them to enter Industry 4.0 technology domain and effectively use it on a regular basis, not as an exception (supporting transformation processes towards digital economy). In parallel, the UbiCBot technology will be created in a way that enable it to become a commercially recognizable Serbian-Chinese market brand (in global scale).

List of results:

2.1. Report on conceptual determinants of the UbiCbot SME-suitable robotic technology
2.2. Report on identification of the key building blocks of the UbiCbot technology
2.3. Specification of the selected, particularly important key deep diving research activities, as well as required development and production resources

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Subproject title: **Research & Development of the UbiCbot Technology**

Ordinal number of subproject: **3**

Month of beginning of subproject (in the interval from 1 to 36): **6**

Month of completion of subproject (in the interval from 1 to 36): **30**

List of researchers who participate in the project realisation:
1. Prof. Petar PETROVIĆ, **MFB**,, Serbia
2. Prof. Aleksandar RODIĆ, **IMP**, Serbia (Project coordinator from Serbia)
3. Prof. Stevan STANKOVSKI, **FTN**, , Serbia
4. Prof. Xiangrong XU, **AHUT**, China (Project coordinator from China)
5. Prof. Xinjun LIU, **TSU**, Beijing, China
6. Yongqiang XIAO, **EFORT** Co., LTD., Wuhu, China
7. All other reserchers from Serbia and China

Subproject description (up to 2000 characters with spaces):

The subproject SP3 is closely linked to the subproject SP2 and assumes generic research and development activities on ubiquitous collaborative robotics in order to establish specific theoretical background for the UbiCbot SME-suitable robotic technology, following requirements defined by the following formal inputs: 1)Report on conceptual determinants of the UbiCbot SME-suitable robotic technology, 2)Report on identification of the key building blocks of the UbiCbot technology, and 3) Specification of the selected, particularly important key deep diving research activities, as well as required development and production resources. This subproject will generate central theoretical and practical contribution for the overall project and should provide scientific and engineering answer to the key hypotheses and related challenges for building UbiCbot SME-suitable robotic technology, highly compatible with basic requirements of the Industry 4.0 concept of modern manufacturing technology. In particular, research and development activities will be guide with following challenges: a) creation of the tailor-made robotic system which is technologically compatible with specific needs, culture and challenges of Serbian and Chinese manufacturing SMEs, b) creation of the robotic technology able to work in highly unstructured and highly uncertain dynamical

environment, i.e., the system that have inherent ability for adaptation by autonomous recognition, learning and inference, c) highly collaborative robotic system capable to intimately collaborate with robots and humans without explicit programming, and capable to effective immerse into customized manufacturing environment, d) cognitive abilities beyond conventional flexibility that enable human-robot interaction in cognitive layer, not only in physical layer, and based on that development of new generation of HMI technology for intuitive bidirectional communication and knowledge transfer from human workers to robotic agents, including extensive networking abilities of intelligent agents for exchanging knowledge and experience among them, and allowing continuous improvement of working performances of the overall hybrid system, and e) autonomous and/or supervised exploitation and enhancement of data/meaning along the industrial IT-chain, extending far beyond the workshop or production plat floor. Accompanied development activities will be directed to physical realization of basic building blocks, necessary for physical validation of the developed theoretical contributions (as listed above) in laboratory conditions and practical testing of critical hypothesis and assumptions which are used to postulate the overall concept of the UbiCbot SME-suitable robotic technology.

Subproject objectives (up to 2000 characters with spaces):

The objectives that are associated with the subproject SP3 are as follows: a) development of the new technological background for building light-weight robot-arm (enabling the mass-payload ratio close to 1 as in biological arm) and ultra-compact multi d.o.f. joint module with sensory, drive and local control system embedded into robot joint mechanics (the innovative concept of embedded and distributed/networked highly modularized control and drive system), b) theoretical study of mathematical and computational aspects of highly redundant bimanual and multi-arm robotic structures, c) development of the multi-fingered grasping and multi-fingered hands for dexterous manipulation, d) development of the 3D cognitive visual perception and fast processing of depth data (fast, multi-view point cloud registration, polygonization and feature based recognition of its topological structure, including matching with the referent CAD model, as well as model-free robot working space/scene understanding, e) development force and tactile sensing system, including stiffness control in particular in kinematic redundant robotic structures, f) development of the multimodal interface for intuitive / natural and highly effective human-robot interaction, including Virtual and Augmented Reality technology for seamless human and robot integration into virtual industrial robotic cyberspace.

Task 1

Task name: **Building the theoretical background**

Task description (up to 500 characters with spaces):

This task is strictly related to generic research activities, necessary to underpin the development activities of the UbiCbot SME-suitable robotic technology, highly compatible with basic requirements of the Industry 4.0 concept of modern manufacturing technology. The research activities will be based on combined analytical, computer simulation and laboratory experimentation approach, followed with extensive identification and systematization off existing theoretical and empirical background

developed recently in the field of collaborative robotic, in both domains – service and industry.

List of results:

1.1. General theoretical model of the innovative industrial humanoid soft joints (hardware and software) for UbiCbot SME-suitable robotic technology

1.2. General concept and theoretical models of the robot open control system

1.3. General concept and theoretical model of the shop-floor-suitable, intuitive human-machine interface robot, based on integration of visual/force perception, customized CAD modeler and virtual/augmented reality technology (for seamless integration of human worker into Cyber-Manufacturing Robotic System)

1.4. Virtual and Augmented Reality model of the robot working space for cognitive human-robot interaction and integration of the human worker into virtual operation space of the UbiCbot SME-suitable robotic technology

1.5. Theoretical concept and general analytical model of multi-fingered underactuated grasping with integrated tactile and force feedback

Task 2

Task name: **Conducting activities and test installations building**

Task description (up to 500 characters with spaces):

This task is strictly tied with conducting activities necessary to produce physical prototypes for experimentation and practical validation of critical theoretical components developed in Task 1 of the subproject SP3. The results achieved in the Task 2 will be feedbacked to the Task 1 of the SP3 in order to refine and / or confirm developed theoretical models and basic hypotheses of the developed concept of industrial humanoid, i.e., the UbiCbot SME-suitable robotic technology.

List of results:

2.1. Prototype of the robot soft joint compatible with basic requirements of the UbiCbot SME-suitable robotic technology + extensive experimentation and systematization of obtained experimental results

2.2. Prototype of the open robot controller compatible with basic requirements of the UbiCbot SME-suitable robotic technology + extensive experimentation and systematization of obtained experimental results

2.3. Development of the shop-floor-suitable, intuitive human-machine interface robot, based on integration of visual/force perception, customized CAD modeler and virtual/augmented reality technology, all together compatible with basic requirements of the UbiCbot SME-suitable robotic technology + extensive experimentation and systematization of obtained experimental results

2.4. Development of the Virtual and Augmented Reality system for cognitive human-robot interaction and integration of the human worker into virtual operation space,

compatible with basic requirements of the UbiCbot SME-suitable robotic technology + extensive experimentation and systematization of obtained experimental results

2.5. Development of the prototype of the industrial robust and dexterous/sensored multi-fingered robotic hand for bimanual robotic assembly, compatible with basic requirements of the UbiCbot SME-suitable robotic technology + extensive experimentation and systematization of obtained experimental results

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Subproject title: **UbiCbot Technology Physical Demonstrations & Experimental Validation**

Ordinal number of subproject: **4**

Month of beginning of subproject (in the interval from 1 to 36): **7**

Month of completion of subproject (in the interval from 1 to 36): **30**

List of researchers who participate in the project realization:
1. Petar B. PETROVIĆ, MF, UBG, Serbia
2. Nikola A. LUKIĆ, MF, UBG, Serbia
3. Miloš M. MILIVOJEVIĆ, MF, UBG, Serbia
4. Stevan STANKOVSKI, FTN, UNS, Serbia
5. Đorđe Lj. URUKALO, IMP, Serbia
6. Miloš D. JOVANOVIĆ, IMP, Serbia
7. Dragana OROS, FTN, UNS, Serbia
8. Yongqiang XIAO, EFORT, China
9. Yongqiang XIAO, AHUT, China
10. Fei QIAO, TU Beijing, China

Subproject description (up to 2000 characters with spaces):

The general objective of the subproject SP4 is to provide practical validation of the developed technology within the subprojects SP2 and SP3, i.e., UbiCbot SME-suitable robotic technology in laboratory and eventually industrial environment. Activities that has to be carried out within this subproject will be clustered into two basic groups: 1) System integration activities and building physical robotic systems for selected application scenarios – the technology demonstration systems, and 2) Practical testing activities and validation of the technological performances of the demonstration systems. This project has particular importance for the overall projects, because participating companies of the project consortia should be deeply engaged, each of them having its particular role: 1) Company SOLE d.o.o., Kikinda, SERBIA will have the role of TECHNOLOGY DEMONSTRATOR and TECHNOLOGY USER by providing necessary financial resources which will enable physical realization and deployment of the collaborative, human-centric and Industry 4.0 compatible system for robotic welding of highly customized products, 2) Company MikroElektronika, Belgrade, SERBIA, will take a role of the TECHNOLOGY PROVIDER supplying the project consortia with Industry 4.0 compatible industrial ICT products/systems (tailor-made microcontroller based smart modules for control, sensing and communicating purposes), as well as with specific expertise in developing such kind of advanced systems, 3) EFORT Robotics Company, Wuhu, Anhui, CHINA, will take a role of the TECHNOLOGY PROVIDER supplying the project consortia with advanced robotic arms, including dedicated solutions which are developed following the basic requirements for the UbiCbot SME-suitable robotic