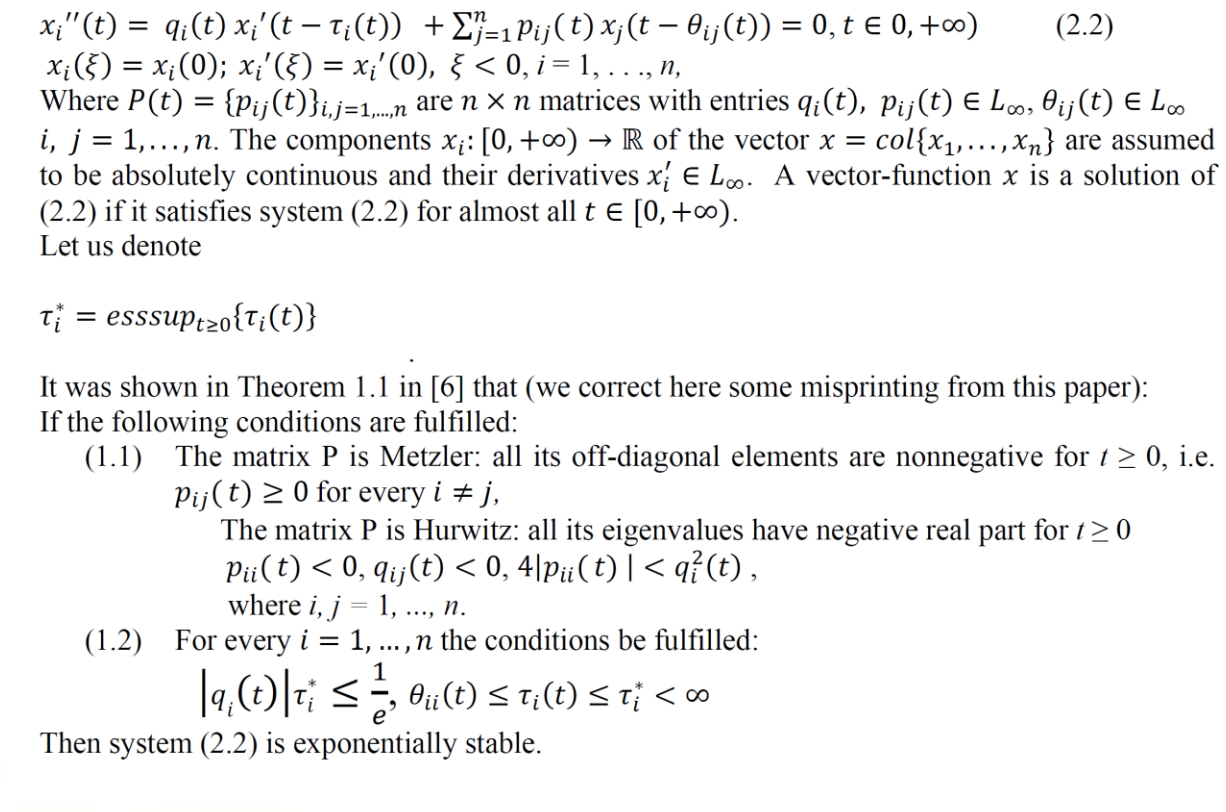
$$\delta v(\mathrm{t}-\tau) = a_x(t)\delta x(\mathrm{t}-\tau) + a_y(t)\delta y(\mathrm{t}-\tau) + a_\alpha(t)\delta\alpha(\mathrm{t}-\tau)$$
$$\delta\omega(\mathrm{t}-\tau) = b_x(t)\delta x(\mathrm{t}-\tau) + b_y(t)\delta y(\mathrm{t}-\tau) + b_\alpha(t)\delta\alpha(\mathrm{t}-\tau)$$

Stability of the system. Theorem

Theorem. If the following conditions are fulfilled, then the system is exponentially stable.

Conditions for coefficients of motion equation

Conditions for $\tau_{max} (\tau \le \tau_{max})$



$$x_i''(t) = q_i(t)\, x_i'(t-\tau_i(t)) + \sum_{j=1}^{n} p_{ij}(t)\, x_j(t-\theta_{ij}(t)) = 0, t \in 0, +\infty) \qquad (2.2)$$

$x_i(\xi) = x_i(0);\ x_i'(\xi) = x_i'(0),\ \xi < 0, i = 1, . . ., n,$

Where $P(t) = \{p_{ij}(t)\}_{i,j=1,\dots,n}$ are $n \times n$ matrices with entries $q_i(t),\ p_{ij}(t) \in L_\infty, \theta_{ij}(t) \in L_\infty$ $i,\ j = 1,\dots,n$. The components x_i: $[0,+\infty) \to \mathbb{R}$ of the vector $x = col\{x_1,\dots,x_n\}$ are assumed to be absolutely continuous and their derivatives $x_i' \in L_\infty$. A vector-function x is a solution of (2.2) if it satisfies system (2.2) for almost all $t \in [0,+\infty)$.

Let us denote

$\tau_i^* = esssup_{t\ge0}\{\tau_i(t)\}$

It was shown in Theorem 1.1 in [6] that (we correct here some misprinting from this paper):

If the following conditions are fulfilled:

(1.1) The matrix P is Metzler: all its off-diagonal elements are nonnegative for $t \ge 0$, i.e. $p_{ij}(t) \ge 0$ for every $i \ne j$,

The matrix P is Hurwitz: all its eigenvalues have negative real part for $t \ge 0$

$p_{ii}(t) < 0, q_{ij}(t) < 0, 4|p_{ii}(t)| < q_i^2(t)$,

where $i, j = 1, \dots, n$.

(1.2) For every $i = 1, \dots, n$ the conditions be fulfilled:

$$\left|q_i(t)\right|\tau_i^* \le \frac{1}{e}, \theta_{ii}(t) \le \tau_i(t) \le \tau_i^* < \infty$$

Then system (2.2) is exponentially stable.

By substitution coefficients of our motion equation to these conditions we can find parameters of control:

- $a_x(t), a_y(t), a_\alpha(t)$
- $b_x(t), b_y(t), b_\alpha(t)$
- τ_{max}

Solution

Final solution are following:

1) For rotation, the stationary solution is

$\alpha(t)=\omega t+\phi$; $v(t)=0$; $\phi=0$

where control parameters are following:

$\delta v(t-\tau)=-2a_r\cos(\omega(t-\tau))\delta x(t-\tau)-2a_r \sin(\omega(t-\tau))\delta y(t-\tau)$ where $\omega\neq 0, a\_r>|\omega|$;

$\delta\omega(t-\tau)=b_\alpha\ \delta\alpha(t-\tau)$ where $b_\alpha<0$.

2) For linear motion, the stationary solution is

$\alpha(t)=\alpha$; $v(t)=v$

where control parameters are following:

$\delta v(t-\tau)=-\ a_l\cos(\alpha)\delta x(t-\tau)\ -\ a_l\sin(\alpha)\delta y(t-\tau)$ where $a_l>0$

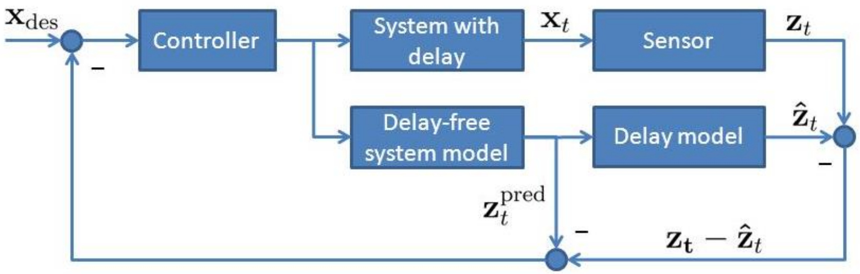
$\delta\omega(t-\tau)=a\ \sin\llbracket(\alpha)\ \ \delta x(t-\tau)\rrbracket-a\cos(\alpha)\delta y(t-\tau)-2b\ \delta\alpha(t-\tau)$ where $av>0$; $b>(av)^{1/2}$

3) The delay time is following:

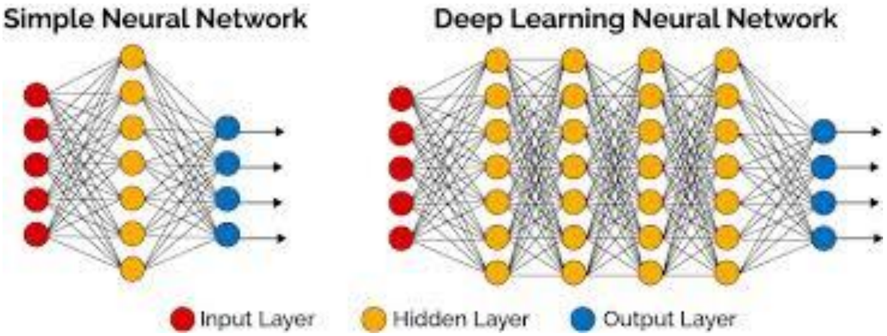
$\tau\leq\min(1/(2e|b|)\ ,1/(e|a_l|)\ ,1/(e|b_\alpha|)\ ,1/(2e|a_r|)\ )$

Automatic control solution

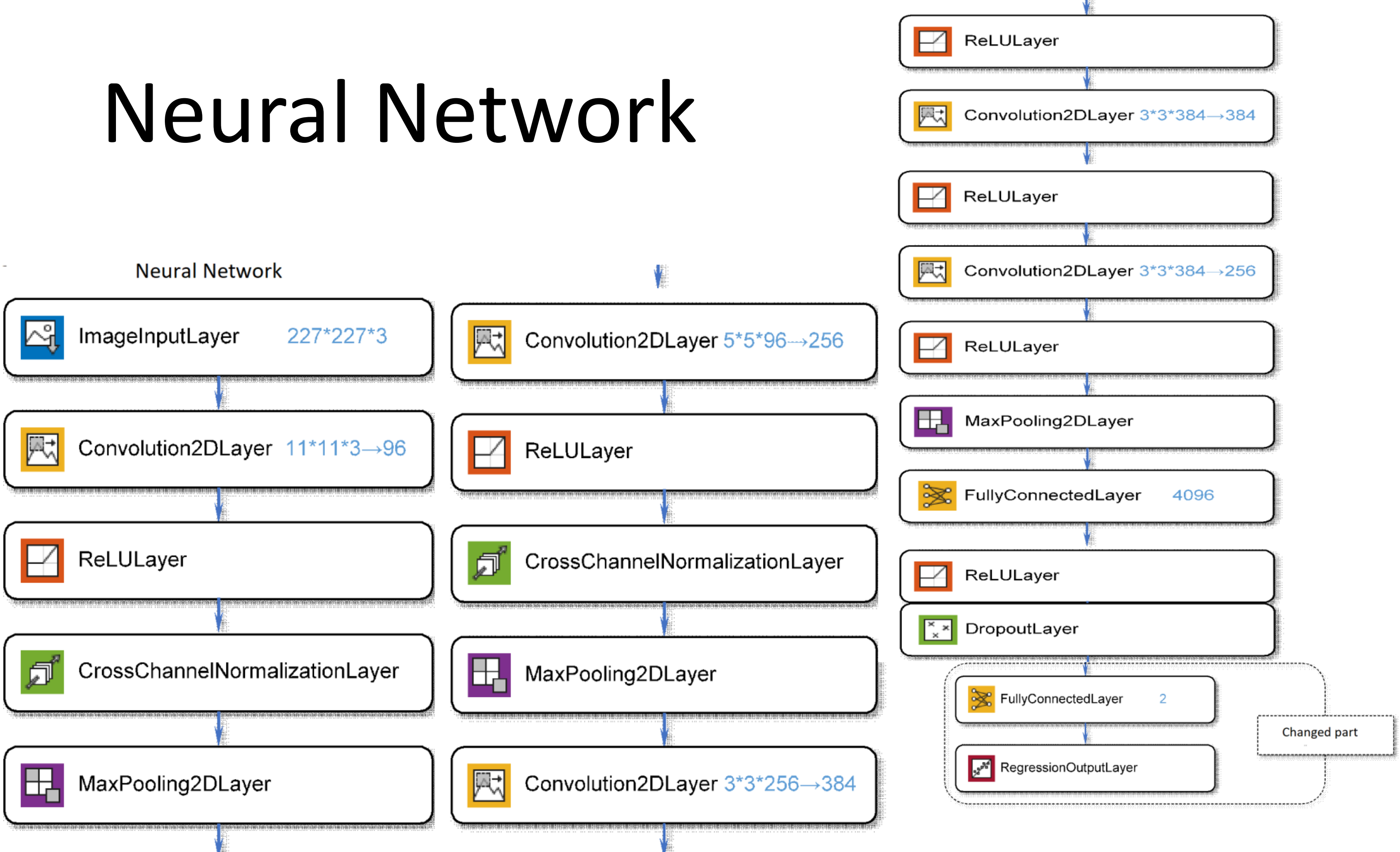
Engineering solution:
Automatic control with delay by prediction

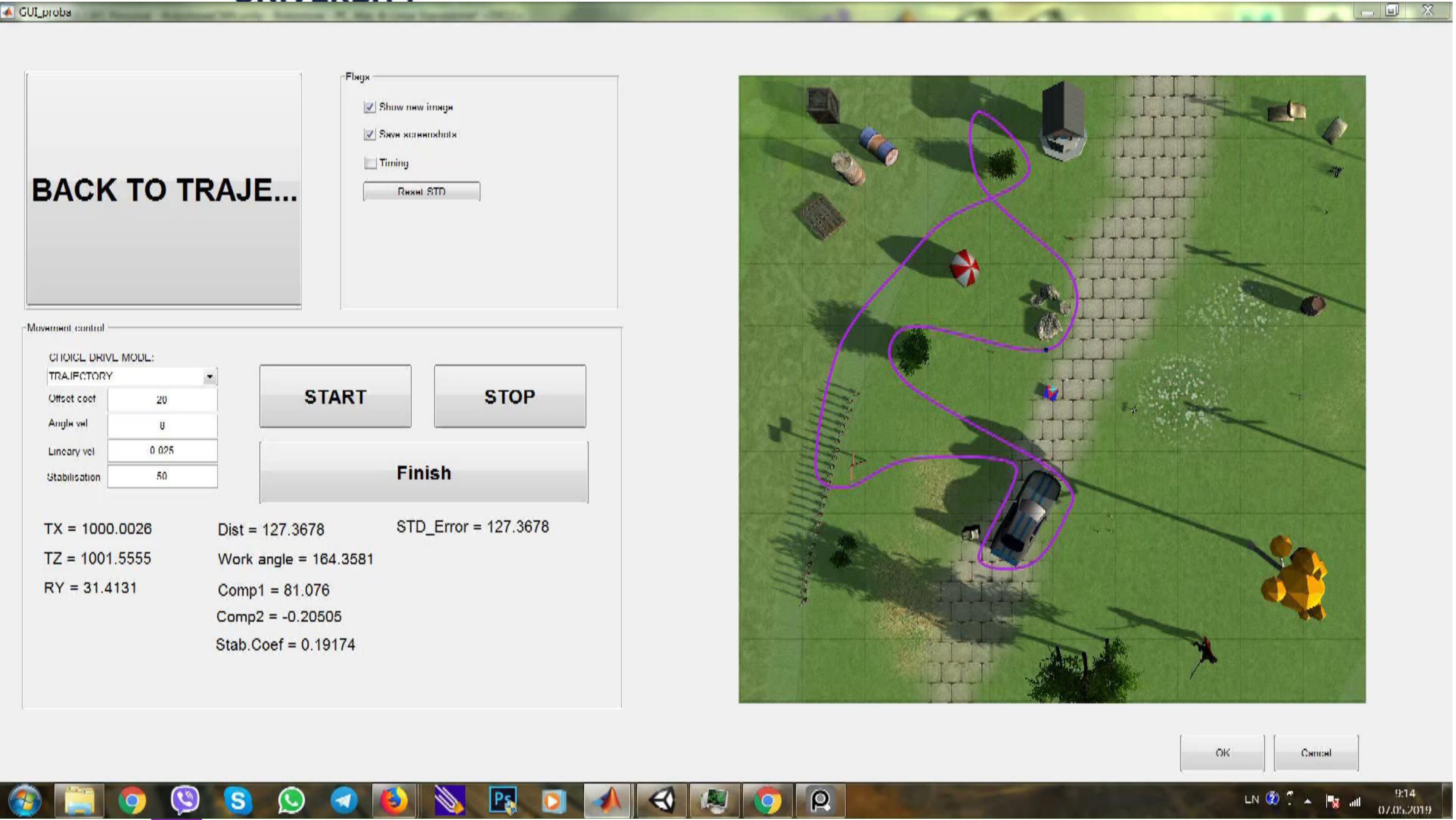


Deep learning:
ground robot recognition and finding position and orientation



Neural Network





☑ Show new image

☑ Save screenshots

☐ Timing

CHOICE DRIVE MODE: TRAJECTORY

Offset coef 20

Angle vel 0

Lineary vel 0.025

Stabilisation 50

TX = 1000.0026

TZ = 1001.5555

RY = 31.4131

Dist = 127.3678

Work angle = 164.3581

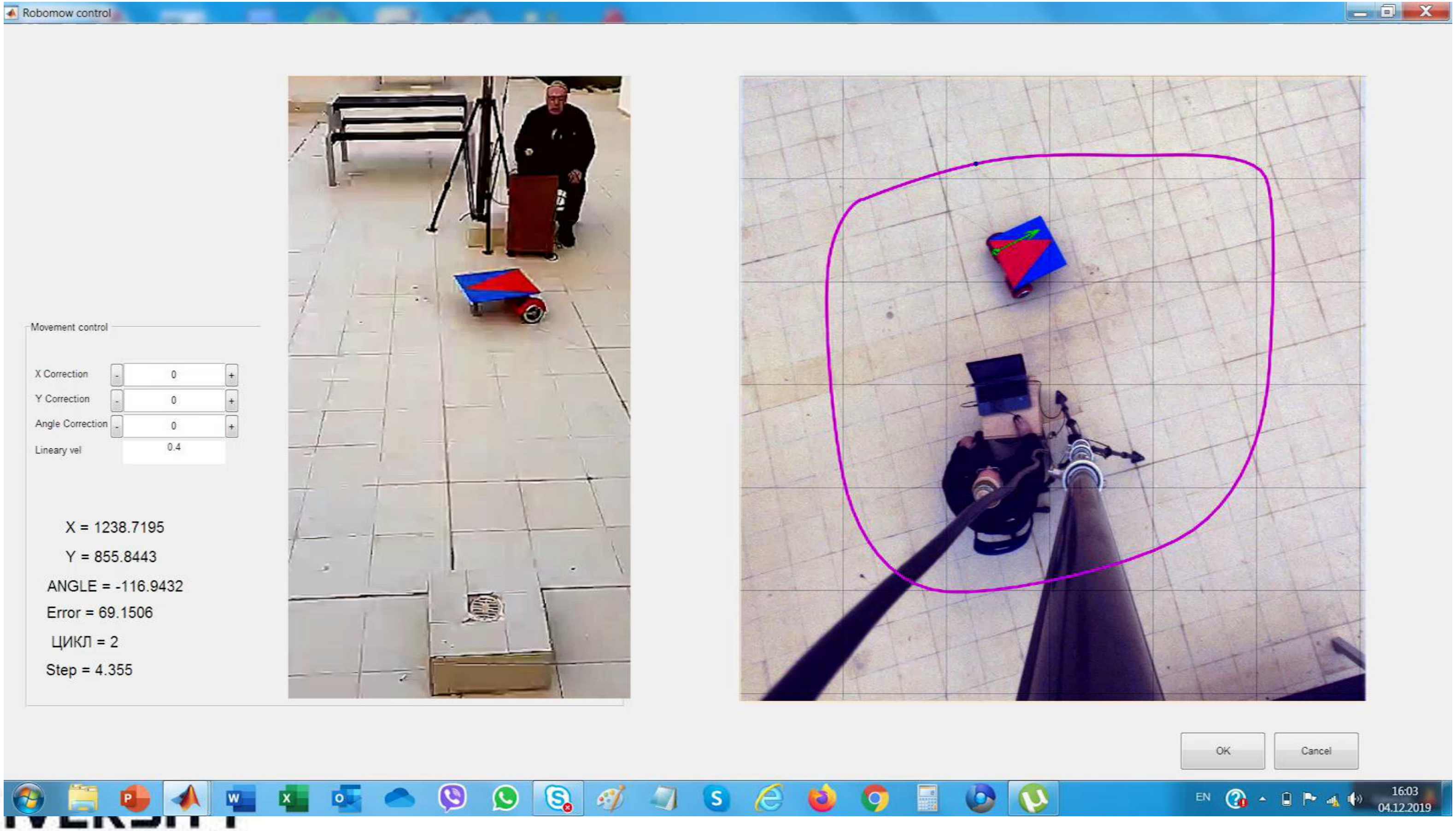
Comp1 = 81.076

Comp2 = -0.20505

Stab.Coef = 0.19174

STD_Error = 127.3678

Proof of concept results (robot version) are achieved (path)

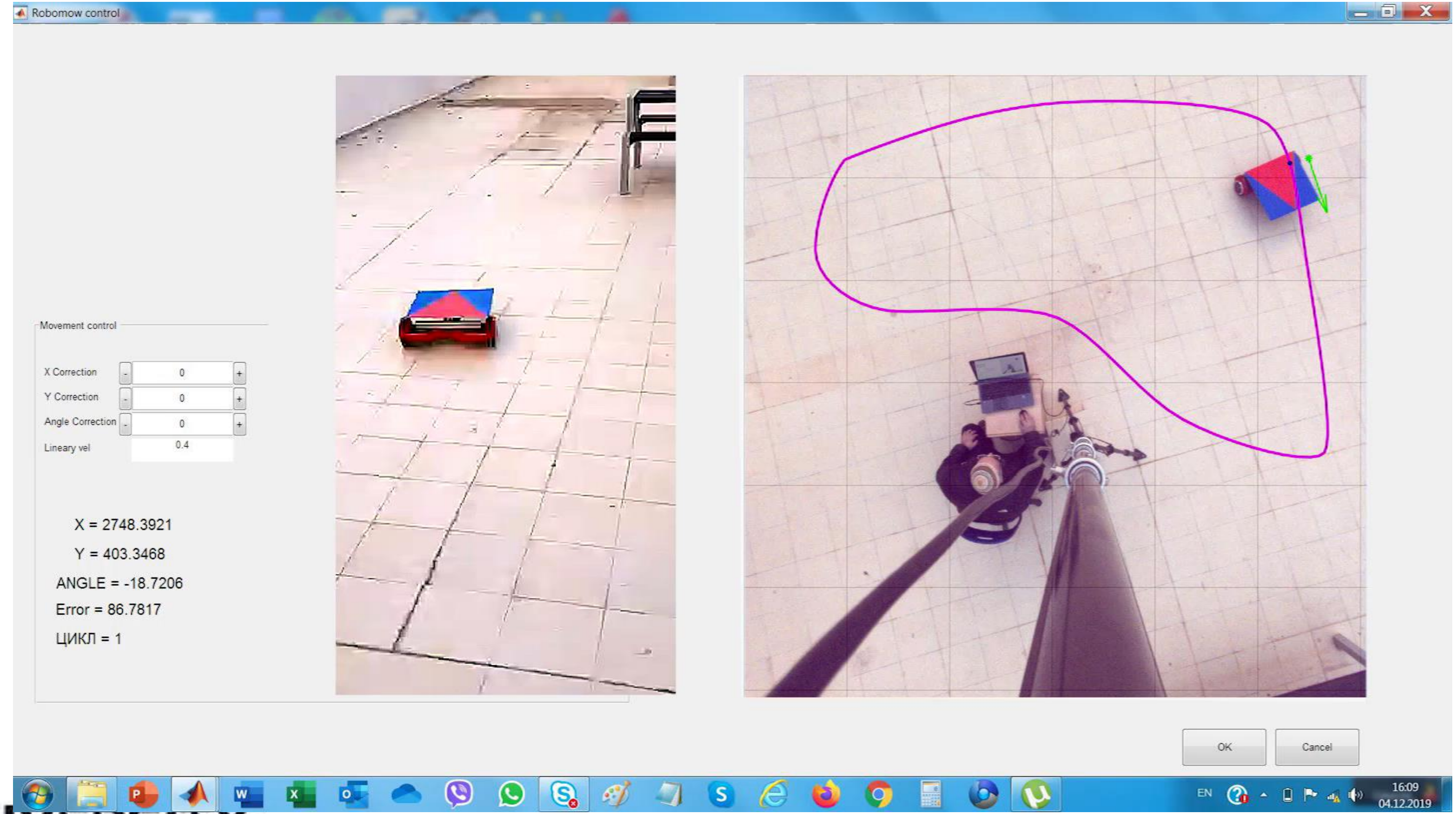


Movement control

X Correction = 0
Y Correction = 0
Angle Correction = 0
Lineary vel = 0.4

```
X = 1238.7195
Y = 855.8443
ANGLE = -116.9432
Error = 69.1506
ЦИКЛ = 2
Step = 4.355
```

Proof of concept results (robot version) are achieved (random walk)



Movement control

X Correction - 0 +

Y Correction - 0 +

Angle Correction - 0 +

Lineary vel 0.4

X = 2748.3921

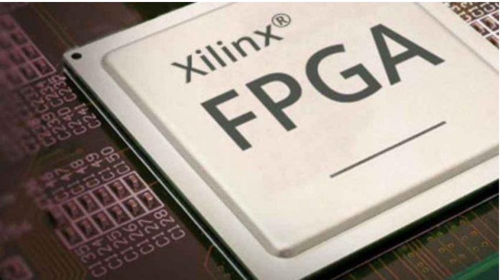
Y = 403.3468

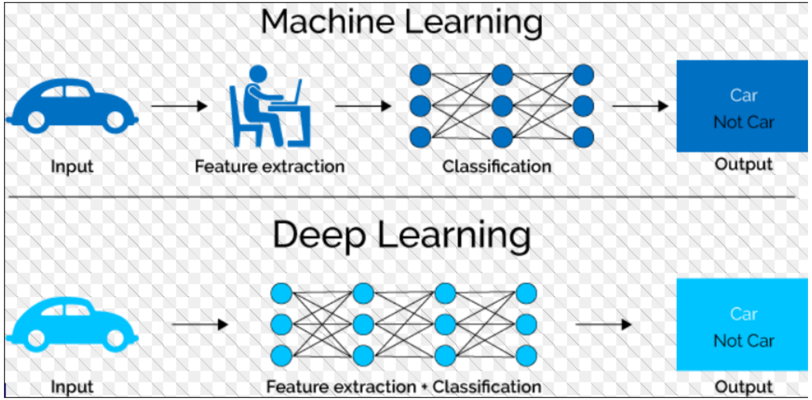
ANGLE = -18.7206

Error = 86.7817

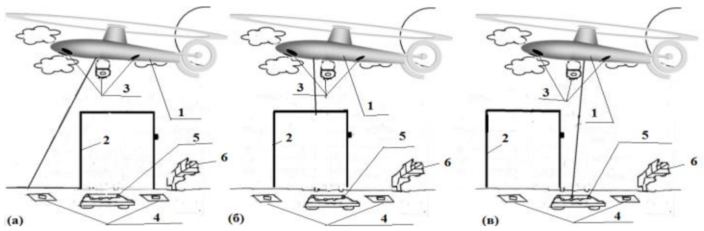
ЦИКЛ = 1

New Technologies - general





Our Intellectual Property: 5 Patents (2 Russia, Germany, France, USA)



Patent 1

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ПОЛЕЗНУЮ МОДЕЛЬ

№ 131276

УСТРОЙСТВО ДЛЯ КООРДИНАЦИИ АВТОМАТИЗИРОВАННЫХ УСТРОЙСТВ

Патентообладатель(ли): *Общество с ограниченной ответственностью "ТРАНЗИСТ ВИДЕО" (RU)*

Автор(ы): *Купервассер Олег Юрьевич (RU), Купервассер Юрий Ильич (RU), Рубинштейн Александр Александрович (RU)*

Заявка № **2012147924**

Приоритет полезной модели **12 ноября 2012 г.**

Зарегистрировано в Государственном реестре полезных моделей Российской Федерации ***20 августа 2013 г.***

Срок действия патента истекает **12 ноября 2022 г.**

Руководитель Федеральной службы по интеллектуальной собственности

Б.П. Симонов

Patent 2

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2691788

СПОСОБ КООРДИНАЦИИ НАЗЕМНЫХ ПОДВИЖНЫХ АВТОМАТИЗИРОВАННЫХ УСТРОЙСТВ С ПОМОЩЬЮ ЕДИНОЙ ЦЕНТРАЛИЗОВАННОЙ УПРАВЛЯЮЩЕЙ СИСТЕМЫ

Патентообладатель: *Общество с ограниченной ответственностью "ТРАНЗИСТ ВИДЕО" (RU)*

Автор: *Купервассер Олег Юрьевич (RU)*

Заявка № **2015121583**

Приоритет изобретения **05 июня 2015 г.**

Дата государственной регистрации в Государственном реестре изобретений Российской Федерации **18 июня 2019 г.**

Срок действия исключительного права на изобретение истекает **05 июня 2035 г.**

Руководитель Федеральной службы по интеллектуальной собственности

Г.П. Ивлиев

Patent 3

Bundesrepublik Deutschland

Urkunde

über die Eintragung des Gebrauchsmusters Nr. 21 2013 000 225

Bezeichnung:
Vorrichtung für Koordinierung automatisierter Vorrichtungen

IPC:
G05D 1/02

Inhaber/Inhaberin:
Kupervasser, Oleg Jurjevich, Moskau, RU

Tag der Anmeldung:
07.11.2013

Tag der Eintragung:
10.07.2015

Priorität:
12.11.2012 RU 2012147924

Die Präsidentin des Deutschen Patent- und Markenamts

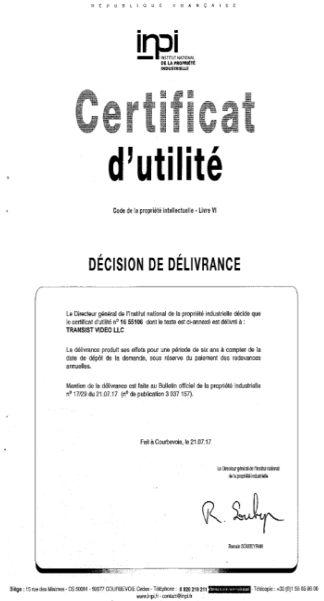
Cornelia Rudloff-Schäffer

Cornelia Rudloff-Schäffer

München, 10.07.2015

Die Voraussetzungen der Schutzfähigkeit werden bei der Eintragung eines Gebrauchsmusters nicht geprüft. Den aktuellen Rechtsstand und Schutzumfang entnehmen Sie bitte dem DPMAregister unter www.dpma.de.

Patent 4



RÉPUBLIQUE FRANÇAISE

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INSTITUT NATIONAL DE LA PROPRIÉTÉ INDUSTRIELLE

Certificat d'utilité

Code de la propriété intellectuelle - Livre VI

DÉCISION DE DÉLIVRANCE

Le Directeur général de l'Institut national de la propriété industrielle décide que le certificat d'utilité n° **16 55106** dont le texte est ci-annexé est délivré à :
TRANSIST VIDEO LLC

La délivrance produit ses effets pour une période de six ans à compter de la date de dépôt de la demande, sous réserve du paiement des redevances annuelles.

Mention de la délivrance est faite au Bulletin officiel de la propriété industrielle n° 17/29 du 21.07.17 (n° de publication 3 037 157).

Fait à Courbevoie, le 21.07.17

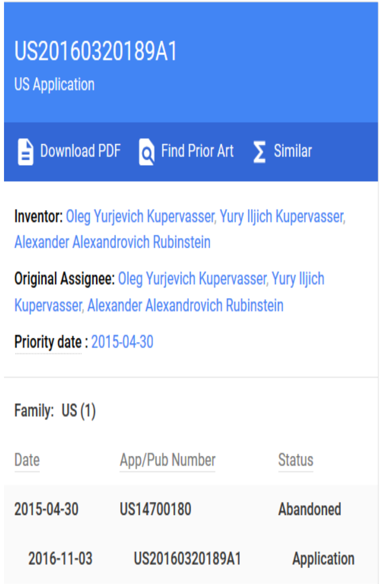
Le Directeur général de l'Institut national de la propriété industrielle

R. Soubeyran

Romain SOUBEYRAN

Siège : 15 rue des Minimes - CS 50001 - 92677 COURBEVOIE Cedex - Téléphone : **0 820 210 211** [illegible] - Télécopie : +33 (0)1 56 65 86 00
www.inpi.fr - contact@inpi.fr

Patent 5



US20160320189A1
US Application

Inventor: Oleg Yurjevich Kupervasser, Yury Iljich Kupervasser, Alexander Alexandrovich Rubinstein

Original Assignee: Oleg Yurjevich Kupervasser, Yury Iljich Kupervasser, Alexander Alexandrovich Rubinstein

Priority date : 2015-04-30

Family: US (1)

Date	App/Pub Number	Status
2015-04-30	US14700180	Abandoned
2016-11-03	US20160320189A1	Application

Application RU 2015121583 is accepted during project realization in 2019 and is transformed to real patent

RU 2691788:

https://findpatent.ru/patent/269/2691788.html

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2691788

СПОСОБ КООРДИНАЦИИ НАЗЕМНЫХ ПОДВИЖНЫХ АВТОМАТИЗИРОВАННЫХ УСТРОЙСТВ С ПОМОЩЬЮ ЕДИНОЙ ЦЕНТРАЛИЗОВАННОЙ УПРАВЛЯЮЩЕЙ СИСТЕМЫ

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Автор: *Купервассер Олег Юрьевич (RU)*

Заявка № 2015121583
Приоритет изобретения 05 июня 2015 г.
Дата государственной регистрации в
Государственном реестре изобретений
Российской Федерации 18 июня 2019 г.
Срок действия исключительного права
на изобретение истекает 05 июня 2035 г.

Руководитель Федеральной службы по интеллектуальной собственности

Г.П. Ивлиев

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New prototype-photo (Robot, Kamin)

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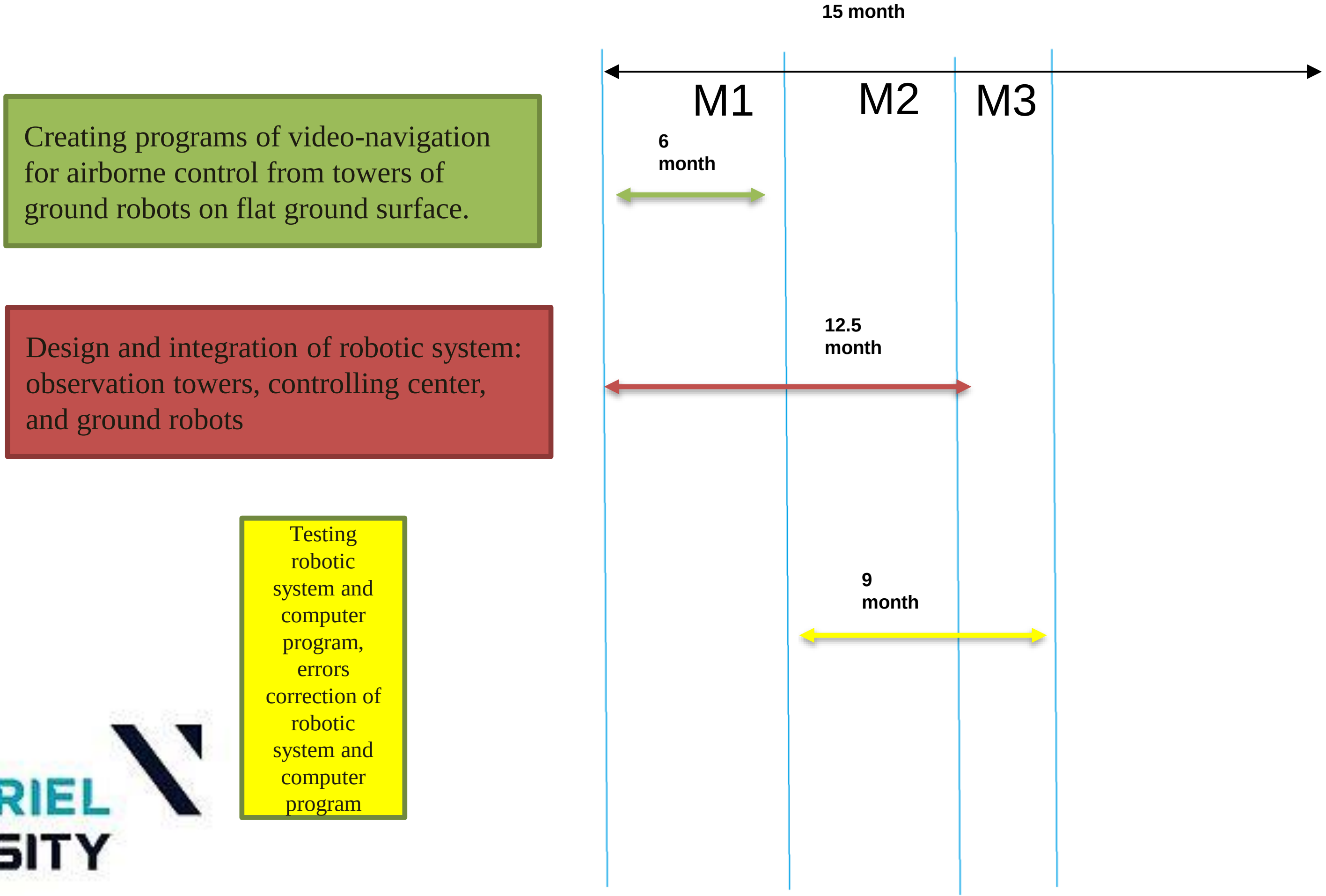
New Project Kamin



15 month

M1 M2 M3

Creating programs of video-navigation for airborne control from towers of ground robots on flat ground surface.

6 month

Design and integration of robotic system: observation towers, controlling center, and ground robots

12.5 month

Testing robotic system and computer program, errors correction of robotic system and computer program

9 month

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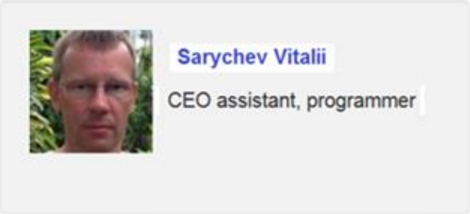
Strong team of experienced professionals from Israel and Russia: Vision-based navigation of UAV

Project leader:

Kupervasser Oleg, works in Ariel University, Israel, PhD (Weizmann, Israel) included to 30th issue of “Marquise Who’s Who in the world”, has 17 years of experience (leading companies in Russia and Israel) and 11 papers, many conference reports



Sarychev Vitalii

CEO assistant, programmer

Kupervasser Oleg

Chief Scientist

Optimal control theory specialist

Name: Alexander Domoshnitsky

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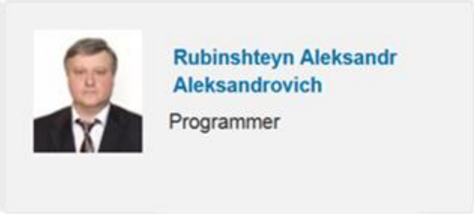

Rubinshteyn Aleksandr Aleksandrovich

Programmer

Hennadii Kutomanov
Programmer

Commercial expert:

Dr. Eli Zamir

Ilan Ehrenfeld
Programmer

Competitors

Robomow
friendly home

OFFICIAL TEAM
SPACEIL
TEAM SPACEIL

Elbit Systems

iRobot

ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ УНИТАРНОЕ ПРЕДПРИЯТИЕ
Научно-производственное объединение
имени С.А. Лавочкина

Technion
Israel Institute of
Technology

PRoVisG

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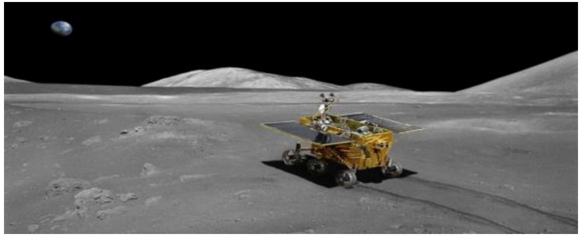
Competitor projects

Unmanned Ground vehicles (UGVs)

ground robots (landrovers, lawnmowers)

planetary rovers

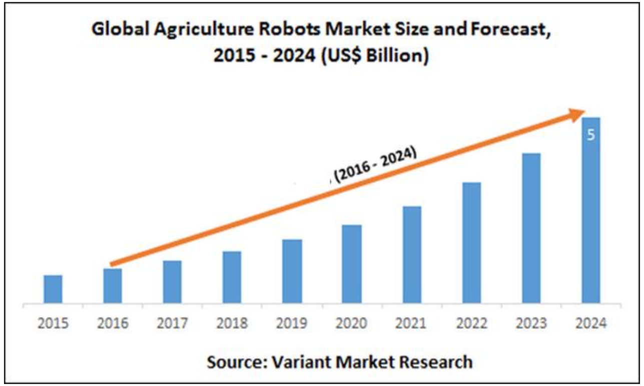
Robot lawnmowers still a work in progress



Market

The agricultural robots market is expected to grow from USD 2.75 Billion in 2016 to USD 12.80 Billion by 2024

https://www.marketsandmarkets.com/Market-Reports/agricultural-robot-market-173601759.html



Global Agriculture Robots Market Size and Forecast, 2015 - 2024 (US$ Billion)

Source: Variant Market Research

Conclusion

As a result, we proved that it's possible to maintain stable movement of a ground robot even when time delay exists in transfer information about output control parameters from navigation measurement devices to autopilot. We can find control parameters for a particular case of visual airborne navigation of ground robot and estimated max possible delay of the system.

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References

- [1] I. Ehrenfeld, O. Kupervasser, H. Kutomanov, V. Sarychev, and R. Yavich, “ALGORITHMS DEVELOPED FOR TWO PROTOTYPES OF AIRBORNE VISION-BASED CONTROL OF GROUND ROBOTS” Proceeding of the 9 Conference on GEOMATE 2019, November 2019, Tokyo, Japan
- [2] Alexander Domoshnitsky, Emilia Fridman “A positivity-based approach to delay-dependent stability of systems with large time-varying delays”, Elsevier Journal, Systems & Control Letters 97 (2016)
- [3] R.P. Agarwal, L. Berezansky, E.Braverman, A. Domoshnitsky, “Nonoscillation Theory of Functional Differential Equations with Applications”, Springer, 2011
- [4] R. P. Agarwal, A. Domoshnitsky, A. Maghakyan, “ON EXPONENTIAL STABILITY OF SECOND ORDER DELAY DIFFERENTIAL EQUATIONS”, Czechoslovak Mathematical Journal, 65 (140) (2015), 1047–1068
- [5] A. Domoshnitsky, "Nonoscillation, maximum principles, and exponential stability of second order delay differential equations without damping term", Journal of Inequalities and Applications 2014, 2014:361
- [6] A. Domoshnitsky, A. Maghakyan, L. Berezansky, “W-transform for Exponential Stability of Second Order Delay Differential Equations without Damping Terms”, Journal of Inequalities and Applications

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References

- [7] O. Kupervasser, A. Rubinstein “Correction of Inertial Navigation on System’s Errors by the Help of Video-Based Navigator Based on Digital Terrain Map”, Positioning, 2013, 4,89-108 http://file.scirp.org/pdf/POS_2013022811491738.pdf
- [8] O. Kupervasser, R. Lerner, E. Rivlin and Hector Rotstein “Error Analysis for a Navigation Algorithm based on Optical-Flow and a Digital Terrain Map”, In the Proceedings of the 2008 IEEE/ION Position, Location and Navigation Symposium, P.1203-1212
- [9] O. Kupervasser, V. Voronov, “A navigation filter for fusing DTM/correspondence updates”, Proceedings of the IEEE International Conference on Robotics and Biomimetics (ROBIO), 2011 , Page(s): 1591 - 1596
- [10] R. Lerner, O. Kupervasser, .E. Rivlin, ”Pose and Motion from Omnidirectional Optical Flow and a Digital Terrain Map”, In the Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems, P.2251-2256
- [11] Kupervasser O. Yu., Voronov V.V., “Correction of Inertial Navigation System's Errors by the Help of Video-Based Navigator Based on Digital Terrarium Map”, PRESENTED AT XIX ST.-PETERSBURG INTERNATIONAL CONFERENCE ON THE INTEGRATED NAVIGATIONAL SYSTEMS (MKINS2012)
- [12] O. Yu. Kupervasser, A. A. Rubinstein “The system of video-based navigation for unmanned aerial vehicles”, IV TRIZ Conference, «TRIZ. Practice for applicaton of methodical instruments», Moscow 19-20 October 2012

References

- [13] R. Lerner, E. Rivlin and H. P. Rotstein, “Pose and Motion Recovery from Correspondence and a Digital Terrain Map,” IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 28, No. 9, 2006, pp. 1404-1417.
- [14] Y. Liu, M.A. Rodrigues, “Statistical image analysis for pose estimation without point correspondences”, Pattern Recognition Letters, vol. 22, pp. 1191-1206, 2001
- [15] P. David, D. DeMenthon, R. Duraiswami, H. Samet, “SoftPOSIT: Simultaneous pose and correspondence determination”, ECCV 2002, LNCS 2352, pp. 698-714, 2002
- [16] D. Shin, S. G. Park, B. S. Song, E. S. Kim, O. Kupervasser, D. Pivovartchuk, I. Gartseev, O. Antipov, E. Kruchenkov, A. Milovanov, A. Kochetov, I. Sazonov, I. Nogtev, S. W. Hyun, “Precision improvement of MEMS gyros for indoor mobile robots with horizontal motion inspired by methods of TRIZ”, Proceedings of 9th IEEE International Conference on Nano/Micro Engineered and Molecular Systems (IEEE-NEMS 2014) April 13-16, 2014,Hawaii,USA, pp 102-107
- [17] V.A. Bodner, M.S. Kozlov “Stabilization of aerial vehicles and autopilots”, Oborongiz, Mscow, 1961 (in Russian)

Bibliography

1. Alexander Domoshnitsky, **Oleg Kupervasser**, Seshadev Padhi, and Satyam Narayan Srivastava, "Vallee-Poussin theorem for Katugampola fractional functional differential equations", accepted to Journal - **Miskolc Mathematical Notes**; ISI (Web of Science): Science Citation Index Expanded (SCI-EXPANDED) ; Web of Science: Quartile – Q2 IN MATHEMATICS, Impact Factor – 0.9; SCImago: Q3, H-INDEX 24; JCR citations: 0, Scopus citations:0, Google scholar – 0, 2024

2. Leonid Berezansky, Alexander Domoshnitsky, **Oleg Kupervasser**, “Bounded solutions and exponential stability for linear integro-differential equations of Volterra type”, Applied Mathematics Letters, Vol. 154, p. 109112; ISI (Web of Science): Science Citation Index Expanded (SCI-EXPANDED); Web of Science: Quartile - Q1 IN MATHEMATICS, APPLIED, Impact Factor – 2.9; SCImago: Q1, H-INDEX 110; JCR citations: 0, Scopus citations:0, Google scholar – 0, 2024

3. **O. Kupervasser**, H. Kutomanov, V. Sarychev, and R. Yavich, “THE NEW ADVANCED PROTOTYPE OF AIRBORNE VISUAL CONTROL OF A GROUND ROBOT”, International Journal of GEOMATE**;** ISI (Web of Science): Emerging Sources Citation Index (ESCI), Web of Science: Quartile – Q4 IN ENGINEERING, CIVIL, Impact Factor – 0.9; SCImago: Q3, H-INDEX 27; JCR citations: 1, Scopus citations:0, Google scholar – 1, 2021

4. **Oleg Kupervasser**, Hennadii Kutomanov, Ori Levi, Vladislav Pukshansky, and Roman Yavich, “Using Deep Learning for Visual Navigation of Drone with respect to 3D Ground Object”, “Functional Differential Equations and Applications”, MDPI journal “Mathematics”, Vol. 8, Issue 12, **https://www.mdpi.com/2227-7390/8/12/2140/xml**; ISI (Web of Science): Science Citation Index Expanded (SCI-EXPANDED); Web of Science: Quartile – Q1 IN MATHEMATICS, Impact Factor – 2.3; SCImago: Q2, H-INDEX 68; JCR citations: 3; Scopus citations:5; Google scholar – 7; 2020

5. **Oleg Kupervasser**, Hennadii Kutomanov, Michael Mushaelov, and Roman Yavich, “Using Diffusion Map for Visual Navigation of a Ground Robot”, “Functional Differential Equations and Applications”, MDPI journal “Mathematics”, Vol. 8, Issue 12, **https://www.mdpi.com/2227-7390/8/12/2175/xml;** ISI (Web of Science): Science Citation Index Expanded (SCI-EXPANDED); Web of Science: Quartile – Q1 IN MATHEMATICS, Impact Factor – 2.3; SCImago: Q2, H-INDEX 68; JCR citations: 1, Scopus citations:1, Google scholar – 4, 2020

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Bibliography

1. Shiran Avasker, Alexander Domoshnitsky, Max Kogan, **Oleg Kupervasser**, Hennadii Kutomanov, Yonatan Rofsov, Irina Volinsky, Roman Yavich, “A method for stabilization of drone flight controlled by autopilot with time delay”, SN Applied Sciences, volume 2, Article number: 225, https://link.springer.com/article/10.1007%2Fs42452-020-1962-6, ISI (Web of Science): Emerging Sources Citation Index (ESCI); Web of Science: Quartile – Q1 IN MULTIDISCIPLINARY SCIENCES; Impact Factor – 2.8; SCImago: Q2, H-INDEX 130; JCR citations: 6; Scopus citations:9; Google scholar – 13, 2020

2. Ilan Ehrenfeld, **Oleg Kupervasser**, Hennadii Kutomanov, Vitalii Sarychev, Roman Yavich, “ALGORITHMS DEVELOPED FOR TWO PROTOTYPES OF AIRBORNE VISION-BASED CONTROL OF GROUND ROBOTS” International Journal of GEOMATE, 19(72), pp. 217 – 224, https://geomatejournal.com/geomate/article/view/1157/995, ISI (Web of Science): Emerging Sources Citation Index (ESCI); Web of Science: Quartile – Q4 IN ENGINEERING, CIVIL; Impact Factor – 0.9; SCImago: Q3, H-INDEX 27; JCR citations: 1, Scopus citations:1, Google scholar – 2, 2020

3. **O. Kupervasser**, V. Sarychev, A. Rubinstein and R. Yavich, “ROBUST POSITIONING OF DRONES FOR LAND USE MONITORING IN STRONG TERRAIN RELIEF USING VISION-BASED NAVIGATION” International Journal of GEOMATE – 14(45)- pp.10-15, https://www.geomatejournal.com/sites/default/files/articles/10-15-7322-Kupervasser-May-2018-g1.pdf, ISI (Web of Science): Emerging Sources Citation Index (ESCI); Web of Science: Quartile – Q4 IN ENGINEERING, CIVIL, Impact Factor – 0.9; SCImago: Q3, H-INDEX 27; JCR citations: 1, Scopus citations:6, Google scholar – 8, 2018

4. A. Abahre, D. Elbhar, **O. Kupervasser,** H. Kutomanov, G. Rubin, G. Shimoni, R. Yavich, “Fusion of inertial navigation system with 10 axes and computer vision for UAV navigation” FUNCTIONAL DIFFERENTIAL EQUATIONS, Volume 26, 2019, No 3-4, pp. 141-166, SCImago: H-INDEX 2, Q4; Google scholar – 0, 2019

5. Alexander Domoshnitsky, **Oleg Kupervasser,** Hennadii Kutomanov, Roman Yavich, Chapter in the book “Functional Differential Equations and Applications” edited by Professor Alexander Domoshnitsky, Professor Alexander Rasin and Seshadev Padhi, Chapter “A method for stabilization of ground robot path controlled by airborne autopilot with time delay”, Publisher: Springer Nature, 2022

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Thank you!

Questions?

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