



МИНИСТЕРСТВО НАУКИ
И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ



St. Petersburg Federal Research Center
of the Russian Academy of Sciences



Project HARMONIC in ERA.Net RUS Plus Call 2017: “Collaborative strategies of heterogeneous robot activity at solving agriculture missions controlled via intuitive human-robot interfaces”

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Director of SPC RAS



ERA.Net RUS Plus Anniversary Meeting
Moscow, Russia
December 09, 2021



International team of the project

Partners:

- SPIIRAS (coordinator)
 - In 2020 SPIIRAS has been transformed into the St.Petersburg Federal Research Center of the Russian Academy of Sciences (SPC RAS)
- Leipzig University of Telecommunications
- Erzurum Technical University
- University of Novi Sad Faculty of Technical Sciences



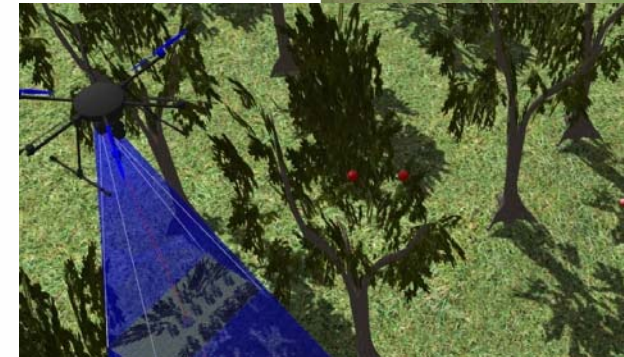


Main goal and objectives of the project

The goal of the project was to model an agricultural robotic system capable of minimizing the efforts and injuries of people during agricultural work

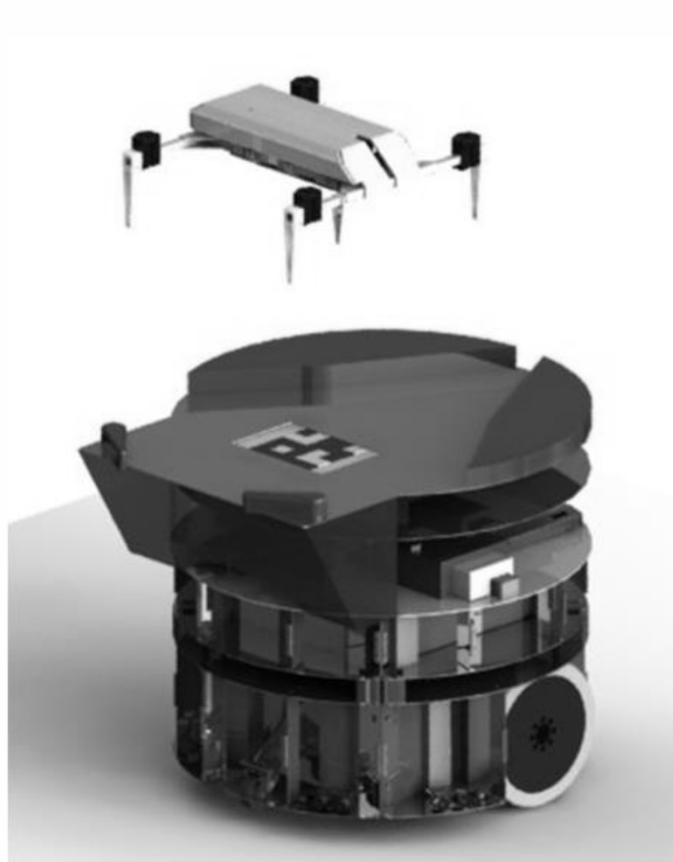
The objectives of the project were:

- development of the theoretical foundations of the autonomous operation of a mobile platform serving UAVs
- development of the theoretical foundations of group interaction of heterogeneous UAVs in solving problems associated with agricultural work
- development of the theoretical foundations of interaction and control "man - mobile platform - UAV", including joint training and components of the interaction through gestures, voice, etc.

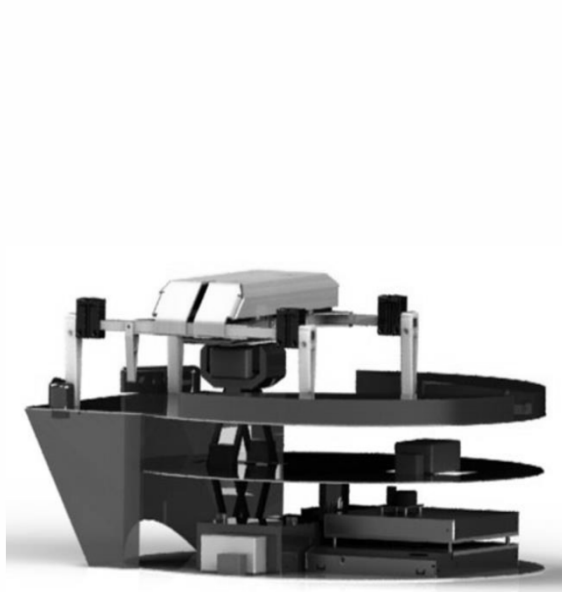




Constructive models of a ground and air robots



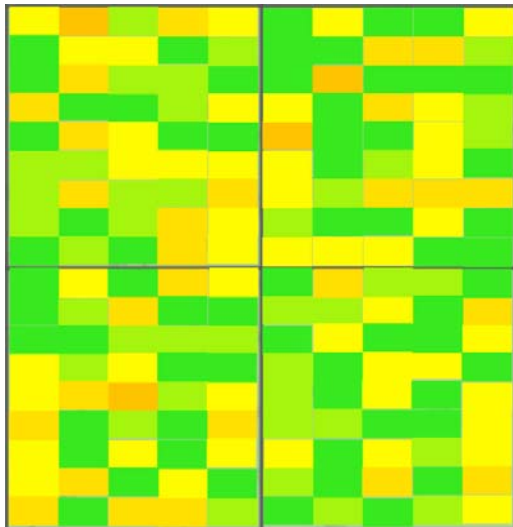
Ground service robot for unmanned air vehicle
with battery replacement mechanism



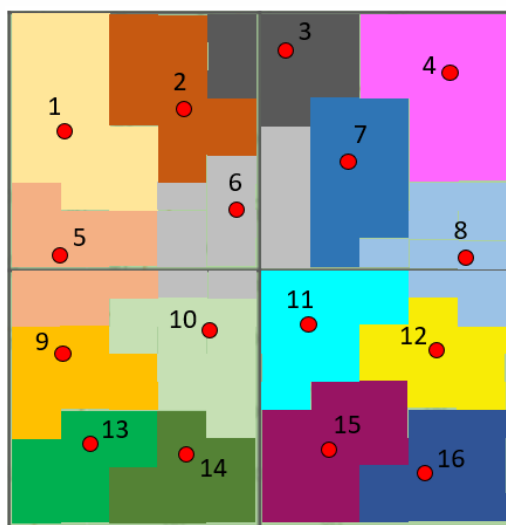
Version of ground robot for
harvesting task



Grouping tasks for collecting fruits



Yield
cartogram of
the surveyed
area



The result of
dividing
collecting fruits
tasks into
groups,
indicating the
stopping points
of ground RTSs



View of a columnar apple garden
model in a fruit picking scenario



Modelling of robot control at fruit picking scenario

AgrobotModeling

Cultivated land parameters

S_{oj}(max)

1000

The total area of the cultivated land

ΔS

1

The area processed by one UAV per Δt

S_{oj}(t)

The current value of the processed land area

Current time t:

529

Status:

Work is done

Start

Platform parameters

N

1

The number of platforms used in the processing of the site

e_P(max)

5000

The maximum amount of energy resources placed on one service platform

r_P(max)

2000

The maximum amount of physical resources placed on one service platform

e_P(min)

10

The minimum amount of energy resources of the service platform required to guarantee the return of the platform to the central base

w_t

1

e_{opt}=

2909

w_e

1

n_{opt}=

1

w_c

1

m_{opt}=

4

t_{sum}

529

e_{sum}

1820

c_{sum}

560

Calculate

Service platform current parameters

Platform 1

e_P(t)

3180

r_P(t)

1000

Platform 2

e_P(t)

0

r_P(t)

0

Platform 3

e_P(t)

0

r_P(t)

0

Platform 4

e_P(t)

0

r_P(t)

0

UAV parameters

M

4

The number of UAV transported on one service platform

e_U(max)

20

The maximum amount of UAV battery charge

r_U(max)

10

The maximum volume of a container with physical resources on the UAV

e_U(min)

4

The minimum amount of UAV battery charge required for a guaranteed return to the platform

☐

The UAV won't take off if the UAV in the field can finish the rest

☐

Simultaneous maintenance of the battery and the container of UAV

UAV current parameters

UAV 1

e_U(t)

20

r_U(t)

10

Status: Service on the platform

UAV 2

e_U(t)

20

r_U(t)

10

Status: Transportation

UAV 3

e_U(t)

20

r_U(t)

10

Status: Transportation

UAV 4

e_U(t)

20

r_U(t)

10

Status: Transportation

UAV 5

e_U(t)

r_U(t)

Status: Transportation

UAV 6

e_U(t)

r_U(t)

Status: Transportation

UAV 7

e_U(t)

r_U(t)

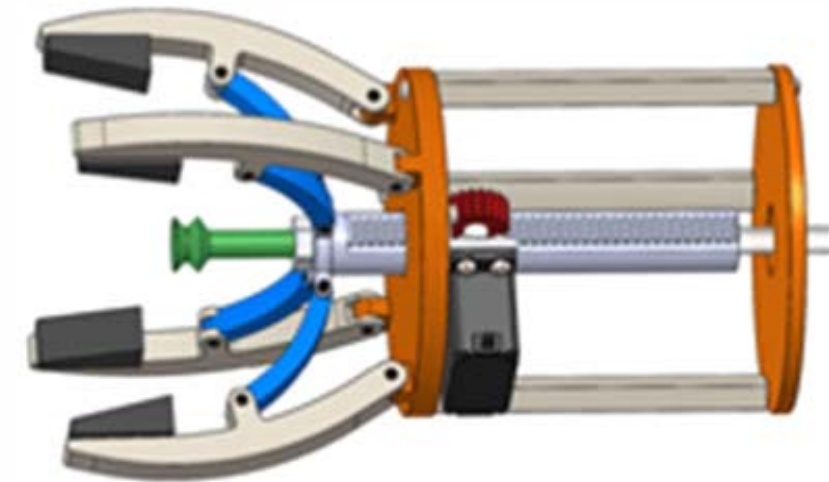
Status: Transportation

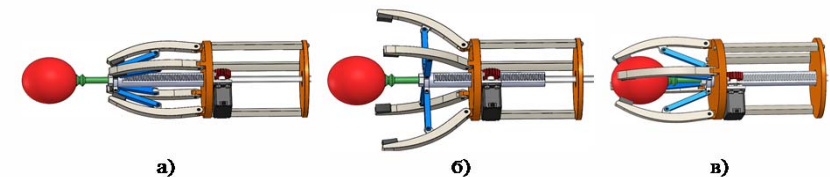
UAV 8

e_U(t)

r_U(t)

Status: Transportation





a) b) v)

6



User interface of robot group control at performing agricultural tasks

☰

Редактирование

Помощь

🕒 16:34

☀️ 25 °C

🔋 12.7 %

☁️ 1 м/с

Группы

- ☒ Группа 1
- ☒ Группа 2
- ☐ Группа 3
- ☐ Группа 4

Операции

- ☒ Этап 1 ✖️
- ☒ Этап 2 ✖️
- ☐ Этап 3 ✖️
- ☐ Этап 4 ✖️
- ☐ Этап 5 ✖️

Уведомления

- Текст уведомления ✖️
- Текст уведомления ✖️



Параметры RTK

- RTK 1

 - Скорость
 - Батарея

Подробнее
- RTK 2

 - Скорость
 - Батарея

Подробнее
- RTK 3

 - Скорость
 - Батарея

Подробнее
- RTK 4

 - Скорость
 - Батарея

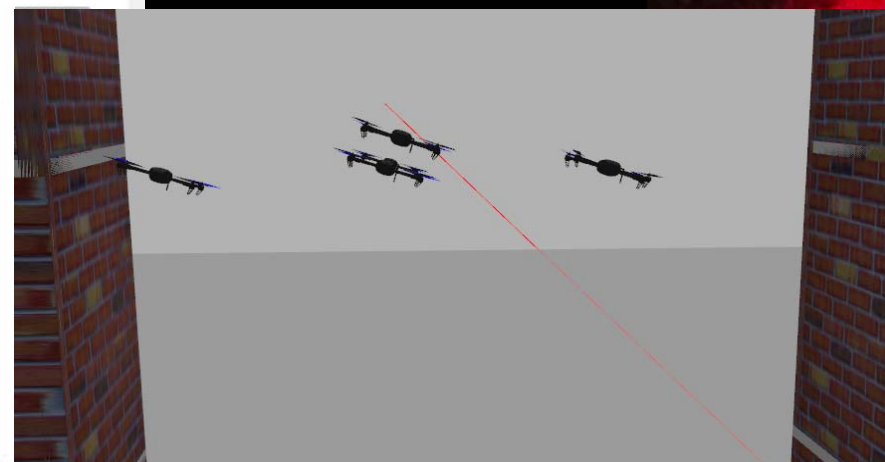
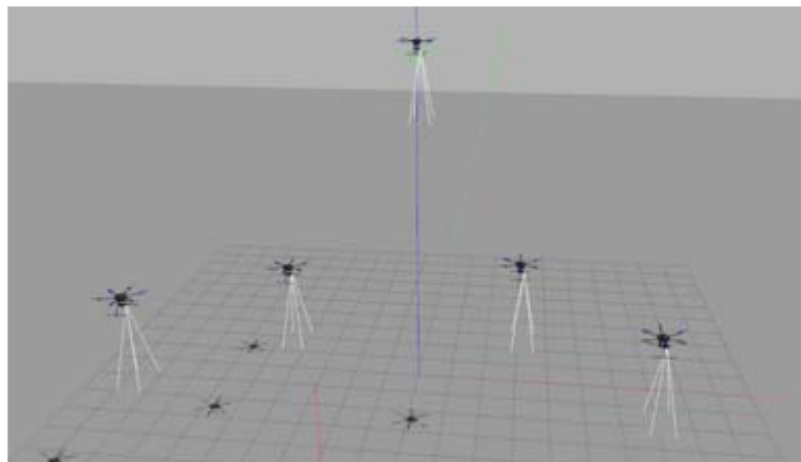
Подробнее
- RTK 5

 - Скорость
 - Батарея

Подробнее

Вывод изображений или других данных устройств с RTK

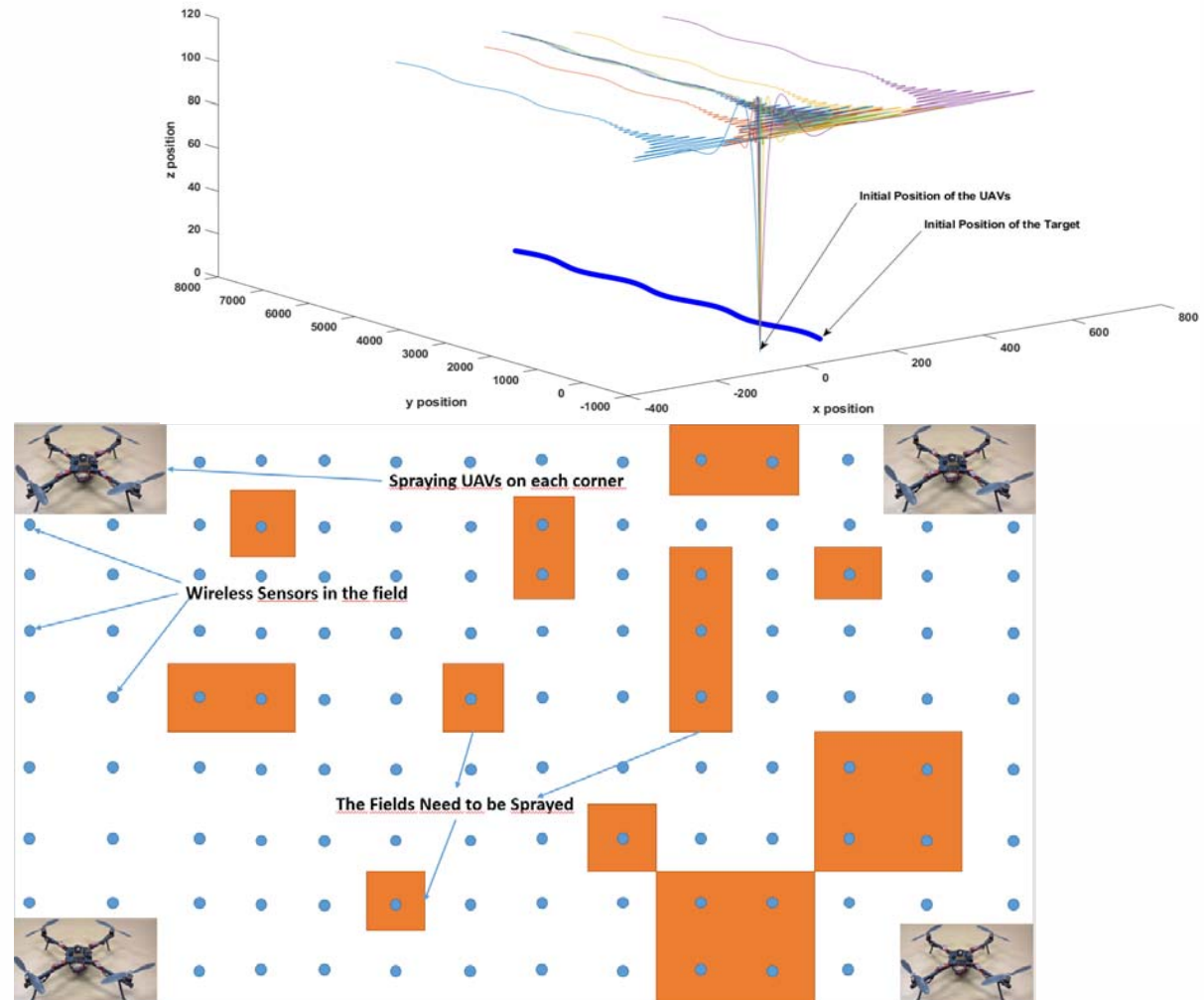
Данные о положении аппарата в пространстве





Main results of Erzurum Technical University

- Novel neuro algorithms of control quadrotor unmanned air vehicles for agricultural applications allows:
 - carrying suspended payload in sliding mode
 - consume optimal energy
- Case study: the routes that the drones will use in spraying has been analyzed using the segmental method developed for the traveling salesman problem in the presence of unknown transmitting power and uncertain target dynamics



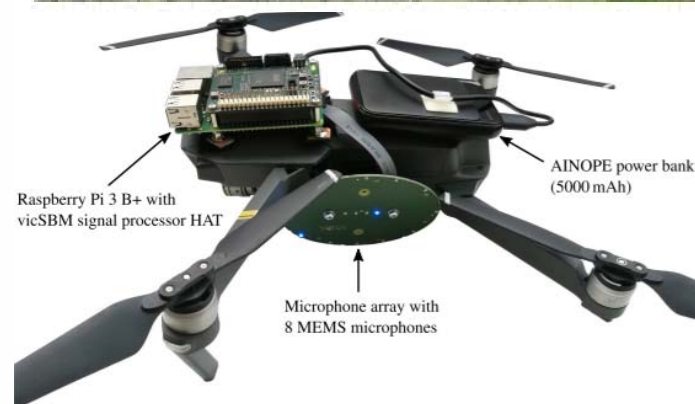
Optimal energy consuming by using multiple UAVs in spraying



Main results of Leipzig University of Telecommunications

Methods for UAV-based audio and video processing that can contribute to the human-drone interaction, precision agriculture and mission safety:

- Classification of agricultural textures (accuracy of 88.7 %) and the detection of typical objects by convolutional neural networks (CNN)
- Combined use of audio and video data on the level of decision making, to enable improved methods for human-drone interaction

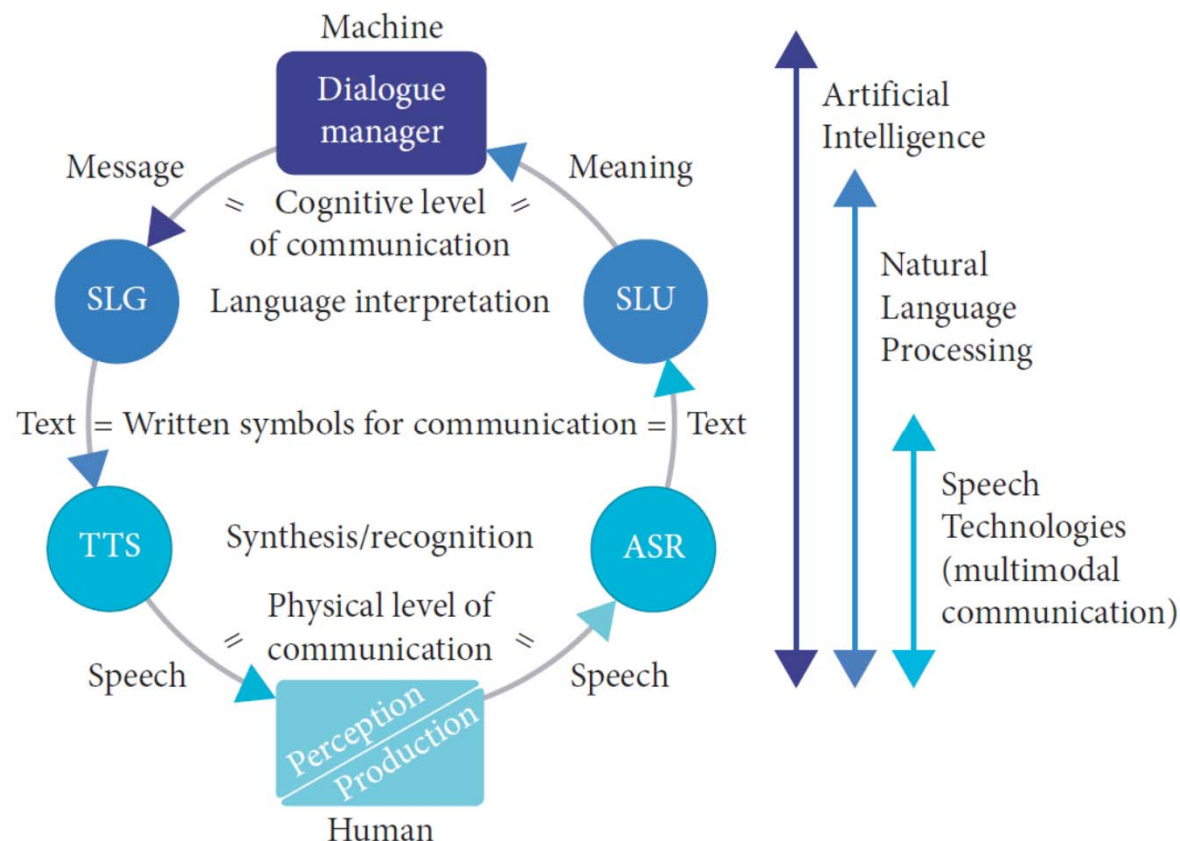


Audio recording system mounted on the test drone from



Main results of University of Novi Sad Faculty of Technical Sciences

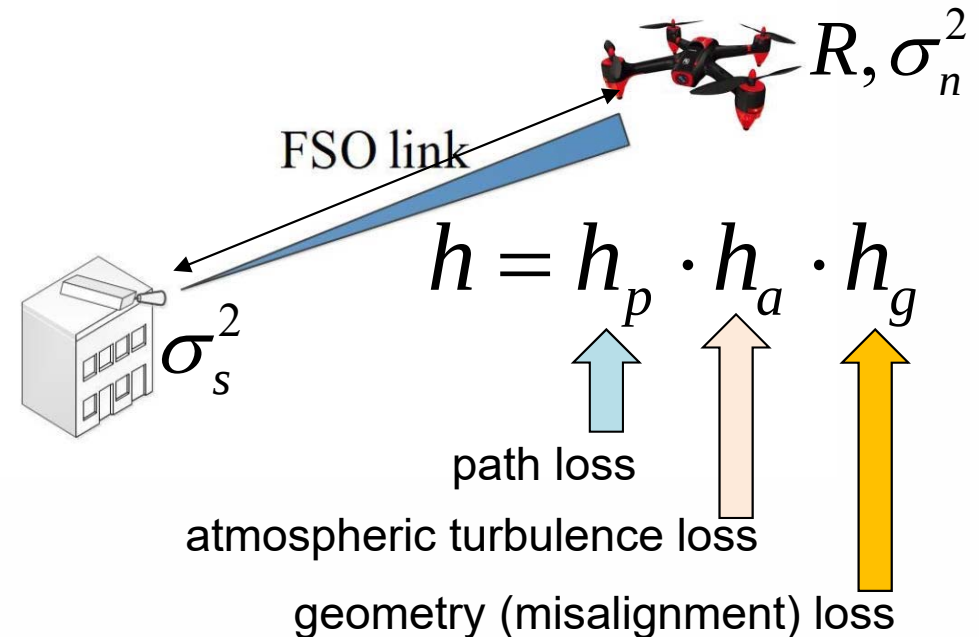
- Methods of automatic speech recognition in noisy environments, which are able to analyze and process the composite audio signal which results from multiple sound sources and contains direct sound as well as reflections/reverberation, extract sound related to one particular speaker (a single sound stream) in the presence of different sounds and ambient noise as well as sound related to a particular speaker from a set of simultaneous speakers (speaker separation), change the focus of attention from one to another speaker in a set of simultaneous speakers, and to improve recognition accuracy.





Main results of University of Novi Sad Faculty of Technical Sciences

- Developed free-space optical communication system for connection between unmanned aerial vehicles provides high speed and safety of information channel
- Unmanned aerial vehicles are used as mobile relays in communication system too and provide coverage extension
- Optical communication system has extended sensitivity to positioning/geometry errors: existing problem of fixed free-space optical transceivers is augmented for mobile units
- Future solutions require increased unmanned aerial vehicles stability and improved optical beam tracking





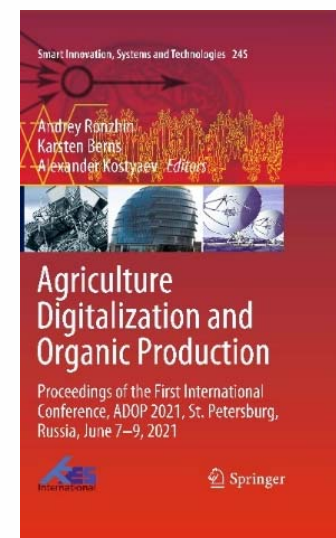
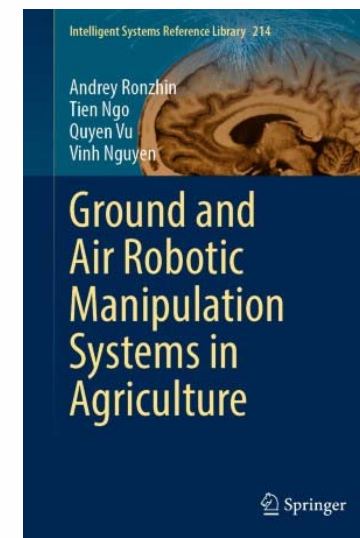
Benefits of international cooperation

Comprehensive review of modern solutions in the field of agriculture, robotics, human-machine interaction and collaboration of heterogeneous robots

Analysis of expanding technical, climate, economic conditions for development, application and introduction robots in agriculture of various countries and climate regions

Expanding the market for introduction of the developed solutions, their adaptation for needs of real farmers, creation of new use cases and ideas for fundamental research

Publication new books and establishing new conference on Agriculture Digitalization and Organic Production (ADOP 2021)



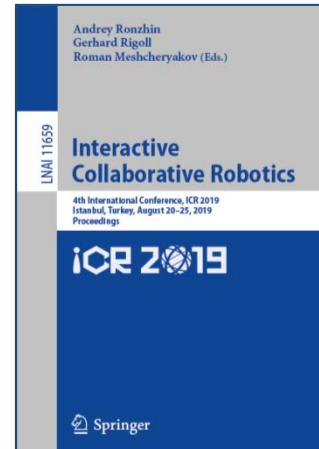
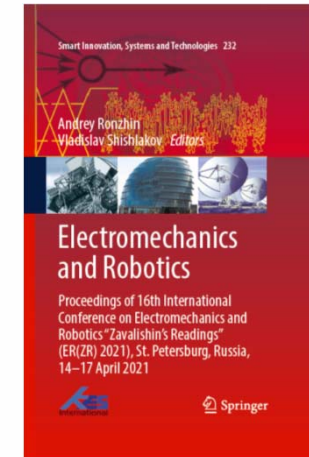


Project meetings and joint participation in conferences

- International Conference on Speech and Computer and International Conference on Interactive Collaborative Robotics: 2018 – Germany, 2019 – Turkey, 2020-2021 – Russia;
- International Conference on Electromechanics and Robotics "Zavalishin's Readings" 2019 – 2021 – Russia;
- International Scientific Conference "Thinking Models and Integration of Information and Control Systems" 2018 – Russia;
- 32nd Conference on Electronical Speech Signal Processing (ESSV) 2021 – Germany.

15 joint publications of project partners were published in journals and conference proceedings

4 PhD thesis was defended by project results





International Project Partners of St. Petersburg Federal Research Center of the Russian Academy of Sciences



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